*Diploma of Honour Antwerp, 1885. Gold Medal Antwerp, 1885.*

*Gold Medal Inventions Exhibition, 1885.*

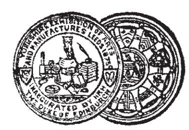
VIENNA MEDAL

1873.

PRIZE MEDAL


For latest improvements in Power Looms for Weaving, London, 1862.

LEEDS MEDAL



1875

# GEORGE HODGSON,

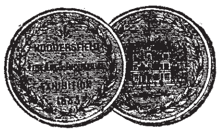
## MACHINE MAKER.

## THORNTON ROAD,

## BRADFORD, YORKSHIRE,

### ENGLAND.

SILVER MEDAL
FOR WEAVING



HUDDERSFIELD, 1883

GOLD MEDAL
FOR LOOMS


CRYSTAL PALACE

1881

**Diploma of Honour, Bradford, 1883.**

GOLD MEDAL

PARIS 1867

JUROR'S AWARD.

The Jury express their high appreciation of the Exhibits of Mr. G. Hodgson, but since they are precluded they are sorry they cannot make the award due to the marked excellence of his Machinery. The Jury however suggest that a Diploma of Honour on Vellum be presented to him. From Report of Jury, Machinery Class.

*Bradford Technical Exhibition.*

GOLD MEDAL

PARIS 1878

**Maker of all descriptions of**

# POWER LOOMS

Amongst which may be mentioned the following :—

# PLAIN LOOM,

This Loom (No. 1) has 32 inches reed space, and can be made to weave **Mohair, Silk, Worsted and Cotton**. It can be fitted up to eight threads as well as figures and Jacquard. It runs very fast from 200 to 220 picks per minute. One of the same kind at the International Exhibition of 1862 ran at upwards of 450 picks per minute, but this was only done as an experiment. This Loom earned the Gold Medal in London, 1862, and in Paris, 1867.

## GEORGE HODGSON,

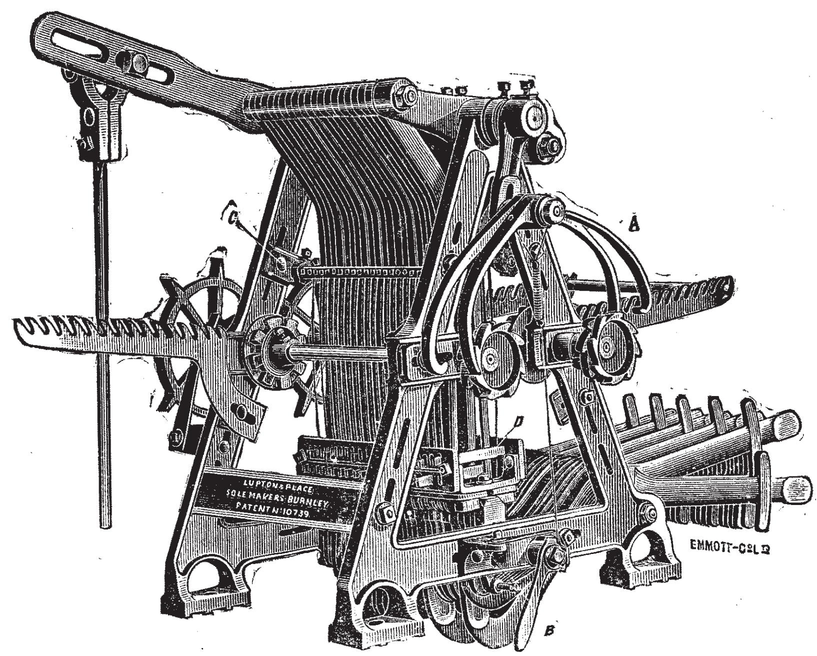
**Machine Maker, Thornton Road, Bradford, Yorkshire, England.**

Extract from "*The Textile Manufacturer*," December 15th, 1892.

"The 'Burnley Dobby,' so far as our experience in matters of this kind go, certainly seems to be attaining a well-deserved popularity amongst manufacturers, and we have again much pleasure in referring to some recent additions and improvements therein which the makers have deemed necessary to adopt, with a view of rendering the machine more accurate and reliable at extremely high speeds."

# The "BURNLEY" DOBBY,

## (With Patent Turning-Back Motion).

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ON

# WEAVING AND DESIGNING

OF

# TEXTILE FABRICS,

WITH CHAPTERS ON THE PRINCIPLES OF CONSTRUCTION OF THE LOOM, CALCULATIONS, AND COLOUR.

---

*FIFTH EDITION.*

---

BY

THOS. R. ASHENHURST,

*Head Master of the Textile Department, Bradford Technical College, and formerly Instructor at Stroud, in connection with Bristol University College.*

WITH ABOUT THREE HUNDRED AND EIGHTY ILLUSTRATIONS.

HUDDERSFIELD:

J. BROADBENT AND CO., ALBERT PRINTING WORKS, NEW STREET.

LONDON: SIMPKIN, MARSHALL, HAMILTON, KENT, AND CO. LTD.

## PREFACE TO FIFTH EDITION.

When this treatise made its first appearance there were no works on the subject with which it deals except a few which were generally looked upon as obsolete, though to those who know such works as Murphy's best, they can never become quite out of date. True, advances have been made in machinery, as well as a general knowledge of designing fabrics, but the fundamental principles are, and will remain the same, though the general knowledge of the subject may be much enlarged. The growth and development of Technical Schools, and the systematisation of the methods of teaching, must necessarily tend to this enlargement. The outcome of this is a greater demand for literature on the subject, and many efforts are being made to supply the demand. That a fifth edition of this work has been called for is some evidence that in some measure at least it helps to supply the requirements.

THOS. R. ASHENHURST.

BRADFORD,
*July, 1893.*

## PREFACE TO FOURTH EDITION.

In issuing a fourth edition of this work, I can only repeat the wishes expressed in the previous editions, that it may be of value to all who may read it, and that it may continue to assist in the work of Technical Education, which is now receiving so large an amount of recognition.

THOS. R. ASHENHURST.

BRADFORD,
*December*, 1887.

## PREFACE TO THIRD EDITION.

Since the two previous editions of this work were issued, it has been my privilege to continue the work of teaching the subjects dealt with in this treatise, and also to issue several other works bearing more or less upon many of the matters treated upon in this one. During this time, of necessity, many questions have been brought under my notice in reference to this work, and many weaknesses have been pointed out in it, and in this edition I have endeavoured to deal with those questions and to strengthen the weak points, and to endeavour to make this work, along with the others just mentioned, cover the ground of Textile Manufacturing, as far as Weaving and Designing are concerned, as completely as possible, and to render all the assistance in my power to students engaged in this work.

Owing to the numerous alterations, considerable delay has been occasioned in the issue of the work, the duties of my position having prevented me giving the necessary time to it to complete it at an earlier date. I can only hope the delay will be compensated for by the completeness of the work.

THOS. R. ASHENHURST.

BRADFORD,

*September*, 1885.

## PREFACE TO SECOND EDITION.

No better proof of the need of a treatise on weaving could be afforded than the early demand for a Second Edition of this bcok; nor could a better proof be found, that the youths and workmen engaged in textile manufactures are fully alive to the necessity of a better knowledge of their business, than the general demand for the work in a cheaper form, so as to come easily within the reach of the working classes.

The subject of "Weaving and Designing of Textile Fabrics" is one which covers a wide field, and the few works which do exist upon the subject can, at the most, only be considered as elementary works; but the eagerness with which even these are sought up, by those most interested, induces the hope that the new literature of an old industry may, ere long, develop to such an extent that it may be worthy of the fame of that industry.

In preparing this Edition for the press, I have been enabled to revise it, and to correct many of the errors which appeared in the First Edition, and to make such alterations and additions as appeared necessary. That the work may prove an assistance to the student and workman, and be a stepping-stone for further efforts, is the earnest hope of

THOS. R. ASHENHURST.

BRADFORD,
*January*, 1881.

## PREFACE TO FIRST EDITION.

In writing and placing this work before the public, the object which I have had in view has been to assist in furthering the efforts which are now being made to promote the advancement of technical education in connection with the textile trades in this country.

For a considerable time it has been apparent that our Continental neighbours have been making rapid progress in the art of manufacture, and it only required a little inquiry to explain the reason of that rapid progress. Schools of instruction have been in existence, and have been spreading over the country, for the purpose of training those who were intending to devote their lives to the production of textile fabrics, and in those schools everything has been taught which would have any bearing upon the branch of manufacture to which they gave their attention. While this has been going on abroad, not the slightest attention has been paid to the subject at home until the matter has been forced upon those engaged in the trade by the discovery that foreign competition was affecting very materially the markets in which they were wont to sell their goods, and that the nature of this competition clearly proved that the competitors were thoroughly masters of their business. This discovery having been made, inquiries began to be instituted as to the cause, and the best means of meeting it, the result being the establishment of schools of instruction in the textile trade in various centres of industry. In the promotion and establishment of these schools the Worshipful Clothworkers' Company, of London, have taken a most laudable part by granting liberal endowments to the principal ones, and taking a lively interest in their progress and welfare, and in other ways fostering and supporting technical education.

The writer of the present work having been brought into connection with those schools under the auspices of the Worshipful Company of Clothworkers, by his appointment in the year 1877 to the lectureship on the technology of textile manufactures, at Bristol University College of which they were the promoters, and again by the liberal endowment they have been pleased to grant to the school of which he has now the honour of being chief instructor, he has great pleasure in dedicating to the Master and Wardens of the Worshipful Company this the result of his labours, in the hope that it may be of some little value in assisting the great work they have in view, by placing before the students, in as concise a form as possible, the information which he has been able to acquire upon the subject with which he has attempted to deal.

If the perusal of this volume should assist the student in any degree in mastering the details of his craft, the author will feel that his labours have not been all in vain and that he has done something towards maintaining the supremacy of our manufactures, and thereby maintaining that commercial position which has been the great source of wealth, as well as the pride and glory of the English people.

The rise and progress of the textile manufactures of this country have, within the last century, been something marvellous, and the products of the loom have in no small degree contributed to the wealth of the nation. Yet it is a remarkable fact that this art, which has done so much for the wealth of this country, and which plays a greater part in civilisation than perhaps any other, possesses fewer works or treatises than any other of the arts or manufactures of this country.

## PREFACE.

The present work does not profess to deal exhaustively with the subject; the aim has been to reduce the whole art of weaving and designing of textile fabrics to simple principles, and to lay them before the reader in as brief and concise a form as possible, with just sufficient illustrations to make the matter clear and intelligible, and free it from that ambiguity which frequently characterises works of this description.

It is quite possible that the attempts here made at classification may not coincide with the views or meet with the approval or assent of many engaged in the trades. If such be the case, I must ask those who differ from me to believe that the object I have in view is to simplify, and by that means promote a more extensive knowledge than has hitherto existed of the principles of "Weaving and Designing of Textile Fabrics."

T. R. A.

BRADFORD, 1879.

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# Weaving and Designing of Textile Fabrics.

## INTRODUCTION.

Man in his natural state has few wants to provide for, food and clothing being the principal, and to provide the latter in a suitable form is a subject which occupies a considerable portion of time in civilised life. One writer observes that, "though we find finery and external adornments common to every people, yet comfortable clothing is almost exclusively confined to the inhabitants of those portions of the globe which are far advanced in civilisation." Man's first article of clothing seems to have been fig leaves, and immediately afterwards the skin of beasts. If we refer to Holy Scripture we shall find that the skins of animals were the coverings of our first parents. "Unto Adam also and to his wife did the Lord God make coats of skin, and clothed them."—*Gen.* iii. 21. The immediate descendants of Adam also used coats of skin, and shortly afterwards the *Simla*, an upper garment consisting of a piece of cloth, according to Professor Hurwitz, about six yards long, and two or three wide, and greatly resembling a blanket in shape, became their chief article of dress. Other garments made of wool, and other materials also, were in course of time fabricated. In *Leviticus* xiii. 47, 48, we read "The garment also that the plague of leprosy is in, whether it be a woollen garment or a linen garment, whether it be in the warp or woof," thus showing, by the reference to "warp and woof," that the art of weaving was practised in those days. Other arts also sprung into existence, and were prosecuted with considerable success, but spinning and weaving were undoubtedly among the earliest arts known to man, and at the present day they are among the arts which form the main distinction between savage and civilised life. Manufacturers of goats' hair were at an early period used in making tents, similar to those the Arabs of the present day are in the habit of constructing. This manufacture is supposed by some to have been spun and woven according to the worsted process, resembling to some small extent the manufacture of mohair at the present day, as contra-distinguished from the making of woollen or felted cloths.

The art of weaving is of great antiquity among the Chinese, Hindoos, and Egyptians, and has been practised by them for thousands of years. Pliny says the Egyptians were the inventors of weaving--"That the Egyptians put a shuttle in the hands of their Goddess Isis, to signify that she was the inventress of the art of weaving."—*Strutt on Dress.* However this may be, weaving was undoubtedly practised by them from a very remote period, and this is one of the arts of which, if Egypt was not "the mother," she was certainly "the nurse" and both with the Egyptians, the Chinese, and the Hindoos, spinning and weaving were carried to great proficiency, and the productions of the distaff and the primitive loom would compare very favourably, for fineness and delicacy—if they would not indeed surpass—the productions of the modern manufacturer. It would be very difficult indeed to say which country could claim the palm of invention, because it seems to have been practised very largely by all from a very remote period; and it would be equally difficult to say what material was first used, because different materials were in use by different people about the same time. It is said of the

Chinese that they can trace back documentarily the use of silk fabrics as far as the twenty-sixth century before our era. With the Egyptians linen has long been in use, and at a very early period of their history they spun and wove it so extremely fine that their fabrics have been the wonder and admiration of succeeding ages. Wool was the material used in some other countries, notably in Asia; and the Hindoos worked in cotton, as well as wool and goats' hair.

Not only in the civilised, but in the less civilised portions of the New World, and even among savages, the practice of weaving is to be found. Clavigero, in his history of Mexico, shows that on the conquest of that country, weaving was found to be practised by the natives; and Park, in his Travels, says it is practised by the savages of Central Africa.

There are four kinds of material chiefly used in the fabrication of cloths for garments, viz., Wool, Flax, Cotton, and Silk, without taking into account Jute and other fibres, which are also used occasionally, or which are used in the manufacture of fabrics for other than clothing purposes. Of these it is very probable wool was first used. If we refer to *Gen.* iv. 2, xxxvi. 7, and xxxvii. 13, and to *Job* xlii. 12, we find that the keeping of sheep must have been a profitable employment in very early times, and at later periods in the history of the world this occupation has lost none of its value or importance. That the Hebrews and their neighbours deemed it honourable, even for royalty, there is Bible evidence abundant to prove. If we refer to 2 *Kings* iii. 4, we find that "Mesha, King of Moab, was a sheep master, and rendered unto the King of Israel an hundred thousand lambs, and an hundred thousand rams, *with the wool*." Two eminent authorities, Whitaker in his History of Manchester, and Strutt on Dress, both assert that the first articles of dress were made from wool; and this may be very readily inferred, because those who were in the habit of wearing the skins of wool-bearing animals could not fail to discover the peculiar properties of wool; properties which make it an easy matter, either to make threads from it, or form it into a solid substance without the preliminary process of spinning, or even of weaving.

The manufacture of worsted is supposed by some to have preceded that of woollen, and in support of this the writer of the article in Rees' Cyclopædia says the "long-stapled wool suited to the comb seems more spontaneously the produce of uncultivated sheep than short wool, which is to be manufactured by carding."

Some writers suppose the *Argali* species to be the original sheep. Prof. Archer says, "The fact that the sheep has been so long domesticated has caused it to be a matter of uncertainty whether it has been derived from any of the existing animals of the genus *Ovis*. Many have entertained the opinion that it is the same animal as the Argali, *Ovis Ammon*, Linn., a native of the mountains of Central Asia; and a great weight of evidence in favour of that supposition is obtained from the circumstance, that all the tribes of people who have from time immemorial dwelt on the plains surrounding those mountains have always been pastoral in their habits and occupations. Still, however, there is no positive proof that our sheep was derived either from the Argali or any other known wild species, and the probability has been much lessened by the recent discoveries of the remains of sheep, mingled with stone weapons of a people who existed under such different conditions of the earth's surface, that we may assume with as much probability that they were the progenitors of the Asiatics, as that the latter were their ancestors." And Dr. Carpenter, in his Zoology, says the Argali is not the original sheep.

In addition to woollen fabrics other material appears to have been used by the ancients, viz., linen and silk (the manufacture of the latter having been brought to great perfection by the Chinese in very early times), and not only were they used separately, but they were in the habit of mixing them in their goods. "Neither shall a garment mingled of linen and woollen come upon thee."—*Lev.* xix. 19. The practice of mixing seems to have been carried on at a later period also. The *subsericum** of the Romans was a mixture of woollen and silk, viz., woollen warp and silk weft. It has been supposed by some that the "garment mingled of linen and woollen," forbidden by Moses, was a cloth which the Egyptians were accustomed to manufacture, inasmuch as he prohibited almost every custom prevalent in Egypt.

The Hebrews appear to have obtained a knowledge of spinning and weaving during their bondage in Egypt, and to have exercised their knowledge while journeying in the desert—"And all the women that were wise-hearted did spin with their hands, and brought that which they had spun both of *blue*, and of *purple*, and of *scarlet*, and of fine linen; and all the women whose hearts stirred them up in wisdom spun *goats' hair*."—*Exodus* xxxv. 25.

This practice was no doubt followed up by them after they ceased their wanderings. In the *Proverbs of Solomon* xxxi. 13, some of the qualities of a virtuous woman are said to be that "She seeketh wool and flax, and worketh willingly with her hands." But the Hebrews never seem to have attained great excellence in their manufactures; but to have confined themselves to coarse fabrics, which were spun under the domestic roof.

* Silk is described by the Ancients as coming from *Serica* or *Sereinda*. *Seres* is the designation given by the Greeks and Romans to the people who inhabited those remote regions, and Sereinda is apparently a compound of *Seres* and *Indi*—the latter a general term applied by the ancients to all distant nations. It is generally admitted that the *Seres* of the ancients are the Chinese of the moderns. *Se* is the name for Silk in the Chinese language.—*Treatise on the Silk Manufacture*. London: Longman & Co. 1831.

In 1 *Kings* x. 28, we find Solomon receiving "linen yarn" from Egypt. Linen would appear to have been the chief product of the Egyptians, for we find it very frequently mentioned, and in the manufacture of linen they undoubtedly excelled. We find *Ezekiel* xxvii. 7, speaking of "Fine linen and broidered work from Egypt." And as they cultivated the manufacture of linen to perfection they seem to have almost entirely neglected that of wool; indeed, it seems to have been a part of their religion to eschew the use of sheep's wool, and to abominate the pastoral life. Possibly this arose from political causes, such as repeated invasions by their pastoral neighbours, and the long and tyrannical dynasties of their occasional conquerors – the shepherd kings.

Whatever may have been the cause, the Egyptians disliked sheeps' wool, and cultivated vegetable fibres which, with their fine and equable climate, probably formed the better material for clothing. The perfection to which they brought the manufacture of their favourite material is well seen in the marvellous fabrics which are found in such abundance in the receptacles of their dead.

Dyeing is mentioned as early as the time of Jacob—"Now Israel loved Joseph more than all his children, because he was the son of his old age, and he made him a coat of many colours."—*Gen.* xxxvii. 3. Woollen fabrics appear to have been first named from the peculiar colours in which they were dyed. For instance, in the following verse we read, "Moreover thou shalt make the tabernacle with ten curtains, of fine twilled linen, and *purple*, and *scarlet*."—*Exodus* xxvi. 1. It is pretty well established that the latter portion alludes entirely to woollen fabrics.

We read in *Numbers* iv. 6, 7, 8, of "cloth wholly of blue," a "cloth of blue," and a "cloth of scarlet," and frequently throughout the old Testament we find woollen cloth spoken of in this manner.

Gorgeous colours are still preferred in the East, where the art of dyeing originally made great progress, and the excellence of which is, even at this day, attested by the brilliancy of colour which distinguishes the rich carpets of Persia and Turkey, and gives them such a ready sale in the European markets.

A dress of rich and various colours was in the time of Samuel the distinguishing attire of a king's daughter—"And she had a garment of divers colours upon her, for with such robes were the king's daughters, that were virgins, apparelled." The dyeing of these variegated colours must have been a costly art, as is shown by the fact of this description of dress being worn only in the families of princes and nobles. The Phœnicians attained great eminence in the art of dyeing; the Tyrian purple, believed to be obtained from the animal of a sea-shell, *Murex truncatula*, is known to every classical scholar by the numerous allusions to its great repute amongst the ancients.

Tyre was a city famous for its textile manufacture. Ezekiel in his description shows plainly that the woollen manufacture had made considerable progress there; and that its fabrics were the produce of several large and important districts, the names of which are given, and also the peculiar description of materials in the fabrication of which they each excelled.

The isles of Elisha brought to the emporium of the East for merchandise, "blue and purple" Syria, "purple and embroidered work" and Dedan, "precious clothes for chariots." Damascus is mentioned as supplying the merchants of Tyre with "white wool," which was exceedingly rare, and principally confined in its growth to the district immediately surrounding the city from whence it was conveyed. Speaking of the merchants of Sheba, Asshur, Chilmad, and others, the prophet adds, "They were the merchants in all sorts of things, in blue cloth and broidered work."

No more convincing proof exists of the extent of the manufactures from wool, at this remote period, than this truly eloquent and vivid description of Tyre by Ezekiel in which "white wool" and "blue cloth" are so expressly alluded to.

The Babylonians became famous for their manufacture of stuffs from the finest description of wool. Herodotus says, "They wear a gown of linen flowing down to the feet, over this an upper garment made from wool, and a white tunic covering the whole." "As the climate of Babylonia is excessively hot, we may conclude that these garments made from wool were similar to some of our fabrics, light and of delicate texture."* Babylon, the most celebrated mart of ancient commerce, was distinguished for the extent of its trade, and especially for the productions of its looms. Large and numerous weaving establishments were not confined to the city, but were scattered through the towns of the province, and their woven stuffs conveyed to all the countries of the east. The skill, industry, and enterprise of its inhabitants were unrivalled; the productions of their looms of so fine a texture as to be held in great estimation in all the marts of the world. If we may place implicit belief in the accounts which have descended to us respecting the fineness of their cloths, they were even superior to the extraordinary fabrics of modern times.

The Greek colonies in Asia Minor gave an impetus to the manufacture of wool for ornamental as well as useful purposes, and the Ionian colony of Miletus was especially celebrated for its fine wool and its beautiful carpets; and both of these are supposed to have been first obtained from

* "James' History of the Worsted Trade."

the Coraxi, a native race who are supposed to be represented by the Circassians. The Milesians became so famous for their fine wool that the Coraxi fell into the second rank. Still the latter retained pre-eminence for their shawls, which were so celebrated that they are mentioned in a poem by Hipponax, of Ephesus. 540 B.C. It is, however, considered probable by some that the shawls of the ancestors of the Circassians, and probably too the carpets of Miletus, were made from goats' wool, which is the material of the Cashmerian shawl of modern times. This is the more likely, for some of the ancient authors likened the Milesian fleeces to the wool of the camel, and every one who is familiar with the feeling of camel hair or wool, knows how strongly it resembles in that respect the wool of the Cashmere goat, of which the most beautiful shawls are made.

Like the Phœnicians, the Milesians also became very famous for their dyes; thus we find in Sotheby's translation of the third Georgiac of Virgil, the following lines:—

> Let rich Miletus vaunt her fleecy pride,
> And weigh with gold her robes in purple dyed.

It is almost certain from the facts already adduced, that the textile manufactures received a great impetus in Egypt—the cradle of nearly all known arts—from whence in course of time, as a necessary consequence of war, revolution, and increase of population in other parts of the globe they became extended throughout nearly the whole of Asia, and from thence to Italy, Portugal, and Gaul, keeping steady pace with the march of civilisation.

The woollen manufacture in Europe appears to have been first established in Italy, from whence most other countries of Europe were accustomed to obtain their best description of clothing. Among the Italian cities engaged in the manufacture or merchandise of woollen and worsted, Venice stands pre-eminent. In the earliest periods she traded with Constantinople for the best of these articles. On the sack of that city by the French and Venetians, in the beginning of the thirteenth century, the latter carried away its arts and manufactures, and established them in Venice. The historian of that republic states that it was from Constantinople the Venetians took the first model for their manufactures.

The textile fabrics of both the Greeks and Romans were almost entirely of woollen. Robertson, in his Dissertation on Ancient India, says, "The dress both of the Greeks and Romans was almost entirely woollen, which, by their frequent use of the warm bath, was rendered abundantly comfortable. Their consumption of linen and cotton cloths was much inferior to that of modern times, when these are worn by persons in every rank of life."

The Florentines figure as having been extensively engaged in this branch of manufacture, more so than other portions of Europe, whom they, in consequence, supplied with woollen articles of the finest quality and softest texture.

No sooner was this art known in the Netherlands than it was prosecuted with such unparalleled vigour and success as completely to throw into the shade even Italy, and the towns upon the coast of the Baltic who were engaged in it.

Throughout the early history of Europe the inhabitants of the Netherlands, especially those of Flanders, Brabant, and Hainault, took the lead among manufacturing nations. At a very early period, certainly as early as the tenth century, the woollen and worsted manufacture had been transplanted from Italy. Hallam, in his "View of the state of Europe during the Middle Ages," says, "The only mention of a manufacture as early as the ninth or tenth centuries that I remember to have met with is in Schmidt (Hist. des Allem, t. 2, p. 146), who says that cloths were exported from Friesland to England. He quotes no authority, but I am satisfied that he has not advanced this fact gratuitously." Other authorities, viz., De Witt and Meyer, give the date of the commencement of the woollen manufactures about the year 960, or rather sooner. From this date they appear to have pushed their trade with considerable vigour, for there are many concurrent testimonies that in the twelfth and succeeding centuries the Flemish textile manufactures were in a flourishing condition. Many of our English authors at this period testify to the flourishing state of the manufacture in Flanders, for instance, Giraldus Cambrensis, (Itin. Camb. 1-2, chap. 2), who ascribes great skill in it to the Flemings, and states that a colony of them established it in England; also Gervase, of Tilbury, who states that the art of weaving seems to be a gift bestowed upon them by nature. Similar testimony is borne by Ralph de Dicito, and Henry of Huntingdon; and Matthew of Westminster says that "all the world was clothed from English wool wrought in Flanders." This was no doubt an exaggerated boast but Flemish stuffs were probably sold wherever the sea or a navigable river permitted them to be carried.

Having thus briefly glanced at the textile manufactures among the ancients, to show as nearly as possible their origin and antiquity, we will now proceed to point out a few of the earliest allusions and best authenticated facts to be found on record regarding the manufacture of woollen cloths in England from the time of the Roman invasion, which is the earliest of which we have any record of the manufacture of textile fabrics being systematically carried on in this country.

The fabrication and dyeing of wearing apparel, of a coarse woollen texture, was unquestionably carried on to a limited extent by the ancient Gauls. And at the time of the Roman invasion of Britain it is recorded that the residents of the maritime ports of the island, adjacent to the continent, wore apparel made from wool. Cæsar narrates that he found them clothed in drapery similar to that used in Gaul and the Belgic States, where considerable manufacture from wool then existed.

It is a moot point whether the sheep is indigenous to, or imported into, Great Britain. The first mention of English wool we have on record Professor Millar alleges to have occurred about the time that this country was a mere Roman province. Smith, in his "Memoirs of Wool," contends that the first mention of sheep in English records or history was not made till about the beginning of the eighth century; while Professor Archer says that "there is no proof of its introduction, but there are proofs that it existed long antecedent to the Roman invasion and occupation."

It is interesting, however, to know that our conquerors, among the many other lessons they taught us, systematically manufactured wool first in Britain. They established an extensive manufactory at Winchester for the purpose of supplying the Roman army with clothing. This manufactory must have obtained considerable celebrity abroad. Dionysius Alexandrinus writes of it "that the wool of Britain is often spun so fine, that it is in a manner comparable to a spider's thread."

Now the Romans were not likely to have brought wool to this country for the purpose of making it into cloth, and it is therefore only reasonable to conclude that they found it in such abundance and good quality as to tempt them to utilize it.

For the next half dozen centuries after the Romans retired from this country, history is entirely silent upon the subject of textile manufactures. In the ninth century we again light upon it: "The mother of Alfred the Great was a spinner of wool, and also taught her daughters the art." And we are credibly informed by an old chronicler that King Edward the Elder "sette his sons to schole, his daughters he sette to wool werke," and they employed themselves in spinning, weaving, and embroidery, which "were prudently taught them to fill up the very large vacuities of an unlettered life with an innocent and reputable employment."

From this time forward, even to the commencement of the present century, most of the spinning of wool was done by women, and their industry was only equalled by their skill, it being the pride of a good spinster to make the finest yarn and plenty of it. Several remarkable examples of their skill are recorded, one even by the Royal Society. Mary Pringle, a Norfolk lady, earned this honour, by spinning a pound of wool into 84,000 yards (nearly 48 miles), though this falls far short of the accomplishments of a Lincolnshire lady, Miss Ives, of Spalding, who spun the same weight of wool into 168,000 yards, or 95½ miles of yarn; whilst the ordinary spinners of that time varied from (good) 13,440 yards, to (superfine) 39,200 yards per pound.

It is generally supposed that during the Anglo-Saxon period large quantities of English wool were purchased by the Flemings, who were then, as we have previously remarked, the principal manufacturers of fine cloths for the whole of the European markets. That wool was at this time a commodity of export is rendered highly probable from the high price at which it was sold, compared with the cost of the animal producing it. Macpherson states that in the "laws of Ina, King of the West Saxons, who reigned at the close of the seventh century, a sheep with its lamb is valued at a shilling. In another of Ina's laws the fleece alone is valued at two pennies, that is at one-sixth of the price of the entire sheep and lamb.'

The internal trade of England, during nearly the whole of the period to which allusion is now made, was exceedingly limited. No person was allowed to buy anything above the value of twenty pennies, except within a town, and in the presence of the Chief Magistrate (called the king's port-reeve), or two or more witnesses of well-known veracity. The penalty for breaking this curious enactment was the payment of thirty shillings, besides forfeiting the goods so exchanged, to the Lord of the Manor. This regulation took place in the seventh century, and is to be found in the code of laws adopted by King Hlothaere (or Lothair), of Kent.

In the early part of the tenth century an enactment was made in the reign of Athelstane to the effect that every merchant who shall have made three voyages over the sea with a ship and cargo of his own shall have the rank of thane or nobleman. This wise and liberal proceeding gave an impetus to the commercial transactions of this period, which fully justified the policy of such a step.

King Edgar, during this century, attached such a high value to the growth of wool that he took effectual measures for the suppression of wolves which had rendered the keeping of sheep an occupation highly precarious and uncertain in all parts of the realm. It is said that very few of these ravenous and dangerous animals were left in the island. The monarch, towards the close of his reign, enforced a law to the effect that a weigh of wool was not to sell for more than half a pound of silver. When we take into consideration the comparative value of money and other articles at this remote period, this enactment indicates plainly the high price which wool must have realized in times prior to the Norman conquest.

On the accession of William the Conqueror to the English throne, a large number of Flemish weavers following in his train settled in various parts of England, improving very much the manufacture from wool then carried on here, and introducing some entirely new branches of it. Some of these workmen settled in the parish of St. Peter's, Mancroft, Norwich, and are supposed to have introduced into that locality the art of making worsteds. The Normans and Flemings were proverbial for their love of dress, which imparted to their woven fabrics great elegance and fineness, and tended to encourage the improvement of the textile arts, and gave a stimulus to trade.

In the reign of Henry I, a great inundation drove numbers of these Flemish weavers from their native shores, and they sought refuge in this country, the King giving them a hearty welcome, placing a great number of them in the neighbourhood of Carlisle. This was a very fortunate occurrence for the native inhabitants of this district who were thus taught an improved system of manufacture, for which valuable services the strongest manifestations of envy and animosity were the sole return. In 1110, these Flemish settlers, owing to the latter circumstances, so highly discreditable to the Saxon population, were transplanted into Wales, a district called Ross, and now a part of Pembrokeshire, where they carried on with vigour their useful occupation. They are described by Giraldus Cambrensis as being "excellently skilled both in the art of making cloth, and in that of merchandise." And we are further informed, by William of Malmesbury, that they were a brave, hardy people, equally qualified to handle the plough and the sword, and also skilful in the woollen manufacture, the great staple of their country, so that in every respect they were a very valuable colony, whether considered as a barrier against the enemy, or the first founders of the manufacture of *fine* woollens in England.

Some of these Flemish weavers settled at Worsted in Norfolk, and there commenced the manufacture of stuff goods, which have since borne that name. It seems very probable that the name "Worsted," as given to the fabrics which now form the great staple trade of Bradford, and the surrounding districts of the West-Riding of Yorkshire, was derived from the name of this Norfolk town, and this derivation is generally accepted as the correct one. There have been three hypotheses as to its derivation. The second supposition is that the word is derived from the Dutch term "Ostade," signifying this particular class of woollen fabric; and that the corruption "Worsted" took its rise from the Flemish weavers establishing it at and giving name to the town.* The writer of the article on the worsted manufacture in Rees' Cyclopædia adopts this; he says that, "as the Flemings introduced the manufacture into England, it is probable our appellation is a corruption of theirs. Ostade was long ago a common name in Flanders, and was probably the surname of some person famous for this branch of the woollen trade, which afterwards was appropriated to an establishment of similar manufactures in Norfolk."

The third derivation is founded upon the conjecture of Archdeacon Nares. In his Glossory, he says, "Worsted is usually supposed to be named from the town so called in Norfolk, where it is therefore thought to have been invented, but woollen thread, yarn and stuff might naturally be called woolstead, as being the staple or substance of wool, and it appears to me more probable that the town was named from the manufacture, than that from it. Both might easily be corrupted to worsted, by the common change of the letter *l* to *r*. Worsted thread or yarn must have been known as long as the spinning of wool, that is, as long as clothing was used. The town had probably a much later date, and was originally called

* Since this was written I have visited the town of Worsted, and find from the records of the fine old Parish Church, that the name of the town existed long before the Flemings settled there.

Woolstead, from being a sted or station for woollen manufactures. This however is only a conjecture, and opposite to the opinion of Skinner and others." Skinner, Camden, and others adopt the first hypothesis, and it seems certainly to have the greatest weight of probabilities in its favour. It is certain the town of Worsted existed in the time of the Saxons. In Doomsday Book it is recorded that in the reign of Edward the Confessor, the lordship of Worsted belonged to the Abbot of St. Bennet, of Holme; and at the great survey, to one of the king's officers, who assumed, according to the custom of the times, the surname of Wursted. This is, therefore, conclusive that if the town derives its name from the manufacture it must have done so in the Saxon times.

The woollen manufacture made such rapid progress during this interesting period of its history, that towards the close of the reign of Henry II., it became extended over the whole kingdom, and companies of guilds of weavers were established in London, Oxford, York, Nottingham, Huntingdon, Lincoln, and Winchester, all of whom paid fines to the king for the privilege of carrying on their manufacture exclusive of other towns. There were also dealers, or merchants, in a great many of the towns, who paid fines to the king in a similar manner for the privilege of buying and selling dyed cloths.

Wool was the great native commodity of England in those days, particularly in the reign of Henry II., when it was mainly converted into cloth by English manufacturers. Dr. Whitaker, in his "History of Craven," makes the following statement as to the value of wool about the close of the twelfth century:—"A sack of wool sold for £6. The sack consisted, according to Spelman, of twenty-six stones, each weighing fourteen pounds. A labourer then received a penny a day, and an ox was worth about thirteen shillings and fourpence; whence it follows that at that time two and a half stones of wool would purchase an ox. Whereas a labourer will now earn the value of a stone of wool in a week, and at that time it would require sixty days, so that poor sheep walks were as valuable as the best land."

At this time cloths were made for exportation as well as home consumption, and the Germans were purchasers of English woollens.

In the patent of incorporation of the guild of weavers in London, already alluded to, the mixing of Spanish with English wool is strictly prohibited; from which some writers infer that English woollen cloths of an inferior texture were all made of English wool, and others that English wool was finer in quality than Spanish. In 1197 a law was enacted for regulating the dyeing and sale of home-made cloths, as well as for the purpose of establishing a uniformity of weights and measures.

On the death of Henry II. the textile arts still continued to flourish, notwithstanding the warlike disposition of Richard I. Even then broad cloth appears to have been made in England. In the *Capitulu Placitorum Coronæ* of Richard I., chap. 28, we find that it is ordered that it shall be all of one breadth, namely, two ells within the lists, and of the same goodness in the middle as the edges.

In the reign of King John the manufactures of England declined very much, and, in consequence, large quantities of foreign cloths were imported. Hence it was that about this time a general safe conduct was granted to all foreign merchants, to enable them to pass to and from England without hinderance or molestation.

During the civil wars, when John and Henry III. successively sat on the throne, the woollen manufacture gradually decayed, and English wools were exported in their raw state to foreign parts. The quantity of wool grown in England must have been very considerable.

Spelman relates that the nobles on delivering in a list of their grievances in 1279 to Edward I., when he was about to embark for Flanders, represented it to be their opinion that one-half of the wealth of the kingdom consisted of wool. Danzel, who perhaps comes nearer the truth, states that the wool of England at this time was equal to a fifth part of the substance thereof.

Although these facts are significant of the increase in the exportation of wool, to some extent the natural result of the decay in our domestic manufactures, till the appointment by Edward I., in the 25th year of his reign, of Peter de Edelmeton as aulnager of cloth throughout the kingdom, leads us to infer that the woollen manufacture was carried on to a greater extent than we should have imagined. At this time only the coarsest kinds of cloth appear to have been made in England, and all the finest descriptions were obtained abroad. We are informed by Dr. Whitaker that the canons in Bolton Abbey, in Yorkshire, visited annually St. Botolph Fair, held at Boston, Lincolnshire, for the purpose of buying cloth. As they received commissions from the neighbouring gentry to make purchases for them, their transactions with the foreign merchants at Boston were larger than they would otherwise have occasion to make. It is a curious fact worthy also of mention that in the reign of the above-named king the burgesses of Hedon (a place near Hull) had to pay a heavy penalty for not making cloth of the full measurement required by statute.

From the preceding pages it is obvious that the woollen and worsted manufactures flourished to a considerable extent in this country previous to the time of Edward III., and that the commonly received notion attributing to him their first establishment is erroneous. However, he did much to encourage and advance these branches of the trade, and from his reign may be dated a new era in their history. In 1331, this sovereign invited, by special grant, skilful Flemish weavers, dyers, and fullers to come over and settle permanently in England, with an assurance of his special favour and protection. A considerable number of them responded to the King's invitation, and settled by his directions where the wool grown in the district was suitable for the particular kind of cloth or stuff fabricated by these artisans. The worsted weavers were, according to this arrangement, located in Norfolk, Suffolk, and Essex, having Norwich for their chief seat or mart; others of them settled at Kendal, Halifax, Manchester, and the West of England. Fuller, in his Church History, gives a very racy and graphic account of the introduction of these foreign weavers, and their settlement in this country.

To further encourage the extension of the manufacture from wool, a Parliament convened in the middle of March, 1337, enacted: 1st. That it should be a felony to transport any wool of English growth beyond the seas until it be otherwise ordained. 2nd. That all foreign clothworkers should be received from whatever parts they came, and have privileges allowed them. 3rd. That none should wear any cloths made beyond the sea except the Royal Family. The words "until it be otherwise ordained," contained in the clause prohibiting the export of wool, render it apparent that this was only a temporary expedient for the encouragement of English manufactures, for this prohibition was from time to time dispensed with by the Crown, by virtue of the writ *Non Obstante*, much used in those days. The prohibition of the importation of foreign cloth, except for the Royal Family, was also rescinded at a later period of this reign.

During this reign staples* for wool were established

* Staple in its original sense denoted a place or port to which goods were brought for payment of customs, before they could be sold or exported. Those who exported were termed merchants of the staple.

in various parts of the kingdom, which were, however, abolished by a Parliament assembled at York in the year 1334, with the general consent of the nation. About the same time the foreign merchants, who, in consequence of a slight rupture with the English people, had ceased to have any transactions with them, were induced to resume mercantile operations, by the King confirming a charter originally granted in 1303, to which was added an assurance that no "undue prises, exactions, or arrests" should be inflicted for the future; and that no contributions should be levied on them for the Royal use, or the benefit of the state, without their sanction being obtained even in the case of war breaking out.

The Flemish manufacturers found at this time their most formidable rivals in the Brabanters, who had made great progress in the woollen and worsted manufactures. Large quantities of wool were exported from this country both to Brabant and Flanders, although the people of the former country were only allowed by law to purchase at the towns in England appointed for the sale of wool, and only to such an extent from time to time as was sufficient for half-a-year's consumption, the precise quantities required having to be sworn by two deputies from each of the principal manufacturing towns, furnished with the Duke's letters patent.

Abundant testimony may be found in the records of the period that the produce of wool had, in the days of Edward III., reached an immense amount. From an Act of Parliament passed in the twenty-seventh year of Henry VI. we gather that in the time of Edward III. the subsidies and customs of the staple of Calais amounted to the enormous sum of sixty-eight thousand pounds yearly, of which by far the greater part would arise from the export of wool.

As a striking indication of the value of wool in

England at this important era in the annals of the woollen manufactures, and the immense profit realised by its exportation, owing doubtless to the great demand for it abroad, it may be mentioned that the historian of Edward III. states that the King in November, 1337, "having taken up wool throughout all England, for which he gave the proprietors tallies at the rate of £6 per sack," shipped 10,000 sacks of it for Brabant, "where they were sold at £20 each." A great deal of other interesting information may be collected respecting the value of wool at this period, but this scarcely comes within the scope of the present work.

On the death of Edward III. the woollen manufacture, though somewhat checked in its progress, still continued to flourish to a great extent in the days of his grandson. While Richard II. occupied the throne many enactments were made in favour of foreign merchants settling and trading in England, who had in former periods, to satisfy the home merchants, been restricted in their commercial intercourse with this country.

Multitudes of passages in English History prove that from the first settlement of foreign weavers and merchants in this country, they were viewed with suspicion and dislike. In the days of Edward III. it became necessary to give these weavers especial letters of protection to save them from the violence of the people, who notwithstanding, in some places gave unrestrained vent to the innate jealousy and hatred of the foreigner—strongly characteristic of the English in those days—broke the looms and other utensils of the intruders, and committed outrages upon their persons.

It is narrated in the year 1344, that the maltreatment of the foreign weavers residing in London by the native inhabitants grew so oppressive and riotous that a proclamation was made by the Mayor and Sheriffs of the

City, in obedience to strict orders from the King, that any person doing the least injury to a foreigner, should be *imprisoned for the offence*. This proclamation was made very opportunely, for had these skilful artisans been driven from our dominions, in order to escape the violence of prosecution which seemed to threaten them at one time with remorseless fury, England would not have made the rapid progress she did with the textile arts. Such, however, were the skill and enterprise of these foreigners, that to them we are undoubtedly indebted for the foundation of our great national industry. To this and to events which we shall have to notice at a later period, England undoubtedly owes her manufacturing superiority over the inhabitants of any other portion of the globe,—even those European states that were once the monopolists of the arts, both of design and production,—which has since made Englishmen "the wonder and envy of the world."

There is no doubt the rule of the House of Lancaster proved detrimental to the progress of the manufactures. The reigns of Henry IV. and his son Henry V. were of such short duration, and the latter consisted so much of military conquest, that they are almost a blank in the commercial history of the country.

From the date of Henry IV. ascending the throne to the battle of Bosworth Field England had, during the larger portion of the interval, been a scene of war and bloodshed; and owing to the intestine commotions, and the artisans being arrayed under the banners of the hostile houses, the clothing arts gradually languished and decayed so that the fame of England abroad, for woven productions, became at last, from the smallness of their export, well nigh extinct.

The boroughs and great towns of the kingdom were, in the middle ages, not only cities of refuge for the feudal slaves of the great landowners, but the large demand and high remuneration for labour induced the country people to apprentice their children in them, thereby causing a scarcity of hands for cultivating the soil. To remedy this grievance of the landlords, Parliament, in the seventh year of Henry IV., prohibited "any man or woman from putting their son or daughter to be apprentice within any city or town, unless they had lands or rents to the value of twenty shillings at the least by the year." When one bears in mind the value of money in those days, the sum of twenty shillings a year formed a considerable income, and consequently kept down considerably the number who were at liberty to apprentice their children.

After Henry VII. had firmly seated himself on the throne, and united the claims of the rival houses of York and Lancaster, by his marriage with Elizabeth of York, he appears to have endeavoured to restore the clothing arts, as well as the general trade of the kingdom, to their former condition; and to encourage the enrichment and elevation of his subjects by means of trade and commercial enterprise. He likewise invited numerous Flemish clothing manufacturers to settle in his dominions; and during his reign the woollen and worsted trades, from a state of decay, spread and increased so greatly as to lead some authors into the mistake of attributing to him the introduction of these arts into the kingdom.

This monarch in various ways showed his anxiety to promote the manufacture of wool and the commercial prosperity of his subjects. Among other things—although the export of wool was not entirely forbidden—soon after his coronation it was declared, "that no person during ten years following should buy, take, promise, or bargain for any wool before the fifteenth day of August in each year, except such persons as intended to make cloth or yarn thereof; nor any merchant stranger before the second of

February after " thus giving the home manufacturers an opportunity of satisfying their own requirements first, and then the residue might be sold to foreign merchants, who, however, paid the heavy custom of three pounds six shillings and eightpence per sack, double the duty imposed upon the home manufacturers.

During the reign of Henry VIII. the manufacture appears to have declined, and although numerous attempts were made by the legislature to promote its increase, it does not seem during his reign to have recovered from the state of decay into which it had fallen. Great complaint is made at the dishonest expedients resorted to by the manufacturers, in the making and finishing of their goods, and numerous provisions are made in the statute book to prevent and guard against such injurious practices. Again during this reign the question of the export of wool seems to have received some attention. Lord Herbert, in his "Life of Henry VIII.," says "It was provided that *no unwrought* wool shall be exported out of the kingdom, for the encouragement of the woollen manufacture." James, in his "History of the Worsted Trade," says this statement is incorrect, "for although, in consequence of the enclosure of lands and the conversion of it into tillage, the produce of wool had diminished in comparison with that of earlier times and become barely sufficient for the home clothier, so that the export of it had nearly ceased, yet the statute book at this time did not contain any prohibition against the exportation of unwrought wool, except that of Norfolk sheep."

We now come on to the time of Elizabeth, for although with the fifteenth century the Middle Ages are supposed to terminate, yet the interval was one of mere transition, and with the accession of Elizabeth to the throne a new era seems to have commenced. Events also occurred on the Continent which gave a great impulse to, and in many respects changed, the character of the manufactures in this country. The persecution of the Protestants in Fance and the Netherlands (1567-8), drove thousands of them into this country, bringing with them a variety of manufactures, which they established here. The manufacture of woollens must at this time have risen to a considerable extent. Anderson, in his "Progress of the Arts and Sciences," says that in 1582 the value of the woollen cloth exported from England amounted to £200,000 annually, and other writers have placed it at a very much higher figure than that. Smith, in his "Memoirs of Wool," puts the value of exports to Antwerp alone during the reign of Elizabeth at £750,000 sterling, but this doubtless includes worsted as well as woollen goods.

England at this time appears to have superseded the Netherlands in the quality of their cloths. This has been attributed to the quality of their wool, which even so late as the sixteenth century is said to have been the finest and most valuable in the world, exceeding in quality the wools of Spain, which were largely used in the Netherlands.

Improbable as it may appear, it is nevertheless certain, that although this country had obtained such a position in the manufactures, the best methods of finishing and dyeing, especially of the finer descriptions of cloths, were very little known. Smith, in his "Memoirs of Wool," quoting from Coke, says, "The English at this time were not skilled in the art of dressing and dyeing English woollen manufactures, but, after they were made here, they were vended into Holland, where they were dressed and dyed." Logwood had at this time come into use, but from some cause, probably its improper application, it was, in 1597, forbidden by law to be used.

From this time forward the manufactures of England made rapid progress, and marvellous indeed was the rapid increase of English trade. New branches of industry sprang up and developed themselves in rapid succession, and thus laid the foundation of a national prosperity the like of which the world had never witnessed.

The introduction of the silk trade into this country, appears to have taken place in the early part of the seventeenth century. Anderson, in the book before quoted, viz., the "Progress of the Arts and Sciences," says that silk-worms were first brought into England in the year 1608, and the first broad silk was manufactured in the year 1620. About this time (1614), according to the same authority, the dyeing of cloth in the wool was first invented; and in 1619, tapestry work was first introduced into England.

Shortly after this the French commenced the manufacture of fine woollen cloth, the first establishment, started in 1646, being at Sedan, under the patronage of Cardinal Mazarine. In a very few years this branch of industry must have made rapid progress, for we very soon find complaint made that the worsted manufacturers of that country seriously affect the prosperity of our own. Not only in woollen and worsted articles, but in other goods did the French compete heavily with the English manufacturers. And to encourage their own production they laid an impost of fifty or sixty per cent. upon our drapery, constituting an almost express prohibition.

To counteract in some measure the injurious effects to our textile manufactures arising from the importation of French commodities, the legislature directed that no person should be buried in any woven material except made of wool, thereby intending to prevent the custom of using French linen and lace for the purpose, which at this period was much in vogue, and carried to a profuse length in burials. By virtue of this prohibition, fine worsted stuffs and flannels became common wrappings for the dead; and a vestige of the ancient practice remains in some districts to the present time.

Afterwards, Parliament, in consequence of the loud and incessant complaints of the nation, altogether prohibited, in the early part of the year 1678, the importation into England of all French merchandise whatsoever. Immediately after this our manufactures from wool began to prosper to an amazing extent.

In the meantime the silk manufactures had continued to progress in this country so rapidly that, in the year 1629, the silk throwsters of London were a sufficiently numerous and important body to be incorporated under the style of master, wardens, assistants and commonalty of silk throwsters. And it is said, in 1663, there were forty thousand men, women, and children employed in silk throwing in and near London. The woollen manufactures, too, had been quite alive to their own interests, and, in 1667, the dyeing and dressing of cloth was perfected in England by one Brewer, from the Netherlands.

Shortly after this, events transpired to weaken the manufacturing energy of France. Louis XIV., guided by injudicious councils, determined to revoke the Edict of Nantes thereby depriving his Protestant subjects of their rights and privileges. In consequence of this revocation immense numbers quitted their native country, carrying with them their wealth and industry, and no less than 70,000 of them are said to have settled in Great Britain.

These refugees introduced here many new methods and improvements in the textile arts, and added greatly to our increasing importance as a manufacturing nation. The whole number who for conscience's sake quitted their native country is said to have been no less than 800,000.

The influx of these refugees to our country no doubt gave the greatest impetus to our manufacturing industries, and we are doubtless largely indebted to the intolerant bigotry and persecuting spirit of our continental neighbours for our rapid progress at this time.

That at the close of the seventeenth century the textile industries of England had grown to an enormous extent is evidenced by the fact that competent authorities valued the wool shorn in England at £2,000,000 sterling, and the manufactures from it at £6,000,000. Again, a tolerable notion of the extent of the English trade may be formed from the fact that the merchants of London alone numbered nearly 2,000 in addition to those of other towns, who were both numerous and wealthy. For the next half-century, although at particular periods the trade was in an unprosperous condition, on the whole the manufactures from wool were a growing and improving source of national income; evidence of this may be found in the value of the exports at different periods. In the year 1700 these exports did not quite reach £3,000,000 sterling: in 1708, even when the nation was at war, they exceeded that sum. After many fluctuations they attained, in 1736, the remarkably large sum of upwards of £4,000,000 sterling. Between this time and the termination of the half-century they fluctuated considerably, standing however, at the latter period at considerably over £4,000,000.

We now arrive at a period which is remarkable in the history of the textile manufactures, both for the inventions and improvements that were made in the various processes, and for the remarkable development which took place. For thousands of years the hand of man had directly fashioned the material of his apparel, but now for the first time automatic machines began to be called into use—machines whose wonderful combinations, whose power of production, so infinite and various, so prodigious in their operations and results, awaken in the mind the most profound feelings of wonder and astonishment.

The inventions of Kay, Hargreaves, Crompton, Arkwright, Watt, Cartwright, and a host of others who sprung up almost simultaneously, led the way to the production in abundance, and at little cost, of beautiful and durable materials of apparel for the whole of the civilised world.

The distaff and spindle of the ancients were originally the only instruments employed for converting wool into yarn. The one-thread wheel was next brought into use; the date of its introduction here, however, seems to be lost in obscurity, but this and the rude teak wheel of Hindostan had evidently a common origin.

At the commencement of the eighteenth century, there were three kinds of instruments used for spinning all kinds of material. First the *Rock*, as the ancient distaff and spindle were called in England. In the process of Rock spinning the spinners drew out the thread from the end of a sliver of combed wool, and communicated the necessary motion to a rough kind of spindle by twirling it between the right hand and thigh, allowing the spindle to revolve when suspended by the thread, which was gradually lengthened by the fingers. By this primitive process a yarn of the most delicate quality could be produced. No doubt the process would be tedious and the production small, and long and incessant practice would be required to acquire the skill and delicacy of manipulation necessary to overcome the difficulties arising from the rudeness of the instrument, and to produce the fine quality of yarn for which the spinsters of these times were famous.

Next came the common one-thread wheel, which, up to the end of the eighteenth century, was ordinarily used in spinning wool. This instrument was nothing more or less than the above-named loose spindle, mounted in a frame and turned by a cord passing over the rim of a large wheel, thus the spinner's hands were left freer than by the loose spindle method to draw out the thread, consequently it had a capability of production which was evidently its main advantage. In this kind of spinning the operator took the wool with the finger and thumb of the left hand, a few inches distant from the spindle and drew it towards her, while with the right hand she turned the wheel ; she thus extended and twisted repeated portions, and as they were twisted she wound them upon the spindle, guiding the thread with her left hand.

The third kind of machine was also in use at the commencement of the eighteenth century and was named the *small* or *Saxon wheel*. This, though a more perfect machine than the last-mentioned, was only applicable, except in particular instances, to the spinning of flax. In this machine evidently lay the germs of Arkwright's invention. The spindle in the Saxon wheel had on it a bobbin, on which was wound the thread ; round the bobbin a flyer revolved at a greater speed than the bobbin itself, which gave the thread the necessary twist. The wheel being very small, it received its motion from a treadle. Spinning by this wheel seems to have formed the favourite occupation of lady spinsters during the seventeenth and eighteenth centuries.

It appears that previous to the eighteenth century, an attempt had been made to spin by a process making some approach to the apparatus of modern times. In the year 1678 a patent was taken out for "a spinning machine whereby from six to one hundred spinners may be employed by the strength of one or two persons to spin linen and worsted threads, with such ease and advantage that a child of three or four years of age may do as much as a child of seven or eight years old, and others as much in two days as without the invention they can do in three days." It appears that this invention only shortened the labour by about one-half; but it leads one to the conclusion that it contained the embryo principle of the wonderful inventions which succeeded it.

The origin of spinning by means of rollers, like every other great invention, is involved in considerable doubt. This arises probably from the numerous gradations by which the machine was brought to maturity. It has been generally supposed that the process of spinning by rollers either originated in the mind of Arkwright or of a person named Highs; but Mr. Baines, in his "History of the Cotton Manufacture," proves that the principle had been discovered, and to some extent carried out, at least thirty years before, by John Wyatt, who patented a machine containing this principle in 1738. This machine first essayed its powers in 1741 at Birmingham, where it was turned by a gin; worked by a couple of asses, and attended by ten girls; but owing to the poverty of Wyatt and his partner (one Lewis Paul), the concern was, after a short trial closed. Another factory was opened at Northampton by Mr. Cave, the proprietor of the "Gentleman's Magazine." This appears to have been on a larger scale than that of Wyatt and Paul, and was driven by water-power. It appears to have been carried on up to the year 1764, when it was given up as an unprofitable concern.

There is some difficulty in ascertaining correctly to whom we are indebted for the next step in the improvement of spinning machinery, Arkwright or Highs. The evidence as given at the trial which took place in the year 1785, to try the validity of Arkwright's patent, seems to point to Highs as having been in advance of Arkwright in this matter; indeed, Arkwright appears to have received information from Kay, the clockmaker, of the principle of construction in High's machine, which he improved and perfected in many respects.

From whatever source Arkwright obtained the first idea for his spinning machine, it must be admitted he used it well, and proved himself one of the most remarkable men of his day, and to his ingenuity and perseverance may be attributed the remarkable revolution which took place in the textile manufactures, and placed England in the first rank as a manufacturing nation.

Nearly contemporaneous with the invention of Arkwright, James Hargreaves invented the spinning jenny. This machine exercised considerable influence on the manufactures from wool, as Arkwright's had done on the cotton manufactures. Another spinning machine came into existence also about this time, combining the principle of Arkwright's drawing roller with Hargreaves' jenny. This invention owes its existence also to a Lancashire man, Samuel Crompton, a weaver residing near Bolton. Of the value of this invention no estimate can be formed. Yet Crompton himself benefited little by it, and his life was made miserable by the spy system and persecution which ultimately compelled him to give his machine to the public on the faith of promises which were never fulfilled, and by the ingratitude of those who grew rich around him by the means which he had placed in their hands.

Mr. Epinasse gives an admirable narrative of Crompton's career in his "Lancashire Worthies."

From this time the improvements in spinning machinery have been both numerous and valuable, as the present state of perfection to which they have been brought amply testifies.

We now come to the class of machinery with which this work is more directly connected, viz., the loom. It is claimed for the Egyptians that they were the first inventors of weaving, and certainly the earliest looms of which we

* "Lancashire Worthies," by Francis Epinasse. Second Series, London: Simpkin, Marshall & Co.

have any evidence are those of the Egyptians. Of these they had two kinds, one horizontal and the other perpendicular. The shuttle in the form of the present day was unknown to them; but, instead of the shuttle they used a stick with a hook at the end to pass the thread of weft through the warp; this stick also had to act as a batten, for they had no slay or batten, such as is used now. "The use of treadles was also unknown, and the threads of the warp are kept apart by sticks,"* so that the sticks had to answer all the purposes of healds, treadles, slay, and shuttle. On the perpendicular loom, which consisted simply of an upright frame with warp threads stretched from top to bottom, the practice of the Egyptians was, according to Herodotus, contrary to that of other nations, to push the weft downwards, and this is shown in many of the paintings depicting their method of making cloth; but it appears from a representation found at Thebes, of a man employed at weaving, that he pushes the weft upwards. It is therefore evident that both methods were employed by them. The horizontal loom, however, appears to have been mostly in use. On the tomb of Beni Hassan there is a representation of a weaver at work with a horizontal loom. "It is fastened to four pegs pushed into the ground, and the workman sits on the part of the web already finished, which is a small chequered pattern of yellow and green."† This loom in some respects resembles the loom employed by the Hindoo weavers, and which has very probably been used by them for thousands of years. The following is a description of the Hindoo loom, taken from Martin's "Circle of the Mechanical Arts," p. 239:—"The loom consists merely of two bamboo rollers, one for the warp and the other for the web, and a pair of gears. The shuttle performs the double office of shuttle and batten, and for

* Kenrick's "Ancient Egypt." Vol. 1. p. 216.
† "Minutoli." Vol. 2. p. 34.

this purpose is made like a huge netting needle, and of a length somewhat exceeding the breadth of the cloth. This apparatus the weaver carries to a tree, under which he digs a hole large enough to contain his legs, and the lower part of the gear. He then stretches his warp by fastening his bamboo rollers, at a due distance from each other, on the turf, by wooden pins. The balance of the gear he fastens to some convenient branch of the tree over his head. Two loops underneath the gear, in which he inserts his great toes, serve instead of treadles, and his long shuttle, which also performs the office of batten, draws the weft through the warp, and afterwards strikes it up close to the web."

It is very evident that the implements used, not only by the early Egyptians, but by other contemporaneous nations, and even by the Hindoos of the present time, were of the rudest possible character, and nothing but the most exemplary patience, dexterity, and great delicacy of hand, acquired by long traditionary habit, can account for the extraordinary beauty and fineness of their textile productions.

The Greek and Roman nations in the first period of their history appear to have used looms somewhat similar to those of the Egyptians. The Romans when they had made some advance in the arts, used a loom somewhat nearer approaching the loom of modern days, inasmuch as though they still preserved the perpendicular stretching of the threads, the weft was thrown through by means of a shuttle more nearly approaching the style of shuttle now used. In this loom the operator separated the threads of the warp by means of straight canes passed through the warp; the number being regulated by the pattern being woven on the cloth, whether plain or otherwise. For batten or slay, they used an instrument held loose in the hand, called a *spatha*, formed like a wooden sword, to drive the weft home up to the cloth, while with the other hand they passed the shuttle (rather boat-shaped) carrying the weft through the warp threads thus separated. This is the first indication we have of the use of the shuttle. In the fourteenth century we find a still nearer approach to the modern loom ; instead of the warp being perpendicular, we find it is stretched horizontally in the loom, and a species of healds and treadles used for separating the warp threads to make a passage for the shuttle, which is thrown through with the hand. This continued to be the method of weaving for several centuries. The introduction of the fly shuttle, said to have been invented by John Kaye, of Bury, who, as a reward for his ingenuity, was driven from that town and was obliged to take refuge in France, was the next great step in weaving ; but this for a very long time did not altogether supersede the use of the old hand shuttle. Not many years ago the writer saw this ancient method of weaving with the hand shuttle in full practice among the Welsh. The introduction of the changing shuttle box must have followed shortly after the introduction of the fly shuttle ; thus enabling the weaver to change the colour of his weft without stopping in his weaving. Improvements now began to follow each other more rapidly. Machines were invented for separating the warp threads so as to produce patterns of greater extent. Various machines were invented for working large numbers of healds, the principles being used at the present day in power looms. Another method known as the draw loom enabled the weaver to weave more extensive and intricate patterns than could possibly be done by healds, the disadvantage of this loom being that a second person was required to draw the cords, to open the warp, and thus enable the weaver to proceed with his operations. An invention by one David Bonnar in 1803, however, dispensed with this labour, by using a number of iron combs which enabled the weaver to perform the work himself. This invention was afterwards improved upon, and various kinds of draw looms came into use with varying success. But the great invention of Pierre Jacquard outstripped them all, and placed a power of producing patterns in the hands of the weaver which is practically without limit, thus enabling the productions of the loom to become what they more frequently ought to be, viz., works of art.

Early attempts appear to have been made to produce an automaton loom. The first of which we have any record was put up at Dantzick, in Poland. It is thus described in "Human Industry, or History of the Manual Arts," a work published in the year 1661. "In Dantzick, in Poland, there was set up a rare invention for weaving four or five webs at a time without any human help; it was an automaton, or engine that moved of itself, and would work night and day, which invention was suppress because it would prejudice the poor people of the town, and the artist was made away secretly, as 'tis conceived, as Lancellotti, the Italian abbot relates out of the mouth of one Mr. Muller, a Polonian, who had seen the device." From this it is apparent that the idea of the power loom is very old. A few years later than this, viz., in the year 1678, a loom was constructed by a Frenchman named De Gennes. This loom is described in the Transactions of the Royal Society, and in the main features exhibits some resemblance to the modern power loom. The description is as follows :—"The advantages of this machine are these: 1. That one mill alone will set ten or twelve of these looms at work. 2. That cloth may be made of what breadth you please, or at least much broader than any which has hitherto been made. 3. There will be fewer knots in the cloth, since the threads will not break so fast as in other looms, because the shuttle that breaks the greater part can never touch them. In short, the work will be carried on quicker and at less expense. Instead of several workmen, which are required in making of very large cloths, one boy will serve to tie the threads of several looms as fast as they break, and to order the quills in the shuttle."

From some cause or other it does not appear that this machine, although it promised so many advantages, ever came into practical use, or rendered any very great services to the country or the trade. Another loom was made by Vaucanson, and came into operation in 1762, in a weaving factory at Manchester, erected by a Mr. Gartside; but this did not succeed, and was soon disused. Hitherto all attempts to attain this end had been futile, and led to no practical result. To the Rev. Edmund Cartwright must be conceded the distinguished merit of originating the present power loom, which has effected a complete revolution in the weaving department, and increased the producing powers of our textile manufactures to a degree that could never have been anticipated, even by its inventor. The following graphic account of the origin and completion of this useful and valuable invention was given by Cartwright himself to Mr. Bannatyne, the author of the article on the Cotton Manufacture, in the "Encyclopædia Britannica." "Happening to be at Matlock in the summer of 1784, I fell in with some gentlemen of Manchester, when the conversation turned on Arkwright's spinning machinery. One of the company observed that as soon as Arkwright's patent expired so many mills would be erected, and so much cotton spun, that hands could never be found to weave it. To this observation I replied, that Arkwright must then set his wits to work to invent a weaving mill. This brought up a conversation on the subject, in which the Manchester gentlemen unanimously agreed that the thing was impracticable; and, in defence of their opinion, they adduced arguments which I certainly was incompetent to answer, or even comprehend, being totally ignorant of the subject, having never at that time seen a person weave

I controverted, however, the impracticability of the thing, by remarking that there had been lately exhibited in London an automaton figure which played at chess. 'Now you will not assert, gentlemen,' said I, 'that it is more difficult to construct a machine that shall weave, than one which shall make all the variety of moves which are required in that complicated game.' Some little time afterwards a particular circumstance recalling this conversation to my mind, it struck me that, as in plain weaving, according to the conception I then had of the business, there could only be three movements which were to follow each other in succession, there would be little difficulty in producing and repeating them. Full of these ideas I immediately employed a carpenter and smith to put them into effect. As soon as the machine was finished, I got a weaver to put in the warp, which was of such material as sail cloth is usually made of. To my great delight a piece of cloth, such as it was, was the product. As I had never before turned my thoughts to anything mechanical, either in theory or practice, nor had ever seen a loom at work, or knew anything of its construction, you will readily suppose that my first loom was a rude piece of machinery. The warp was placed perpendicularly, the reed fell with the weight of at least half a hundredweight, and the springs which threw the shuttle were strong enough to have thrown a Congreve rocket. In short, it required the strength of two powerful men to work the machine at a slow rate, and only for a short time. Conceiving, in my simplicity, that I had accomplished all that was required, I then secured what I thought was a most valuable property, by a patent, dated 4th of April, 1785. This being done I then condescended to see how other people wove, and you will guess my astonishment when I compared their easy mode of operation with mine. Availing myself, however, of what I then saw, I made a loom in its general principles nearly as they are made now. But it was not till the year 1787 that I completed my invention, when I took out my last weaving patent, August 1st of that year."

There were, as may be readily inferred, many imperfections in Cartwright's loom, and although the Rev. Doctor made subsequent attempts to remedy them, for which he took out other patents, the last of which is dated 13th November, 1788, and not the first August in the preceding year, as erroneously stated in the foregoing letter, the consequence of these imperfections was the failure of a weaving factory set up by Dr. Cartwright at Doncaster. In the year 1790 two gentlemen named Grimshaw, of Manchester, obtained a license from the inventor, and brought into use his power loom, and although they made many improvements in it, their project did not succeed. Dr. Cartwright's plan accordingly slept until the expiration of his patents destroyed all hope of his deriving any benefit from them. In the year 1808 he presented a petition to the House of Commons, backed by a memorial signed by nearly all the principal manufacturers of Manchester and its neighbourhood, and a committee was appointed to consider it, and upon the evidence reported by this committee the House proceeded to vote to Dr. Cartwright the sum of £10,000, as some compensation for his outlay and disappointment. It is said that Dr. Cartwright had expended the sum of between £30,000 and £40,000 in trying to make his invention a success.

Soon after this time Dr. Jeffray, a physician, of Paisley, invented a power loom, very similar in construction to Cartwright's. It had, however, an advantage over Cartwright's in means for preventing the breakage of the weft. This was improved upon again by a person named Miller, of Dumbartonshire, who substituted for the spring in throwing the shuttle the direct action of the motive power. Since that time invention has followed upon invention;

the loom has been brought to a high state of perfection, and may now be considered as beautiful and complete a machine as could well be put together, and produces work which would have astonished in no small degree the knights of the shuttle of less than a century ago.

Such is a brief history of one of the arts which plays a part of no inconsiderable importance in civilised life, and which exercises considerable influence on the tastes of individuals; for by raising the standard of excellence in articles of dress, and making the product of the loom artistic as well as useful, the standard of taste must also be raised. Dress has undoubtedly an influence on the mind of the wearer. Therefore an elevated taste in dress not only indicates taste in the wearer, but also assists materially in forming or developing that taste.

The object of this work, however, is not to attempt to educate the taste either of those who design or use textile fabrics, but to deal with the practical application of such taste as the weaver or designer may possess in the production of textile fabrics, by dealing with the technicalities of the art of weaving in such a manner that any one engaged in the trade may make himself master of his craft and ascertain the reason why he does certain things in certain ways, and do his work upon intelligible principles, instead of by mere haphazard or rule of thumb.

## WEAVING.

Weaving is the art of combining threads, yarns, filaments, or strips of different material so as to form a cloth or fabric. This combination may take a variety of forms, according as the intention is to produce plain or fancy fabrics.

To produce this combination of threads a number of processes or operations require to be gone through, these operations varying only in detail in the production of different fabrics, the principle remaining the same in all cases. Before entering fully into the details of the actual process of weaving, we shall just glance at the preliminary processes required, and at the nature of the machinery used in the operations.

For the ready and rapid combination of threads they are divided into two sets or classes, which are generally known as warp and weft, one set consisting of the threads which run longitudinally through the piece of fabric, and which is termed the warp, the other set being thrown or placed transversely, and termed the weft. The longitudinal or warp threads are first prepared by arranging the required number of threads of the desired length side by side, so that they may be placed in the loom ready for the process of weaving. This is what is known as warping, or making the warp.

The first process necessary after the spinning of the yarn, for the preparation of the warp, is, that the yarn should be wound upon bobbins, or in the case of yarns that have not undergone the process of dyeing or stoving, or any other process, it may be warped direct from the cop or bobbin upon which it has been spun. The usual method of warping is by means of what is known as the *warping mill*. This warping mill consists of a huge skeleton reel, or frame mounted on a vertical axis, and moved round by means of an endless band, which connects the bottom of the axis with a wheel which is under the immediate control of the warper, whether the mill be driven by hand or steam power. A number of bobbins in proportion to the number of ends or threads of which the warp is to consist are placed in an upright frame, at a convenient distance from the mill. This frame consists of a number of divisions just wide enough to hold the bobbins horizontally; the bobbins are placed in the divisions upon iron pins; the ends of the pins resting in the frame, so as to allow the bobbins to revolve freely upon them. The threads are now taken from the bobbin and passed through an instrument called a *jack* or *heck-box*. This jack is placed between the bobbins and the warping mill, and is made to slide up and down on an upright post, or between two posts; it is suspended by a cord which passes over a pulley, and is made fast to the central axle of the mill, so that as the mill revolves a portion of the cord is wound on the axle, and thus the heck or jack is slowly raised from the bottom to the top; and when the mill is turned the reverse direction it descends by means of its own weight. The heck-block contains a number of steel pins, each having an eye at the upper end, through which a warp thread is passed. Each alternate pin is mounted in a separate frame, which are so constructed as to be raised alternately, for the purpose of making a lease in the warp, so as to enable the weaver to take each thread separately and spread them on the beam for the actual process of weaving. When the threads are passed through the eyes of the heck, their extremities are tied together, and fixed on a peg attached to the mill. The mill is turned a little until the lease pegs come nearly opposite the heck. The warper then lifts half the heck-frame, and passing the forefinger of the left hand through the open space thus formed in the threads, drops that half and raises the other half. Through this he passes the thumb of the left hand. By this process each alternate thread of warp is made to cross each other, thus forming the lease, which is now put upon the lease pegs of the warping mill. The mill is now made to revolve, and by the arrangement previously described the heck gradually lowers, thus winding the warp round it in a spiral form until sufficient length has been wound on, which is easily determined by the number of revolutions made by the mill, the circumference of the mill being known. The warp is again passed over lease pegs at the bottom, but this time instead of being divided in alternate ends, it is divided in beers, half-beers, or porties, each consisting of a given number of ends, according to the custom of the district. The process is repeated a number of times until a sufficient number of ends have been put together to make up the warp. The leases are then secured by bands being threaded through them and tied securely. The warp is then removed from the mill and in the case of a cotton warp, is made up into a huge ball, or if a woollen warp, it is linked up in the form of a chain to keep it in a compact form, and to prevent the threads from being shaken and so intermixed as to become afterwards inseparable. After undergoing a dyeing or sizing process the warp is taken possession of by a beamer or dresser, whose business it is to wind it upon a beam or roller, each thread being separated and laid side by side as nearly as possible, as they go round the beam, and in the case of a fancy pattern, such as a check or a stripe, the various colours of warp must be placed in their proper order.

When the warp has been regularly wound on the beam each thread must be drawn through the eye or loop of the healds, and afterwards through the slay, and, as will be afterwards shown, upon this part of the business depends in great measure the extent and variety of the patterns which may be produced. The warp is now ready for the loom, and before proceeding any further it will be well to give some description of this most important piece of machinery.

The great variety of looms in use in the different branches of trade in this country renders this a somewhat difficult task, but to obviate this difficulty as far as possible, I shall deal with general principles rather than with actual details, and where reference to a loom is necessary, I shall take one of the fast-going looms as my model. But before going into details of the power looms I shall just glance over the system of hand-loom weaving, because, although the hand loom is now rapidly going out of use, the principles of weaving both by hand and power are precisely the same, and there are some things which may be more readily explained by a reference to the hand loom than they can by the power loom; but in these details I shall be as brief as possible.

### THE LOOM AND ITS ACCESSORIES.

As mentioned in the first chapter of this work, the loom of the ancients was a very simple contrivance, consisting merely of a frame in which to stretch the warp, and a stick which answered all the purposes of healds, shuttle, and batten, but by degrees separate articles came to be used to perform the various parts of the operation. The first and one of the most important parts of the loom to claim our attention are the healds. By means of these the warp is separated to allow the shuttle to pass and re-pass through it, and it is by the arrangement of the healds and the way in which the warp is drawn through them that any pattern is formed on the cloth. The first form of heald introduced, and known as the clasped heald, is shown at

Fig. 1, and consists simply of two long loops, linked or passed through each other, and then each passed over flat wooden shaft, and made secure to a waxed band, known as the ridge band, the object of which is to keep each loop in its proper place. The loops are placed at such distances apart as to regulate the number per inch required. The next form, as shown at Fig. 2, has an eye formed by the

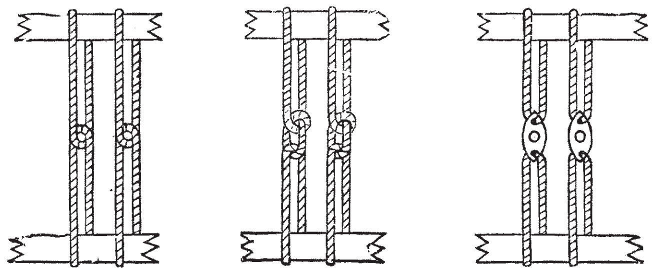

*Fig.* 1. *Fig.* 2. *Fig.* 3.

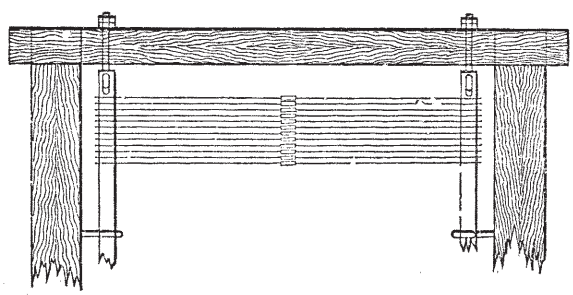

*Fig.* 4.

upper loop being knotted at a short distance from where it links with the lower half; the kind shown at Fig. 3 has a metallic eye; and Fig. 4 is a wire heald, made of small twisted wire, a small loop being left in the centre for the thread to pass through, and a larger one at each end for the shafts.

The mode of working the healds in the hand loom for weaving plain cloth is shown in Fig. 5. This is done by means of treadles and levers ; A A are the treadles, each of them being suspended by a cord from the long lever B, working on a pin at the point C. These in turn are suspended from the healds. Above the healds are two other pairs of levers D, the opposite ends of which are attached to each separate heald, the two pairs being used for the purpose of ensuring steadiness of working ; jerking or

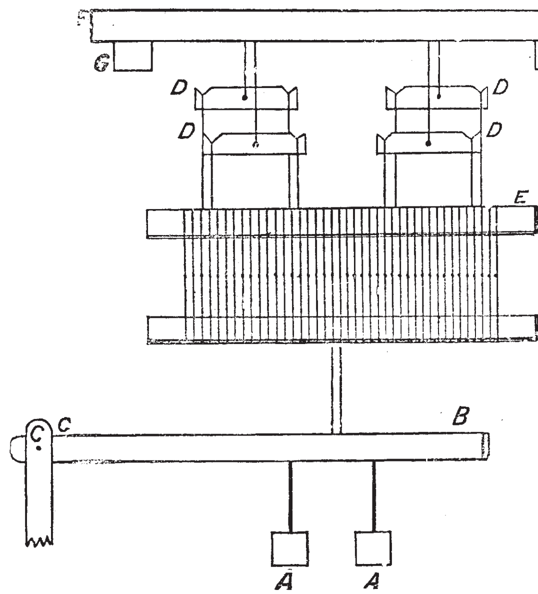


*Fig.* 5.

unsteadiness being detrimental to the warp, causing the breakage of a good many ends. It will thus be readily seen that as each treadle is depressed alternately the one heald rises and the other lowers, and *vice versa*. By this arrangement of gearing of course only plain cloth could be woven, as the warp threads are drawn through the two healds alternately, therefore each succeeding pick of weft is interwoven with alternate warp threads ; but by an arrangement shown at Fig. 6 a great variety of patterns could be woven; and this arrangement has existed and continued up to the present time, though not always in the exact form shown here; sometimes the long cords passing up the sides of the loom, and connecting the long levers below the healds with the short levers above the healds, being replaced by others passing down through the middle

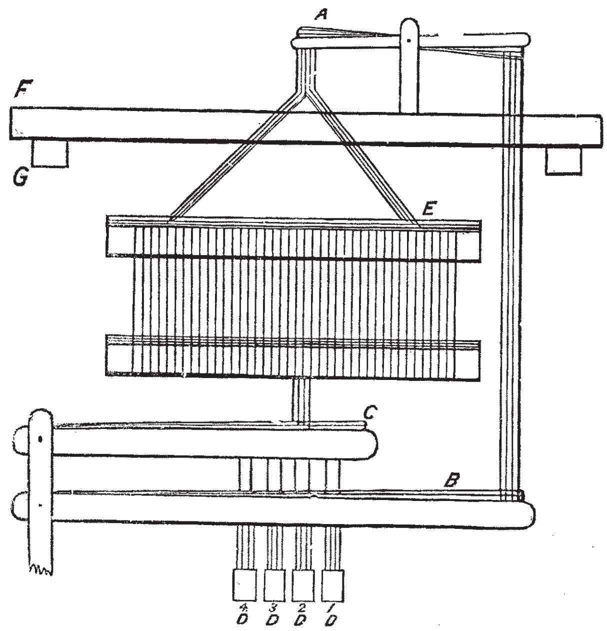


*Fig.* 6.

of the warp; in that case a double set of short levers are required above the healds, with cords passing from the outer ends, instead of as shewn in this drawing. The *modus operandi* of this method of gearing is as follows:—Each heald is suspended from one end of one of the short levers A above, the other end of which is attached to the end of the long levers B; from the bottom of the heald is suspended another lever C, not quite so long as the lever B;

below these again are placed the treadles D. Suppose by treadle No. 1. you wish to raise the first and second healds and to depress the third and fourth, (assuming that there are four), attach a cord to each of the first and second long levers B, and one to each of the third and fourth levers C. It will be obvious when that treadle is pressed down the cords acting upon the long levers B will act upon the levers A, and so raise the corresponding healds, while the other cords acting upon the levers C will depress the healds to which they are attached. The treadles must be tied up to correspond with the pattern intended to be woven, and by this means a very great variety of patterns could be produced. Another method of mounting the healds is by substituting pulleys for the levers above the healds.

In the preceding methods it will be observed that every shed—that is every pick in the pattern—which is different from the rest must have a separate treadle, though the same shed may be many times repeated in the course of a pattern; yet it must be obvious that the patterns must be comparatively limited in extent, on account of the number of treadles, so as to keep them within a limit which the weaver could comfortably work. To extend the limits of the patterns various machines have been invented, the culminating point being reached in the Jacquard machine.

Before the invention of machines for opening the sheds the place of a great part of the treadles was supplied by what was known as the draw boy. To each of the healds that were to be raised was attached a cord, either by means of a lever or pulley, similar to the arrangement for treadles. All these cords were connected to another cord which descended at the side of the loom, and passed through a hole in a horizontal board, which regulated their distances. To the bottom of each cord was appended a weight to keep it straight, and sink it into its position after being used. Each shed of the pattern had its side cord, as in the treadle loom each shed had its treadle, and the whole were arranged in a straight line in the hole board, in the order in which they occurred in the pattern; the draw boy had thus only to draw the cords in the order of succession to produce the pattern required.

The description given will perhaps lead the reader to a readier conception of the principles of the machine required for this purpose, and to more easily understand the working of such machine, and why it should be required.

Without attempting to describe all the various inventions which have been introduced for accomplishing this work, such as the Draw machine, the Parrot machine, the Dobby, and numerous others, elaborate descriptions of which may be of some historical but not of much practical value, I will attempt to describe the simplest form as used at the present day. I do not intend to go over all the various kinds of machines that are used, nor attempt to enumerate all the improvements that have been made; to do so would be to extend the limits of the present work far beyond what it is my intention it should go. I shall content myself with describing as briefly and succinctly as I possibly can the principles of the machine, and leave the reader to make himself acquainted with the details of construction adopted by different makers of the various kinds of machines, and to form his own opinion of their respective merits, in the only place where such information can be acquired, and such opinions formed, if either the one or the other are to be of any practical value, viz., in the workshop or the mill. The machine which came into most universal use with hand-loom weavers for producing patterns which were too intricate or extensive to be woven upon treadles, approaches very nearly in principle the Jacquard machine. In place of the levers which are shown in Figs. 5 and 6 above the healds, a machine was substituted containing a number of hooks. To each of these hooks a heald was suspended, the hooks being so arranged that they could be raised at will by means of a lever passing through the machine, and connected with a long treadle. For the purpose of regulating the pattern, cards or lags are used, these cards or lags being perforated or pegged as the case may be, according to the pattern, so as to strike back any hook connected with the heald which it is desired to leave down, the rest being caught by the lever, and raised up so as to form the shed.

It will be seen at a glance that there is no limit to the number of cards or lags that may be used, and as each card or lag represents a pick of the pattern, the same as the treadle of the treadle loom, or the side cord of the draw loom, the advantages of this loom over both the other descriptions must be obvious.

Though unlimited in the number of lags that may be used, there is a limit to the number of healds that may be used, although before the invention of the Jacquard the number of healds that were employed in one of these machines was enormous, as many as ninety-six having been used at once; and to enable them to put so many in a loom at once, without taking up too much space, or inconveniently crowding, the shafts on which the healds are placed, were made extremely thin, and the healds themselves were made of two or three heights, so as not to interfere with each other in working, as shown in Fig. 7. The hooks in the machine were also placed in two rows to economise space.

One great objection to this kind of machine is the weight attached to the bottom of the heald, and this objection is even greater in the power loom than the hand loom. Yet it is very largely used, or springs, which are if anything, still more objectionable, are substituted for them.

This difficulty of the weights may be and is sometimes obviated by using levers under the healds, having two sets of hooks in the machine set opposite to each other, so that when one is struck off the lifting blade the other

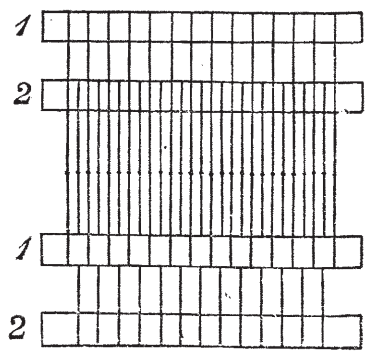


*Fig.* 7.

is struck on. The heald is suspended from one as in the previous case, and the other is connected with the levers underneath by means of a cord passed down through the warp, so that if the one hook is not lifting the heald, the other is pulling it down; to do this effectually the bottom board of the machine is fixed on movable arms, which give way as the healds are pulled down, and is then brought back to its former position by means of a lever and weight, or any other simple appliance.

Such is the principle of the machine which comes between the treadle loom and the Jacquard, and contains in fact some of the principle features of the Jacquard machine itself, and although for extent of pattern which may be worked it cannot for one moment be compared with the Jacquard, yet it will never be entirely superseded by the latter machine, as it possesses considerable working advantages, and with skilful manipulation may be made to produce patterns of greater extent and variety.

### THE JACQUARD.

The Jacquard machine was the invention of a Frenchman, whose name it bears, a straw hat manufacturer at Lyons. His attention was first directed to the subject of mechanical invention by seeing in a newspaper the offer of a reward for a machine for making nets. He produced the machine but did not claim the reward. The circumstances becoming known to some persons in authority in Paris, Jacquard was sent for, introduced to Napoleon, and was employed in correcting the defects of a loom belonging to the State, on which large sums of money had been expended. Jacquard stated that he could produce the effects intended to be produced by this loom by far simpler means. He was requested to do so; and improving on a model of Vaucanson, he produced the apparatus that bears his name. He returned to Lyons with a pension of a thousand crowns, but his invention was regarded with so much mistrust and jealousy by the weavers that they attempted to suppress it by violent means. The "Conseil des Prud'hommes," who are appointed to watch over the interest of the Lyonese trade, ordered his machine to be broken up in the public *place*, and, to use the pathetic expression of Jacquard himself, "the iron sold for iron, the wood for wood, and he, its inventor, was delivered over to universal ignominy."

The machine of Jacquard, or at least the machine bearing his name, which is in use at the present day, and which possesses many improvements upon the original machine, is in principle somewhat similar to the one just described. The sheds are opened by means of wire hooks of exactly the same form as those used in the last machine, but these hooks are more numerous in the Jacquard machine than in the witch machine. Fig. 8 shows a section of a Jacquard

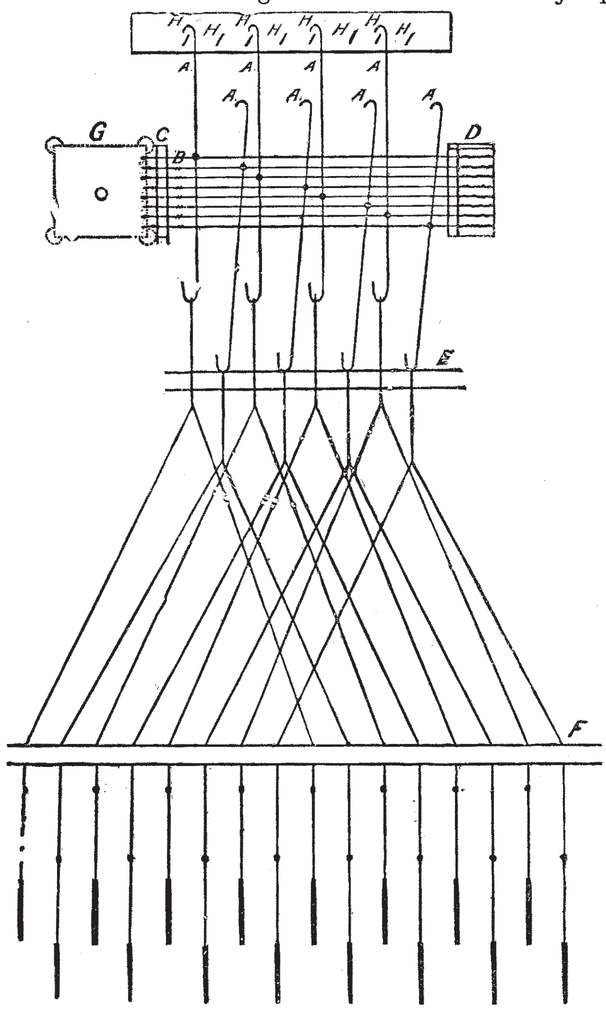


*Fig.* 8.

machine. The hooks A, A, A, A, A, A, A, A are placed, as will be observed, in eight rows (this varies according to the extent of the machine, the model taken for the present purpose being what is known in the trade as a 400 machine, that is, the machine contains 400 of these hooks for the purpose of making patterns, and eight which are sometimes used for selvages, or other purposes, as the case may be, thus making a total of 408 hooks in a machine). Each of these is supported or kept in position by a crosswire B, having an eye through which the hook passes. One end of this wire is kept perfectly straight, while on the other end is formed a loop, as shown at Fig. 9; the straight end is

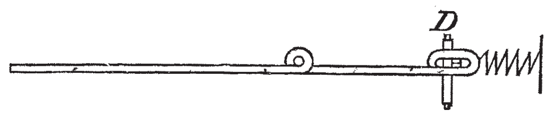


*Fig.* 9.

passed through a perforated board C, called the needle-board, and is allowed to project about $\frac{3}{8}$ of an inch in front of it; the loop end is secured by a wire pin passed down through it at D. Immediately behind this is placed the spring-box which contains as many small helical springs as there are crosswires, and which are so arranged that each one acts upon the loop at the end of the crosswire. The pressure thus bestowed upon the crosswires keeps them in position through the needle-board C, and at the same time keeps the hooks A in an upright position. To the bottom of the hooks is attached a cord termed the neck-cord; this cord is passed down through the bottom board E of the machine upon which the hooks rest. At a distance of a few feet from the bottom of the machine, and a short distance above the warp-line, is placed another perforated board F, known as the cumber-board; but this board is very finely perforated, the holes only being large enough to admit of a strong linen thread. These holes are at regular distances, in rows of eight, the distances apart being arranged according to the number of ends per inch required in the cloth. This board is divided into divisions of as many holes as there are hooks in the machine. Taking the first hook in the machine, a cord is passed down from it and through the first hole in each division of the cumber-board. The second hook is treated in like manner, a cord being passed down to every division of the cumber-board, and so on, until every one of the four hundred hooks in the machine have as many cords attached to them as there are divisions in the cumber-board. Each of these cords has in it what is called a "mail eye," through which the warp passes, and which answers the purpose of the heald; to the bottom of each cord is attached a lead or wire weight for the purpose of bringing it back into its position after being lifted to form a shed. If the reader has followed this description carefully, he will at once observe that, every cord in each division being tied up to separate hooks, each can be worked separate and distinct from the others, and the effect is precisely as if he had four hundred healds in the loom, the divisions being each a repetition of the other. This four hundred, then, represents the limit of the number of ends upon which a pattern can be produced. It will be observed that the position of the Jacquard is such that the row of eight in the machine stands at right angles to the row of eight on the cumber-board, so that the harness cords, on being tied to their respective hooks, are bound to cross each other very much. This is what is known as the London tie up. Another method, which is known as the Norwich tie up, is that the Jacquard machine is placed with the rows of eight in the same direction as the short rows of the cumber-board. The result of this is that each harness cord is connected with the hook which stands in the most natural relation to it,—thus diminishing the friction among the cords and practically confining the harness within a more limited space.

In the London tie the cards are worked over the side of the loom. In the Norwich tie they are either over the head of the weaver, or over the warp. Having described in detail the harness, as this corded portion is called, it is necessary now to describe the working of the machine and the method of producing patterns by means of it. It has been shown that the crosswires are allowed to project in front of the needle-board C. From the top of the frame depends an arm, which carries a square perforated bar, or, as it is termed, a cylinder G. In this cylinder the holes are bored to correspond in position with the needle-board, but the holes are larger, so as to allow the needles to enter them the more easily. It will be apparent that if this cylinder be brought in contact with the points of the needles which project through the needle-board, no effect would be produced, simply because each needle would enter a hole, the spring in the box D keeping them in position; but if any of the holes in the cylinder are stopped, it immediately strikes back the needle, the spring giving way under the pressure; the result is that the upright hook is pushed back out of its position over the lifting blades H. These blades are fixed in a movable frame, and their duty is to lift such of the hooks as are not pressed back in the manner described. The manner in which the pattern is formed is by having a number of cards cut to the desired pattern and passing over the cylinder. At each tread of the loom the arm is thrown back, and all the needles are liberated; then, as the shed closes, the cylinder again comes forward with the card upon it, and presses back such of the hooks as are not required to be lifted for the pattern which is being woven. The cylinder is made to revolve by means of catches or pawls, and so change the card at each pick of the loom. To ensure the cards following each other in the proper order of succession, they are fastened together in a continuous chain, by means of string laced through holes which are cut for the purpose at each end and in the middle.

In the diagram I have purposely omitted some of the details, (in fact merely showing a skeleton of the machine so as to leave the interior working more clear, and make it more intelligible to the beginner, as it is this part which it is absolutely necessary should be understood, the rest being merely matters of mechanical detail which a glance at the machine would make plain.

The preparation of the cards is an important process in figure weaving, and requires a great amount of care and attention. The first thing that is necessary is that the design should be drawn on an enlarged scale, upon squared paper, which is intended to represent the warp and weft. This being done, it is taken, and upon a machine which is composed of a number of cords corresponding with the number of hooks in the machine, the pattern is woven as it will be in the cloth. The cords in the machine represent the warp threads, and across these are woven other cords, representing the weft threads. On the opposite side of the machine from that on which the reader sits, each of the warp cords passes through a needle, somewhat similar to the needle or crosswire in the Jacquard. When all the cords are woven in, a roller is substituted for the first cord, and, on being pulled forward, the needles are made to act upon a number of punches which are resting in a plate, and such of the needles as are pulled forward by the cords force corresponding punches out of this plate into another plate, which is then taken and placed on a machine in which a blank card has previously been placed, and the punches are forced through the card, the process being repeated until the pattern is complete. This machine is only used in branches of the business where large and elaborate patterns are made. Very frequently the punches are placed in the plate with the fingers. The cards are made of strong paper, about two and a-half inches wide, and varying in length according to the extent of the machine.

It may not be amiss before leaving this branch of the subject, to give an example of the manner in which the cards are cut from the design, and to do this the more clearly we will take a plain cloth, as the simplest and most easily understood. The design, Fig. 10, shows a plain cloth working, that is, the black dots represent the weft as passing over the warp thread. To effect this, the threads represented by the white spaces must be raised, and those represented by the black left down for the shuttle to pass over. The design is placed before the card-cutter, between two laths, in such a manner as to leave in view the line which represents the pick of weft he is about to cut the card for. Supposing he is putting the punches in the plate with his fingers, he places a punch in every hole of

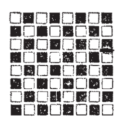

*Fig.* 10.

the plate corresponding with the white space upon his paper, every eighth line upon his paper being thicker than the rest, so dividing the squares into eights to correspond with the number of holes in a row of his plate. The card and plate are then placed in the stamping machine and the card cut, which will then present the appearance of alternate rows of holes. After one set of cards has been cut from a design, any number may be repeated by means of the repeating machine. In this machine the cards to be repeated are placed on a perforated bar, exactly similar to the one on the Jacquard ; through a box in front of this are passed long needles, each having upon it a long helical spring ; a plate is bored to correspond with the revolving bar and with the stamping plate ; the stamping plate containing all the punches is placed in front of the plate with the heads of the punches towards it: the holes in the plate are sufficiently large to admit the head of the punch. To obtain an exact copy of the card it is placed on the perforated bar, which is brought forwards by means of a treadle or a lever, generally the former. As the card strikes the needles the holes corresponding with the cylinder on which it is placed admit the needles into the cylinder, thus allowing them to remain stationary, while the portions of the card which are not perforated strike the needles opposite which they come, and force the punches out of the stamping plate into the stationary plate. The stamping plate is then taken and put on the machine, into which a blank card is placed, and the card is punched. The stamping plate is then replaced upon the repeating machine, and a comb, which consists of strong wires placed exactly opposite the holes in the stationary plate is pushed forward; the wires, entering the holes, push the punches which it contains into the stamping plate, when it is again ready to repeat the next card.

The cards are all numbered in the order in which they are cut from the design, put upon a frame to hold them in proper position in consecutive order, and laced or strung together as previously described.

## THE POWER LOOM.

In the preceding chapter I have described the mode of gearing and some of the working parts of the hand loom more fully than might seem necessary, as the hand loom is rapidly going out of use, but my reason for doing this is to make the nature of the operations to be performed as clear as possible before entering upon the mechanical details of the power loom, so that the student might more readily comprehend the nature of the various movements, without being harassed with too many considerations at once.

The conception of Dr. Cartwright as to the nature of the process of weaving, and of the movements involved in the production of textile fabrics of a plain nature which led him to attempt to make a machine capable of producing and repeating those movements, was strictly correct. Those three movements which are technically known as shedding, picking, and beating up, are what may be termed the primary movements in weaving. It is true, that sundry others must also be performed, but they are all subservient to, and must work in harmony with, these three.

In modern power-loom weaving various means are adopted for producing these various movements, but in all they have the same object in view, and aim at producing precisely the same movement. Consequently in all classes of looms, the difference consists solely in the means for producing, and not in any degree in the nature of such motions, except in so far as the various degrees of perfection are attained by the several means adopted.

Such being the case, it will be necessary to describe the nature of those movements, and some of the means for producing them, and to endeavour to show in the clearest possible manner the necessity for these movements having a peculiar character imparted to them, but before going into the details of each movement separately, it may be as well to point out what they are and what purpose they serve.

The warp being stretched in the loom, it is necessary that the threads should be separated to allow the shuttle to be passed through from side to side, carrying with it the weft, and so interweaving the warp and weft together. This is what is termed the shedding.

The second motion is the picking or propelling the shuttle from side to side of the loom through the division of the warp, or shed, produced by the first motion.

The third motion consists of beating the weft, which has been passed through the warp, up to the cloth, so that each succeeding pick becomes part of the cloth.

## SHEDDING.

We will then commence with the first and perhaps the most important of these movements, viz., the shedding, or in other words, the separating the warp into two portions to allow of the shuttle which carries the weft passing between them, so as to interweave the weft with the warp. This is the most important of the three movements, not only as to the order of arrangement in which the warp must be divided for the production of the intended pattern, but also as to the particular manner in which it must be accomplished, for upon the successful or unsuccessful shedding, depends in great measure the quality of the cloth produced, as well as the quantity which may be made by one loom. There are various ways in which the quantity and quality may be materially affected by this movement. For instance, over-shedding, that is, opening the shed more than is necessary, or imperfect shedding, which may mean that the shed is not sufficiently opened or that it is not properly equalised, are both very productive of breakages of the warp during the process of weaving, and consequent imperfections in the cloth, as well as materially affecting the appearance of the cloth in other ways.

The question then arises, How is this operation to be performed in such a manner as to arrive as nearly as possible at perfection, and to avoid as far as practicable those faults? I will endeavour to show how this may be best accomplished; and to do this I shall illustrate it with heald working, as being the most perfect as well as the simplest form of shedding.

The movement of the healds should be smooth and steady, commencing to move slowly, increasing in speed towards the centre of the stroke, and becoming gradually slower after passing the centre, until they finally merge into a full pause or rest. If the movement is regular and uniform, that is, maintaining the same rate of speed throughout, the strain upon the warp is too sudden, and considerable breakage must take place, particularly if the warp is of a soft or tender material. The opening and closing of the shed must also be timed, in the proper manner to the beating up of the weft to the piece.

The period of opening and closing, and the pause to be given to the healds, must be determined in their relation to the beating up by two considerations, viz., whether the warp threads are required to be spread evenly over the surface of the cloth, or otherwise.

The shed must not be larger than is absolutely necessary for the free passage of the shuttle; indeed, unless the yarn has a good deal of loose fibre projecting from it, which may be liable to choke up the shed and retard the progress of the shuttle, or in the case of very heavy work, it is not necessary that the shed be so far open as to quite clear the shuttle. The small amount of extra friction on the yarn will in most cases be more than compensated for by the diminution of strain. Then, first of all, as to imparting the proper movement to the healds. This movement is generally imparted by what is known variously by the name of tappet and wiper. In the loom there are two shafts which go across its entire width, and which are marked in the perspective view here given, Fig. 11, A and B respectively. The shaft A is called variously the main, crank, or driving shaft, and from this shaft motion is imparted, directly or indirectly, to all the other parts of the loom. The shaft is provided with two cranks for giving motion to the batten or lay, consequently at every revolution the weft is beaten up to the cloth. The shaft B is driven from the shaft A by toothed wheels, and carries upon it the tappets for the opening and

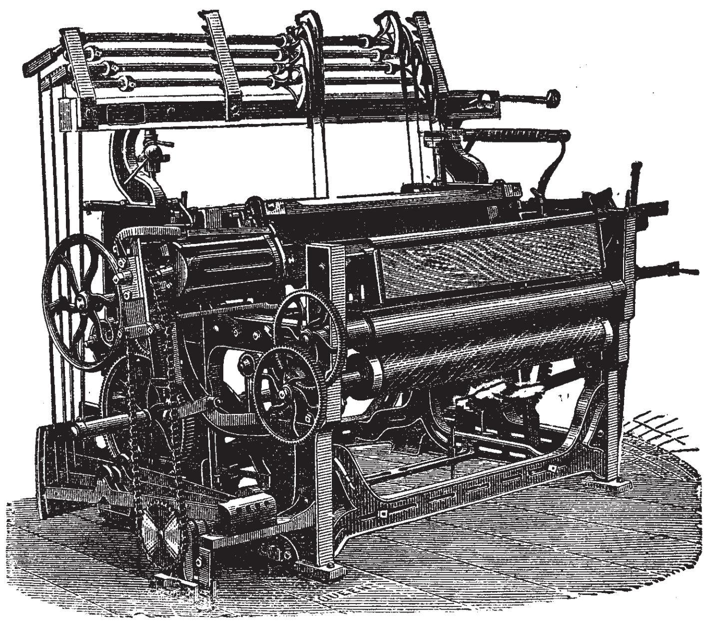

*Fig.* 11.

closing of the shed, also the picking tappets. The revolutions of the tappet shaft must therefore be regulated in relation to the crank shaft according to the arrangement of the picking tappets, and the shedding tappets must revolve at a speed proportionate to the number of picks in a complete round of the pattern.

We will, first of all, commence with shedding for a plain cloth. The end elevation of a loom, Fig. 12, shows the relative positions of the various parts with which we are at present most concerned. Beneath the tappet shaft B is placed the treadle C (in this case I am supposing the

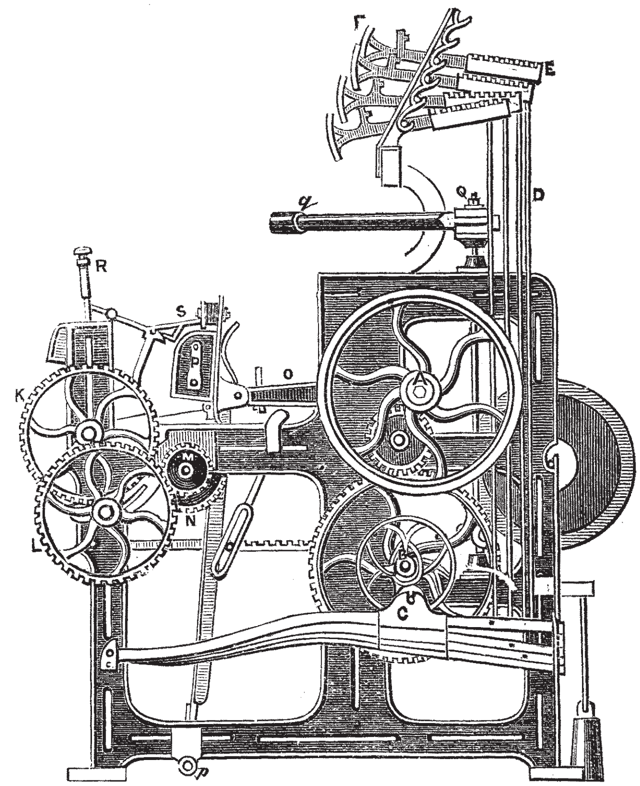


*Fig.* 12.

shedding motions to be at the side of the loom, as being the most convenient for illustration). From the end of these treadles are connecting rods D to lever arm E, which are fixed upon shafts or rods, working in stands over the top of the healds. Upon each of these shafts are also affixed a pair of arms, F, the ends of which form an arc of a circle. From these arcs the healds are hung, being connected with each other below by means of pulleys.

In Fig. 13 I have separated this motion from the rest of the loom, so as to show more effectually the connection and working of this part. The treadles C are simply levers working upon the centre *c*, and acted upon by the tappet at a point between that centre and the point of connection

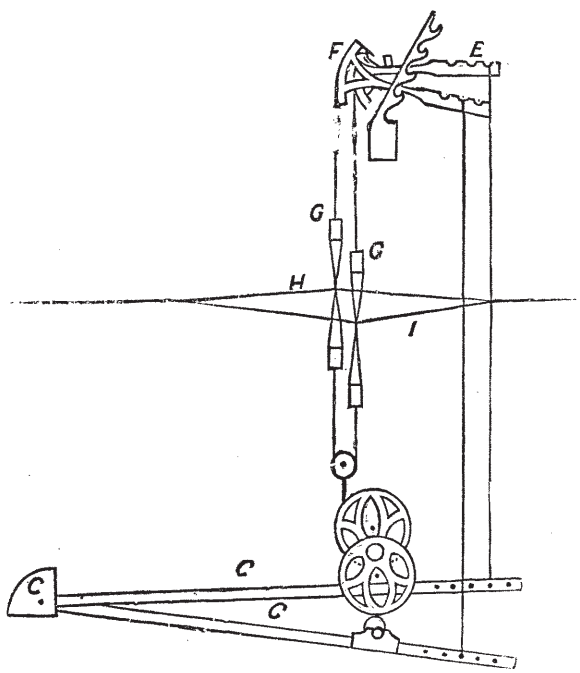


*Fig.* 13.

with the rod at the other end. This rod simply communicates the motion to the heald G by means of the lever E F, and the connection of the healds with each other at the bottom is so arranged that as one goes up the other is drawn down, and *vice versa*. The lines H I shows the warp separated by the healds.

The arm F of the lever is made to form an arc of a circle, so that in the act of raising and lowering the heald the latter maintains its proper position throughout, instead of moving to or from the centre upon which the lever works, as it would otherwise do.

The nature and extent of the movement given to the heald, then, must be determined by the form and dimensions of the tappet. We must first of all ascertain the two principal dimensions, that is the distance from the centre of tappet shaft to the point of contact with the friction roller of the treadles, when the latter is in such a position as to allow the heald to be at the lowest point of its stroke, and the length of stroke which must be given to them; or, to put it in another way, at a certain point of the tappet which is a given distance from the centre of the tappet shaft, the heald rests at its lowest point. We must then determine the dimensions of the tappet to give the required length of stroke to raise the heald to its highest point. In determining this dimension we must take into consideration the leverage of the treadles, as giving so much more of a traverse to the healds.

The treadles are levers of the third order, working upon the fulcrum or centre *c*. The power is applied between the fulcrum and weight. Then, according to a well-known rule in mechanics, as the distance between the power and fulcrum is to the length of lever so is the weight to the power. But as we are dealing with length of stroke rather than with actual weight, we may say, as the distance between power and fulcrum is to length of lever, so is the length of stroke of the motive power to that of the body which receives the power.

Assuming that the total length of the treadle may be thirty inches, and the distance between the point of contact with the tappet and the centre *c* is twenty inches, then as twenty is to thirty so will the stroke of the tappet be to the stroke of the heald.

We will suppose the length of stroke of the tappet is to be three inches, the stroke of the heald, or the distance which it would traverse, would be four and a half inches. Then assume that the friction roller of the treadle is in contact with the tappet at a distance of three inches from the centre of the tappet shaft when the heald is at its lowest point. With a radius of three inches, describe the

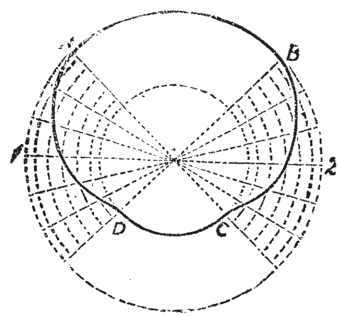


*Fig.* 14.

circle C, Fig. 14. From the same centre and a radius of six inches (three added to the first radius) describe the outer circle B. This gives us the relative distance of the inner and outer circle of the tappet.

We will first construct a tappet for a plain cloth, which simply consists of the warp and weft interweaving with each other alternately. This tappet must be so constructed that it will raise and lower the heald at alternate picks. That being the case, divide the circle C and B into two equal parts by the diameter 1, 2. The tappet must be affixed to the lower or tappet shaft of the loom, and made to revolve at half the rate of the crank or driving shaft. Suppose the point 1 is the point which would be in contact with the friction roller of the treadle when the crank is at the fore-centre of its stroke, so that the reed is in contact with the cloth, while the crank makes one complete revolution from that point, the tappet will have traversed the distance 1 to 2, or one-half of its revolution. Assuming that we desire to give a length of pause to the heald at its highest point equal to half a revolution of the crank shaft, and the same length of pause at its lowest point, divide each half of the circle into four equal parts, take the two central parts A B for the pause at the highest point, and the two central parts C D on the opposite side for the pause at the lowest point, then the distance D A must be occupied in raising the heald from the lowest to the highest point, and the distance B C in settling from the highest to the lowest. It is necessary now to draw curved lines from D to A, and from B to C, of such form as will impart the proper motion to the heald. To do this divide the distances D A and B C into any number of equal parts—say six—by radial lines. Divide the distance between the two circles into the same number of unequal parts, commencing with a small division near the inner circle, increasing the size of the divisions as we approach the centre of the space, then decreasing towards the outer circle. Through each of those divisions describe concentric arcs of circles to cut the radial lines. From the point D draw a curved line through each intersection successively, until it reaches the outer circle at the point A; from B draw a curved line in the same manner to C, that will give the complete form of tappet. This tappet would act upon one treadle, and consequently upon one heald only. Then we must have another tappet to act upon the second heald. As both the healds must work in the same manner, but alternately with each other, the construction of the second will be the same as the first, but placed with the projection in the opposite direction.

There are one or two matters in connection with the construction of this tappet to which it is necessary attention should be called, and as these matters are of the highest importance the student cannot observe them too closely. First we take the point 1 as the point of contact with the friction roller of the treadle when the reed is in contact with the cloth. On examination it will be found that the two healds will each have traversed the same distance from the highest and lowest points respectively, that is, they would be passing each other in the centre of their stroke, so that by the time the crank has made one-fourth of a revolution they will have reached their highest and lowest point, or opposite extremities of their stroke. They both remain in that position, keeping the shed full open for half a revolution of the crank shaft, or while the lay carrying the reed has traversed the distance from the centre of its stroke to the furthest point from the cloth, and back again to the centre of stroke; the reason for this being to allow time for the shuttle to pass through from side to side of the loom before the shed begins to close, the same process being repeated for the next pick. Secondly, it is necessary that some explanation should be offered of the reason why the distance between the two circles should be unequally divided to obtain the curve of the tappet. It has been pointed out that the movements of the healds must be of an eccentric character; this division is for the purpose of producing that eccentricity. Suppose we take a plane surface and place it in a horizontal position, and place at one end of it a weight, so long as the plane maintains that horizontal position the weight will not move, but if we lower the end which is furthest removed from the weight so as to form an angle, say of thirty degrees, with the horizontal line, the weight will begin to move gradually down it; if the angle is increased to sixty degrees the velocity of the moving body will be considerably increased, and the nearer the angle which the plane forms with the horizon approaches a right angle, the greater will be the velocity of the moving body. The same thing applies to the tappet, which is a power imparting motion to the treadle. When the friction roller of the treadle is in contact with any portion of the arc of the circle between C and D, the treadle is stationary, because, although the surface of one is acting upon the surface of the other, as it maintains the same distance from the centre upon which it works it continues to be in the same plane. From the point D it begins to descend from that plane, first gradually, then increasing in speed to the centre of the stroke, and from that decreasing till it reaches the lowest point, when it again becomes stationary. The radial lines being at right angles to the circumference of the circle, the nearer the curved line approaches the direction of that radial line, the more rapid is its motion, and the nearer it approaches the direction or the circumference of the circle, the slower is its motion.

One word more respecting the leverage of the treadles. I have pointed out the relative length of the stroke of the tappet and heald, in respect to the leverage of the treadle, but the length of the stroke of the healds may be altered again by means of the lever E F, Fig. 13. The length of stroke pointed out represents the displacement at the point of the treadle, and there would be a corresponding displacement at the end E of the lever; and if the arm F be of a length corresponding to E, the displacement or stroke of the heald would be the same; but sometimes the length of the two arms of the lever E F do not correspond, E being frequently made longer than F, therefore in proportion as E is longer than F the displacement of F is reduced, so that this must be taken into consideration along with the leverage of the treadle in determining the stroke of the tappet.

The arm E of the lever is provided with notches so that the rod D may be moved nearer to or further from the centre, thus shortening or lengthening the arm. The object of this is not so much to increase or decrease the size of the shed, but for the purpose of equalising or making all the ends of the upper or lower shed form as nearly as possible the same straight line. If a number of healds are working together, the warp threads which are drawn through those furthest from the piece would not form the same straight line with those drawn through the healds nearest the cloth, if all are raised or depressed the same distance, as shown in Fig. 15. Consequently

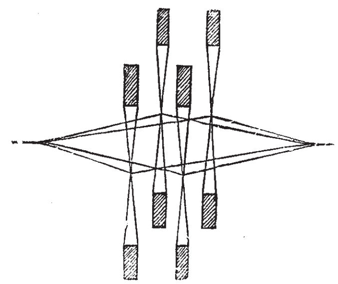

*Fig.* 15.

those furthest from the cloth must be raised higher or sunk lower than those near the cloth, so as to obtain this straight line, otherwise the shuttle will not run smoothly over them, but will be very materially obstructed in its passage, besides a probability of its passing under some of the threads which it should pass over. The object of the notches in the lever E, is therefore to provide a ready means of obtaining this equalisation.

It is sometimes necessary that the length of pause given to the healds be greater than half a revolution of the crank shaft. In the construction of this tappet we have assumed that the reed is in contact with the cloth just at the moment when the healds are passing each other in the centre of their stroke, but in weaving some fabrics it is necessary that the healds should pass each other, so that the shed for the succeeding pick is somewhat open before the pick is actually beaten up. In that case the length of pause to be given must be somewhat greater, so as to give time for the shuttle to pass through before the shed begins to close, otherwise the shed will be partly closed again before the shuttle gets clear, and would consequently both retard its progress, and in all probability cause breakage of the warp.

To effect this we may give a pause equal to two-thirds of a revolution of the crank shaft, which will give ample time to have the shed partly open before the pick is beaten up.

Then supposing the length of pause which is to be given at each extremity of the stroke is to be one-third of a revolution of the tappet, which will be equal to two-thirds of

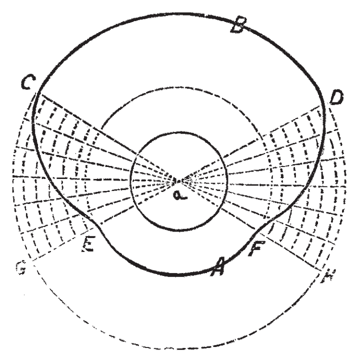


*Fig.* 16.

a revolution of the crank shaft. From the centre *a*, Fig. 16, describe the two circles A and B; with the radius of the circle B divide the circumference into six equal parts. The arc of the circle C D will be one-third of the circumference (there is a fraction in the matter, but this is sufficiently near for all practical purposes). From the points C D draw lines through the centre, and produce them till they cut the smaller circle at the points E F. The arcs C D and E F give the respective pauses at each extremity of the stroke. Produce the lines C F and D E until they cut the large circle in G H, this will give the distances C G and D H, each one-sixth of the circumference. Divide the distance C G into any number of equal parts, say six, draw lines from each of those divisions through the centre, and produce them till they cut the arc of the circle D H, thus dividing it also into six equal parts.

Divide the distances C E and F D each into six unequal parts, beginning with a small portion near the inner circle, and getting gradually larger to the third division, and then gradually smaller towards the outer circle, and describe arcs of circles, cutting all the radial lines; connect the point C E and F D with curved lines drawn through the points of intersection of the arcs with the radial lines and the form of tappet is complete. If this curved line from the inner to the outer circle is carefully followed, it will be seen that the required eccentricity is obtained, and it will also be seen that the cause of this eccentricity is the variation of the distances set off by the arcs on the radial lines. Had those distances been equal the curve would have been regular, and consequently the movement of the heald would have been regular. Just as in the last tappet the nearer the curve approaches the radial line the greater will be the momentum of its stroke, and the nearer it approaches the line of the circle the momentum will be proportionately decreased.

If care be not taken this eccentricity of movement may to some extent be neutralised by the position of the treadles. The treadles at the point of contact with the tappet describe an arc of a circle, the curvature of which is in proportion to the distance of the centre upon which the treadle works from the point of contact with the tappet. This distance must, so far as the dimensions of the loom will admit, be such as to reduce the curvature to a minimum, and the point of contact with the tappet must be so arranged that at the centre of the stroke it will be in a perpendicular line with the centre of the tappet shaft, And the larger the arc described by the treadles at the point of contact the nearer will the position be maintained.

If the point of contact of the treadle with the tappet be either on one side or the other of this perpendicular line from the centre of the tappet shaft, the relative speed of the rising and falling of the treadle will be proportionately affected thereby; that is, it will rise quicker than it falls, or *vice versa*, according to the centre upon which it moves is placed nearer to or further from the tappet shaft. If the centre upon which the treadle moves is brought nearer the tappet shaft, the tappet will strike it sooner than it should, and if that centre is moved in the opposite direction then it will not strike it so soon; consequently, the movement which the tappet should give will be more or less neutralised.

Again, the fulcrum or centre upon which the treadle moves shall be so placed that the treadle during its stroke moves the same distance on each side of that centre above and below. By doing so the eccentric form of the tappet is slightly assisted, the eccentricity of the movement of the heald being slightly increased. Fig. 17 will show this. A line drawn perpendicularly through the centre of the tappet *a* passes also through the centre of the friction roller *b* of the treadle when in the centre of its stroke, therefore, as the treadle rises above or falls below that point, the centre of the friction roller passes slightly to one side of the perpendicular line; at the same time the rod D is in a perpendicular position at the centre of the stroke, the treadle being in a horizontal position at the same moment; consequently, when the treadle is at the highest or the lowest point, the rod D is the same distance removed from the perpendicular position, and the same loss of time in the movement of the heald occurs at each extremity of the stroke. If on the other hand, the treadle occupied the horizontal position and the rod D the perpendicular position at either extremity of the stroke, then no loss of time would occur in the movement of the heald at one extremity of its stroke, while a considerable loss would occur at the other extremity when the rod was furthest removed from the perpendicular position, and consequently the eccentric form of the tappet would be somewhat neutralised.

Another matter requiring careful attention also is, that the treadle must be in continuous contact with the tappet, otherwise a jerking movement is imparted, which is seriously detrimental to the warp as well as materially

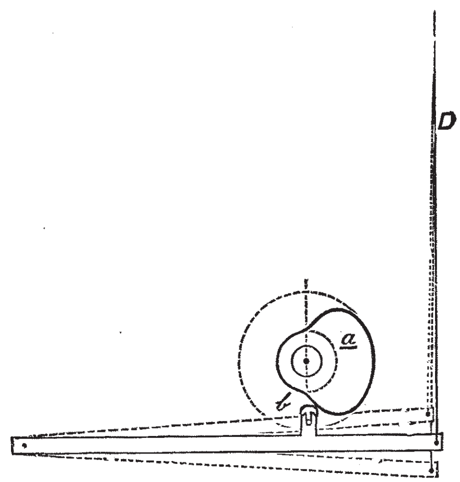


*Fig.* 17.

interfering with the appearance of the fabric, therefore the tappet must be so formed and of such dimensions that the friction roller is always in contact with it and running smoothly upon it. The question of warp spreading will be more fully dealt with in a subsequent portion of this work.

In this last form of tappet the length of pause given is equal to two-thirds of a revolution of the crank shaft, the tappet making one complete revolution only while the crank shaft makes two; one-third of a revolution of the tappet must be equal to two-thirds of a revolution of the crank shaft. But it is not general to give this length of pause for every kind of cloth, in fact only in such cases as already pointed out. That being the case it will be well to give a method by which any length of pause can be obtained that may be desired. We will take as an example a four-thread twill, and arrange that the length of pause shall be equal to one-half the revolution of the crank shaft. In a four-thread twill each revolution of the tappet shaft represents four picks, and consequently four revolutions of the crank shaft; that being so, describe the two circles—as in the plain tappet—of the proper dimensions according to the length of stroke to be given; divide

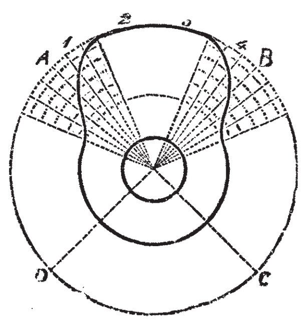


*Fig.* 18.

the circumference of the two circles by diameters crossing each other at right angles into four equal parts. Each of those parts represents one of the four picks which will be thrown in during one revolution of the tappet. In the example we here take, it is required that each heald rises in turn and remains up for one pick only. If we then divide one of the divisions of the circle into four equal parts, 1, 2, 3, 4, Fig. 18, lay off the two central parts 2 and 3 for the pause, and 1 and 4 are the portions which respectively raise and lower the healds. Taking the point 1 as the point at which the crank commences to revolve for the first pick, for the healds to cross each other in the centre of stroke we must take one-fourth of the preceding pick to find the point at which to commence rising, and one-fourth of the succeeding pick to find the point at which to cease settling, and proceed just as in the tappet for plain cloth. Each of the four tappets would have exactly the same construction, and be so placed in relation to each other as to raise and depress the healds at the proper time.

The length of pause may be varied to suit the class of work for which the tappet is intended. Thus three-fifths may be taken for the pause, and one-fifth each for the rise and fall.

If, on the other hand, it is desirable that each heald

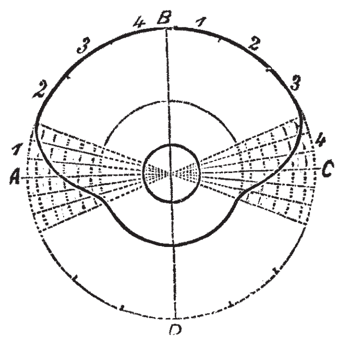


*Fig.* 19.

shall remain up for more than one pick, as for example in the case of a cashmere or four end twill, where each heald remains up for two picks, and down for two picks, then take two of the divisions and divide them each into four, Fig. 19, take part 1 of one division and part 4 of the second division for the rising and settling portions, and proceed as before.

What has already been said shows accurately the nature of the movement which must be imparted to the healds and, generally, the mode of drawing a tappet which will impart that movement; but it is now necessary to enter more into detail and also to show what other influence may be at work to neutralise or otherwise affect the particular movement at which we are aiming. So far everything has been given in very general terms, it now remains to give more definite particulars.

In the first place with respect to the construction of the tappet itself. The drawings made and the modes of drawing, are made upon the assumption that the contact of the tappet with the treadle is at one point, and that point is always the same. Now anyone familiar with the loom knows that upon the treadle is placed a friction roller as shown at Figs. 12, 13, and 17, and that the tappet acts upon the treadle through the medium of this friction roller. If this friction roller be of smaller dimensions the drawing of the tappets already given will answer all the purposes, because although the tappet drawing is made on the assumption that the rollers is a point, or having no dimensions, a small roller, say one of an inch in diameter, would not materially affect the nature of the movement desired to be imparted. But the moment the friction roller begins to assume larger dimensions it does very materially affect the nature of the movement, and consequently it becomes necessary that the dimensions of the roller should be taken into account.

This is perhaps not a matter of so much importance when there are few picks in the pattern as when there are many, for example, tappets for weaving plain cloth or some of the smaller twills may be drawn without taking the friction roller into account, and would do their work fairly well, whereas for larger patterns, or when there are several projections upon a tappet they could scarcely be made to do their work at all, and certainly not in a satisfactory manner. Though when large friction rollers are used it is better that they should be taken into account at all times, whether there are many or few picks in the pattern.

Suppose we take the tappet given at Fig. 19, for comparison with one drawn with the friction roller taken into account, and for this purpose actual dimensions must be considered. In the drawing referred to, the diameter of the inner circle is six inches—drawn to one-eighth scale—and which is approximately the dimensions of the tappets of this kind commonly used. Now where this tappet is used with a small friction roller, say of not more than one or one and a half inches diameter, the working would be as nearly perfection as possible, but if a friction roller of three and a half or four inches diameter be used, it could not be satisfactory, though to use a common expression, *it would work.*

Suppose we now take one where the diameter of the friction roller is taken into account in the drawing, and let it be of a size commonly used, say three and a half inches diameter, as shown at Fig. 20.

It must be borne in mind here that a diameter of three and a half inches is not by any means a fanciful one. There are thousands of looms at work with rollers of those dimensions and the tendency is rather to increase than diminish the size, therefore it becomes more and more necessary to pay attention to this matter.

Thus, in this drawing, Fig. 20, the radius of the inner circle, and the distance between the inner and the outer circles, or stroke of the tappet are the same. Suppose a friction roller *a* of the dimensions just given is made to revolve upon the circumference of the inner circle, its centre will describe the line represented by the dotted line $A^1$, and if made to revolve upon the outer circle, its centre will describe the dotted line $A^2$. Then it is now necessary to find the line which that centre must traverse from the circle $A^1$ to the circle $A^2$, so as to raise or lower the heald, and give it that kind of motion which has already been described. To do that it is only necessary to proceed according to the instructions already given for drawing, Figs. 14, 16, 18 and 19, but drawing the lines of curvature from the dotted circle $A^1$ to the dotted circle $A^2$, instead of from the true inner to the outer circle of the tappet.

By doing this we draw the lines which will be described by the centre of the friction roller, instead of the lines of the tappet itself, and having done that, it becomes quite easy to find the true lines of the tappet.

Having drawn the lines and which are represented by the dotted lines in Fig. 20—we have a clear indication of the movement of the centre of the friction roller; then taking the

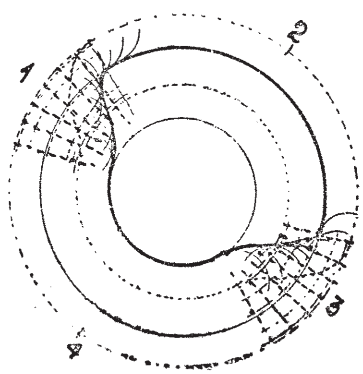


*Fig.* 20.

radius of the friction roller in the compasses, describe a series of arcs of circles, from any number of points on the curved line already drawn, we find the true line of the tappet from the inner to the outer circle. Or in other words, the tappet is a true tangent to all the arcs of circles so drawn.

It is very evident that a tappet so drawn will give in the best possible manner the movement to the healds which is required, and also that the movement from the highest to the lowest point will be the same as in the opposite direction.

There is one point, however, to which attention must be called. Theoretically one heald will ascend exactly as the other descends, and no doubt that is true after the movement has actually commenced, but at the outer extremity of the tappet there must be a slight loss of time in the movement. If the tappet is constructed strictly to the drawing, the corners of the projections on the tappets will be very acute, and it will be a little difficult for the friction roller to travel over them, they must therefore be very slightly rounded, and this of course occasions a little loss of time in the movement, but the loss is so very slight that it can have no appreciable effect upon the actual work, as any alteration in the tension of the cords and healds together could scarcely exceed one-eighth of an inch over the entire length, and that for only a very brief period of time, consequently it need not be considered at all seeing that it could have no detrimental effect.

As already mentioned, when the tappets have more than one projection upon them, the question of taking the diameter of the friction roller into account becomes of much more importance.

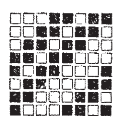

*Fig.* 21.

For the purpose of further demonstration, a larger pattern may be taken, and the tappet drawn for it by both methods. Let the pattern be that given at Fig. 21. This pattern occupies eight picks, and of course there would be eight tappets required, each of the same form but placed in such position as to follow each other consecutively.

Now this tappet is drawn to the same scale, and in the same proportion as Figs. 19 and 20. The drawing at Fig. 22 is drawn without taking the diameter of the friction roller into account, and Fig. 23 on the same method as Fig. 20, the diameter of the friction roller being 3½ inches* It will only require one glance from a practised eye to discover which tappet is best suited for its work.

Let us apply a test to these two drawings for the purpose of seeing clearly where the advantage of one over the other can be found.

We have said that the diameter of the friction roller is 3½ inches, and ostensibly the pause at each extremity of the stroke is equal to half a revolution of the crank shaft of the loom. As has been already shown, this would be strictly so were the point of contact of the tappet with the treadle a *point*, that is, as it is drawn in Fig. 22 the distance between the curved lines which are drawn from one circle to the

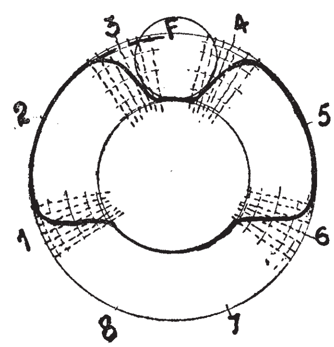


*Fig.* 22.

other is equal to half a revolution of the crank shaft, and had the friction roller no dimensions that would represent the pause given to the treadle, and consequently to the heald. Now draw the friction roller F in the space between the wings of the tappet, and to the dimensions given, and

* I find on examining the drawing that the friction roller F has been inadvertently drawn 3 inches diameter, though the tappet itself is properly drawn for a 3½ inches roller.

then discover what is the amount of pause actually given. It will be seen at once that this friction roller fills, or nearly fills, the space between the wings or projections of the tappet, so that the moment it has ceased to descend one of the inclines it is compelled to begin to ascend the other, and consequently instead of remaining stationary, and in contact with the inner circle of the tappet only, for a period equal to half a revolution of the crank shaft, it remains there for a very brief period only. On the other hand, if the line which its centre describes be carefully drawn, it will be found that the time lost when in contact with the inner circle of the tappet, is gained when in contact with the outer circle. So that whilst the heald is not allowed to dwell sufficiently long at its lowest point, it dwells far too long at its highest point. As will be shown presently, this possesses serious disadvantages. The exact amount of variation can be readily seen by following the line described by the centre of the friction roller, marking the point where it first reaches its lowest position, and where it begins to ascend from that position, and doing the same thing when at its highest point; then having found these points, finding what proportion it represents of the complete circle of the tappet, or, more readily, of that portion of the tappet which represents one revolution of the crank shaft, or one pick.

A reference to Fig. 23 will now show what the advantages are which will be obtained by drawing on the principle laid down at Fig. 20, for on examination it will be found that the space between the wings of the tappet is such as to allow the friction roller to remain at rest for a period of time exactly equal to half a revolution of the crank shaft.

Attention must now be called to another matter which is of some importance, though not vital, to the drawing of a good tappet. It has been shown that the divisions between the inner and outer circles of the tappet, when obtaining the curve, should be irregular, so as to give an eccentric motion to the healds. These divisions may be made in any ratio, provided they are the same in relation to the inner as to the

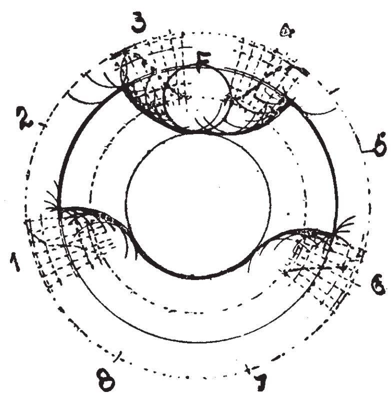


*Fig.* 23.

outer circle, but the best results are undoubtedly obtained if the divisions are made so as to produce what is termed harmonic motion. For example, take the space, or the distance, between the two circles, and upon a line equal to this distance, describe a semi-circle, divide the semi-circle into as many equal parts as you wish to have divisions between the circles; from each of these divisions drop a perpendicular to the base line, and which will divide that line

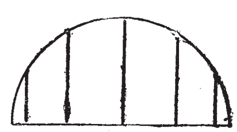

*Fig.* 24.

in such a manner as to produce harmonic motion, then those divisions are such as may be used in the construction of the tappet as shown at Fig. 24.

It will be obvious that by this method of drawing, not only will the increase and decrease of velocity communicated to the treadles, and consequently to the heald, be in the best possible ratio, but that as one heald ascends another will descend at exactly the same rate of speed. This is a matter of no small importance in weaving.

In most looms where tappets are employed, the healds are connected to each other by means of cords or straps and levers, or what is equivalent to levers, rollers or bowls, as they are often termed. The necessity for this kind of arrangement is easily understood, the tappet acts in one direction only, that is, it presses the treadle down but does nothing to bring it back, therefore some means must be adopted to bring it back again, and this must be done either by means of the levers just mentioned or by springs. The use of springs is objectionable on many grounds, although they are often employed with advantage when the tappet is badly constructed, consequently the levers are the best means to be employed when we have good working tappets. The arrangement of these levers then must be such that as one heald is raised, it must, by means of the levers, pull another heald down; this being the case, it is clear that one heald must not begin to ascend before another has liberty to begin its descent, otherwise there will be undue tension upon both the cords connecting the healds and the healds themselves. On the other hand, if the descent of one commences before the ascent of another, the cords will become slack. In either case, bad working must be the result, in fact, they should be so adjusted that there is as nearly as possible the same degree of tension throughout, and it is very evident that this cannot be obtained unless the tappet be carefully constructed.

One other point may be mentioned, viz., that it will very much conduce to accuracy in drawing the curve of the tappet if a large number of divisions be made.

There is but one other matter connected with the tappet itself which now requires consideration. If a tappet be drawn upon the principle shown here, with a small inner circle and a large friction roller, the former say from five to six inches, and the latter from three to four inches, it will be found that the curve of the tappet will, for some distance, very nearly approach a radial line. Now this renders the working rather difficult, as the incline up which the friction roller travels will be rather steep, and ease in working can only be given to it by altering the position of the friction roller in relation to the centre of the tappet. This is a rather unsatisfactory mode of remedying an evil, therefore it is much better, if the friction roller is large, to make the tappet as large as the space in the loom will permit.

By following this method it becomes quite an easy matter to arrange a set of tappets for any given pattern. After dividing the circumference into as many parts as there are to be picks in each revolution of the tappet shaft, each portion may then be made to raise or lower the heald as desired, and any length of pause given to each thread.

It now becomes necessary to deal in some measure with the means of connecting the healds with each other, so that as one is raised it will supplement the action of the tappet by depressing another, or failing this, to provide some means for bringing about this depression. As has been already said, the best mode of accomplishing this is by means of levers in one form or another, because by their use the non-positive, as it is called, action of the tappets is at once converted into a positive action, or the tappet which can act in one direction only, is made to act in both directions through the medium of these levers.

Suppose in the first instance, that two healds only are employed, if the healds are raised by the action of the tappets, then they may be connected at the bottom by means of any simple lever or roller, so that as one heald is raised, the other through the medium of this lever or roller is depressed. In this case there is only one consideration, viz: that the lever or roller, shall be so arranged that the healds are not held too far apart, and if levers instead of rollers be used, the arms shall both be of the same length, so that one shall be depressed just as much as the other is raised.

In arranging these levers—or stocks and bowls as they are sometimes called—for any even number of healds, there is not much difficulty, the considerations being substantially those which have just been pointed out, first, that they shall not spread out the healds too far, nor occupy too much space in the loom, and second that each arm of the lever shall be of the same length. Of course in the case of a large number of healds being employed, it is necessary to arrange a number of rollers upon each end of the lever. Say for example that eight healds are to be used, then an arrangement such as that shown at Fig. 25 may be resorted to where a lever is

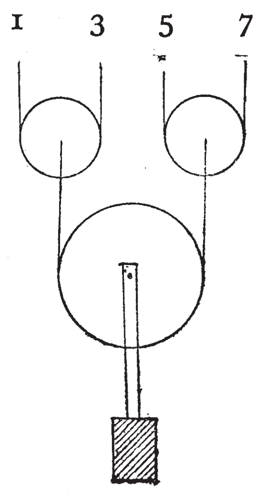


*Fig.* 25.

shown in section with the necessary rollers attached to it; this lever has its fulcrum in the centre, and the rollers, as shown, attached to each end, a strap is passed round the large roller to each end of which is attached a small roller. Again round these are passed straps or cords, and connected directly with the healds. From this arrangement it is obvious that if any one of the four healds be raised, one of them must also be depressed. Suppose for example number 7 be raised, it may bring down number 5, but if number 5 is still held up by its own tappet, then through the medium of the large roller, it will communicate with either number 1 or 3, and so depress them. Again at the opposite end of the lever are similar rollers attached to four other healds, so that if none of those at the end where one is being raised are allowed by their respective tappets to descend, then through the medium of the lever, motion is communicated to one of the healds at the other end. This will be more easily understood by reference to Fig 26, which, as will be presently shown, is an arrangement for seven healds.

It is of course a necessary condition in the use of this kind of arrangement, that as one heald ascends, another must descend, there must always be the same number of healds raised for every pick in the pattern. It does not follow though, that there must always be just half the healds raised, there may be any number, large or small, but whatever that number is it must always remain the same.

It will be noticed that in Fig. 25, the healds, 1, 3, 5 and 7, respectively are shown as being attached to the rollers at one end of the lever; this is the most convenient arrangement, as it prevents the rollers from being too small, and gives more room for the cords to work. Of course the other end of the lever would carry the intermediate healds, 2, 4, 6, and 8.

Whenever the number of healds are even, the plan adopted here will hold good, but when they are uneven, a somewhat different arrangement must be adopted, not different in principle, but taking into account the question of leverage. Suppose for example that seven healds are to be employed, then one end of the lever must carry four healds, and the other end three, as shown at Fig. 26. In this drawing four healds are shown attached to one end of

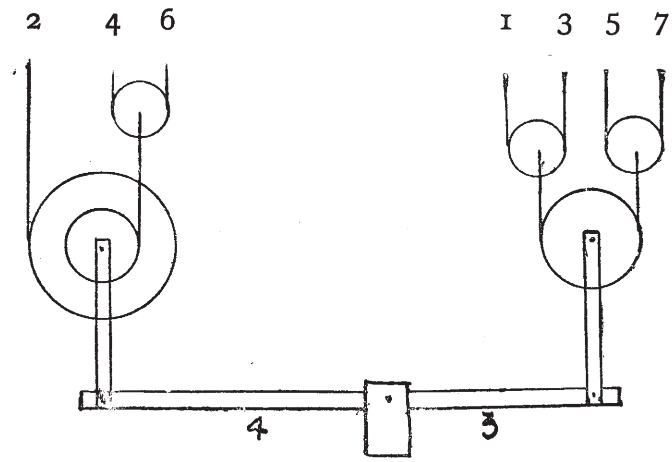


*Fig.* 26.

the lever, and three to the other. Now it is very clear, that if four pounds weight be suspended from one end of a lever and three pounds from the other, that the opposite arms of the lever must be as three to four in their length; the heavier weight suspended from the shorter arm, and *vice versa*, to enable one to balance the other; exactly the same rule will apply to healds. If there are four healds attached to one end of the lever, and three to the other, then the two arms of the lever must be as three to four.

What applies to the long lever applies also to the arrangement of rollers for carrying an odd number of healds as those carrying 2, 4, and 6. Here are two rollers, which by their arrangement constitute a lever, the small roller is made fast to the larger one; to the large roller one of the healds is attached, and to the other is attached another roller connected with two healds. With this arrangement, if the heald 2 be raised, either of the healds 4 and 6 will be depressed, but it is evident from the fact that the diameters of the rollers are as two to one, that both could not be depressed by the raising of the heald 2. In fact the diameters of the two rollers being as two to one, and being made fast together, they constitute a lever, the two arms of which bear those proportions to each other.

One difference must be noted in regard to the rollers at one end of the lever in relation to those at the other end, viz., that whilst the straps pass freely round the former, they must be made fast to two of the latter, otherwise they would cease to be a lever.

From the arrangement shown at Fig. 26, it will be readily seen that others can be easily made for any odd number, as that in Fig. 25 shows how they can be made for any even number. For instance, by taking off the rollers from one end of the lever, they will act for four healds. It is desired to provide for three healds only, the rollers from the other end will serve, or a similar arrangement with the rollers of a size suitable to the space to be occupied by the healds. Again it will be easy on the same principle to make an arrangement for five healds, either by attaching three to one end of the lever—as in Fig. 26—and two to the other, and letting the two arms of the lever be as two to three, or by attaching four to one end, as in Fig. 25, and one to the other, and having the two arms of the lever as one to four. Sometimes one arrangement is adopted, and sometimes the other, according to the materials at hand which can be most readily adapted.

It is very evident from this, that levers and rollers can be easily arranged to suit any number of healds, but it must be borne in mind, as already pointed out, that they will only serve for patterns where the same number of healds are raised for each pick, and that in the event of the pattern being irregular in this respect, resort must be had to springs or weights, or some other means of bringing the healds to their lowest point after being raised.

In constructing a tappet the length of stroke to be given is a matter which must have a due share of attention, so as to regulate the size of shed to suit the size of the shuttle to be employed ; and to avoid as far as possible any undue strain on the warp the shed should not be larger than is absolutely necessary to admit of a clear passage of the shuttle from side to side. Then, having found from the size of the shuttle what size of shed will be required, the stroke of tappet is merely a question of leverage.

Suppose one example is given here, it will serve to illustrate the principle of determining the stroke of the tappet, and can be readily adapted to any class of loom. Fig. 27 shows the position of the various parts of the loom which have a bearing upon this question. In this figure, *a*, is the point where cloth is formed, *b*, the lay carrying the reed, *c* the shuttle, and *d*, the healds. The shuttle is here represented as passing through the shed. For the purpose of making the matter as simple as possible, I will suppose dimensions which will enable the reader to follow the system of calculation easily, these dimensions being such as may be found in existing looms or not, but used merely for the purpose of illustrating the principle. Then we will suppose that what is termed the stroke of the going part is equal to 6 inches—that is, the distance it traverses to and from the cloth is 6 inches—and the width of the shuttle is $1\frac{1}{2}$ inches. So that when the shuttle is passing through the shed, which is when the going part is furthest from the cloth, the front of the shuttle is $4\frac{1}{2}$ inches from the cloth, or $6-1\frac{1}{2}=4\frac{1}{2}$. Then suppose the depth of the shuttle is $1\frac{1}{4}$ inches. Now, as will be seen, the shed is V shaped, and the front of the shuttle being the nearest the cloth, the depth of the shuttle determines the depth of the shed at that point, so that if the depth of the shuttle is $1\frac{1}{4}$ inches, the shed must be of that depth at a point $4\frac{1}{2}$ inches from the cloth. The question then to determine is, if the shed must be $1\frac{1}{4}$ inches

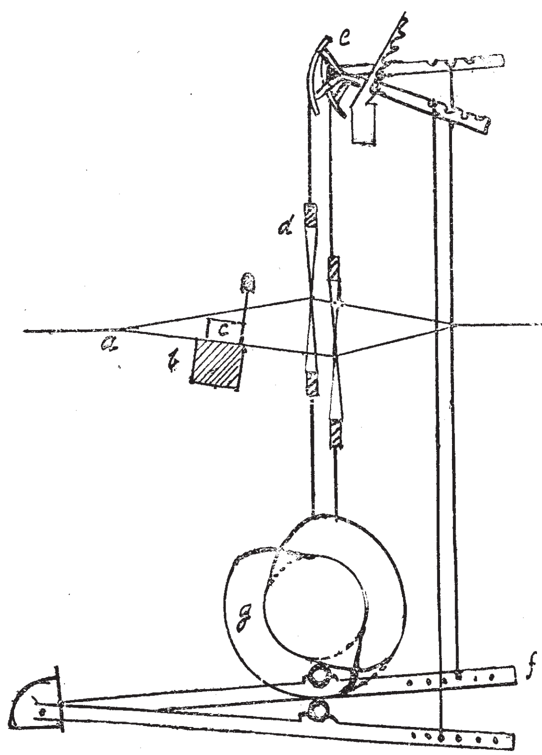


*Fig.* 27.

deep at a point $4\frac{1}{2}$ inches from the cloth, what depth must it be at the healds? The question is one of simple proportion, thus, if the healds are say 12 inches from the cloth, then, as $4\frac{1}{2}:12::1\frac{1}{4}:3\frac{1}{3}$, or the depth of the shed at the healds must be $3\frac{1}{3}$ inches, or in other words, the healds must traverse a distance of $3\frac{1}{3}$ inches from their highest to their lowest point. Then if the healds travel this distance, the lever *e* from which they are suspended must travel the same distance.

For a moment we may suppose that both the arms of this lever are of the same length, and if that is so, each extremity will travel the same distance, and the point of the treadle F, to which the lever is attached, will also travel the same distance, or the displacement of the treadle at the point where it is connected by the rod to the lever E, will be equal to $3\frac{1}{3}$ inches. Then what we have now to find is, if the displacement at the point of the treadle is $3\frac{1}{3}$ inches what is it at the point where the tappet acts upon it? This again is a question of simple proportion. Suppose the entire length of the treadle from the point where it is connected to the lever E, to the fulcrum is 30 inches, and the distance from the centre of friction roller to the fulcrum is 20 inches, then as $30:20::3\frac{1}{3}:2\frac{2}{9}$. Or, the distance which the treadle must travel at that point is equal to $2\frac{2}{9}$ inches, therefore what is termed the stroke of the tappet, or the length of the projection upon it must be equal to $2\frac{2}{9}$ inches, or the distance to be traversed by the treadle at the point where the tappet acts upon it. So that by this means we have an easy mode of determining what the stroke of the tappet should be.

There is only one other point which need be mentioned. The above calculation is made on the supposition that the lever E has its two arms of equal length; that may be so, or they may be different, but if they are different the difference has only to be taken into account, and dealt with as a proportion; suppose that one arm is 7 inches, and the other 9 inches, and that the healds are suspended from the shorter arm, then as $7:9::3\frac{1}{3}:4\frac{2}{7}$, or the arm which is connected with the treadle must traverse a distance of $4\frac{2}{7}$ inches.

The equalization of the sheds is a matter which cannot have too careful attention. In doing this, care should be taken not to raise or lower the healds furthest back from the slay more than is requisite, or an unnecessary strain will be thrown on the warp contained in those healds, and consequently breakages will occur. If, on the other hand, they are not sufficiently raised or depressed, the threads will be slack, and consequently will not bear their share of the strain. The lease rods also play a most important part in weaving. Although their primary function, as their name indicates, is to keep the lease of the warp so that when any threads are broken their proper places may be easily found, yet the way in which they are put in, whether plain or otherwise, and the distance at which they are placed from the healds, have a very material effect upon the warp. In some classes of goods—such, for instance, as are made of soft woollen warps—lease rods are not used, but what are known as clasp rods, that is, a pair of rods, one above and the other below the warp, tied together so that the shed shall not open beyond them; and in some cases clasps are used in addition to lease rods.

The action of the tappets, in relation to the movements of the lay, is a matter which, perhaps as much as any other, requires the attention of the weaver; this relative action influencing as much as anything the appearance of the cloth, as well as materially affecting the warp. If it is required that the warp shall be well spread in the cloth, and also in heavy work when a great number of picks are required to be put in, when the pick is beaten up to the cloth the shed for the succeeding pick should be more or less open. If the pick is beaten up before the shed closes upon it it will spring back a little, and the succeeding pick has to drive it forward again.

This crossing the shed, as it is sometimes called, will explain the necessity for the longer pause which the tappet must give to the healds, because the shed opening as the pick is beaten up it must remain open sufficiently long for the succeeding pick to be thrown in.

If the warp does not require to be well spread, then the shed need only remain open sufficiently long for the shuttle to pass through it, the pick being beaten up to the cloth when the healds are even, and before any strain is thrown on the warp by the opening of the succeeding shed. The shed should then open for the shuttle to pass through as the lay moves backwards, when it will, of course be open widest at the moment when the lay is at its furthest point from the cloth. It will be readily seen that for this kind of shedding the pause must be regulated to suit it.

For tender yarn this method is certainly the best, as it must be obvious that less strain is thrown upon it than by the preceding method. And even where it is necessary that the sheds should be crossed it may be saved considerably by causing the shedding to take place a little later, but the warp will not be so evenly spread, thus detracting from the appearance of the cloth, and as the primary object is, or should be, at all times to produce the best possible effect on the cloth, this latter mode of shedding should only be resorted to when the tenderness of the warp or other considerations make it an absolute necessity, or when the make of the cloth is such that it will be best adapted to it.

### SPEED OF TAPPETS.

We must now take into consideration the question of regulating the number of revolutions of the tappet shaft in its relation to the main driving or crank shaft. In the class of loom to which those illustrations more particularly apply the tappets are worked at the side of the loom, but in all classes of looms the same principles are involved, so that the difference is only a matter of detail. Then in this case we have only two shafts in the loom, the crank shaft A, and the tappet shaft B, Fig. 11. The crank shaft as pointed out at page 72, makes one revolution at every pick of the loom. The lower shaft B carries the picking tappets; these are placed one on each side of the loom, and arranged so as to strike alternately, so that they will propel the shuttle from their respective sides in turn. That being the case, this shaft must of necessity make one revolution while the crank shaft is making two, consequently if the shedding tappets are driven *by* this shaft nothing but plain cloth can be woven, but they may be driven *upon* it, and the number of revolutions be regulated at pleasure. To accomplish this the tappets, instead of being made fast upon the shaft so as to revolve with it, work upon it; in fact, the end of this shaft becomes a stud for them, being kept in place by a movable collar and set screw; the tappets are then driven from the crank shaft by toothed wheels. If convenient it is simplest done by having one large toothed wheel on the tappets, and a smaller one on the crank shaft, then the calculation for the number of revolutions is simply the proportion of the two wheels to each other. The teeth acting alternately on each other their relative speeds will be as the teeth of one are to the teeth of the other. For instance, if it is required to have four picks in the round of the tappets the proportions of the two wheels are as four to one, if for five picks then the proportion is five to one, and so on. Very frequently it may be found inconvenient to have only two wheels. The two shafts are placed at a fixed distance apart; the wheels would therefore have to be of such diameter as to suit this fixed distance; consequently it would frequently happen that in changing from one number of threads to another not only the diameters but the pitch of the teeth would be altered. This it is desirable to avoid as far as possible, and indeed to avoid the necessity of making the wheels of such diameter as to suit the distance of the shafts. This is done by introducing an intermediate wheel, which becomes simply a medium for communicating the power, without in any way altering the relative speed of the two shafts; therefore the same pitch of teeth may be preserved throughout, and the only thing to observe is the relative number of teeth in the two principle wheels.

In some patterns, where a great number of threads are required in the revolution of the tappets, it may not be convenient to obtain the relative speed by these two wheels. In that case *two* intermediate wheels are introduced, these two being of different sizes. The larger receives its motion from, or is geared into, the wheel upon the crank shaft, and carries upon the same stud the smaller wheel which is geared into the wheel connected with the tappets, therefore there are two driving and two driven wheels. Then the driving and driven wheels must stand in the ratio to each other as the speed of the tappets and crank shaft; that is, if the first driving-wheel contains sixteen teeth and the second driving-wheel also contains sixteen teeth, and ten picks are required in the revolution of the tappet, $16 \times 16 \times 10 = 2560$, then the product of the two driven wheels, multiplied by each other must be 2560, thus, $40 \times 64 = 2560$.

When changing from one number of treads to another, it can sometimes be accomplished by changing one wheel only, which may perhaps be any one of the four. We will suppose that we have to find the number of teeth required in the first driving-wheel, the three other wheels being given, multiply the two driven wheels into each other, $40 \times 64 = 2560$, then multiply the given driving-wheel by the number of picks required in the revolution, $16 \times 10 = 160$, and divide the product of the driven wheels by the product thus obtained, $2560 \div 160 = 16$, the number of teeth, required for the first driving-wheel.

If it is desired to ascertain the number of teeth for the second driving-wheel, the process is precisely the same, only substituting the first for the second wheel in calculating. Suppose, then, it is desired to find the number of teeth required for either of the driven wheels, the other three being given, then multiply the two driving-wheels into each other and by the number of picks required, and divide by the driven wheel given, thus, $\frac{16 \times 16 \times 10}{40} = 64$. It will be seen by this that it is very easy to ascertain the number of teeth required in any one of the wheels, but care must be taken that there can be no remainder in any of these calculations, otherwise one portion of the loom will get in advance of the other with its work, and the result would be anything but gratifying.

Sometimes it may be desirable to ascertain the number of teeth in both the intermediate wheels. In that case the easiest and readiest method is to take the first driving-wheel, and multiply it by the number of picks required in the pattern, and whatever proportion the product bears to the last driven wheel, the two intermediate wheels must bear exactly the same proportion to each other. Suppose in this case we are to have seven picks in the pattern, and the first driving-wheel contains 20 teeth, and the last driven wheel contains 120 teeth, it is required to find the two intermediate wheels which will be required, it will be readiest put in the form of a fraction, thus $\frac{20 \times 7}{120} = \frac{140}{120}$ or $\frac{14}{12}$, then the proportion which the two intermediate wheels must bear to each other will be as 14 to 12. Consequently any multiple of those two numbers, as 42 and 36, or 56 and 48, will answer the purpose.

To prove that it is true, multiply the two drivers together, and the two driven together, and divide the driven by the drivers, thus, $\frac{120 \times 42}{20 \times 36} = 7$, so proving that the wheels are correct. Again, suppose we are to have nine picks in the pattern and the first driver contains sixteen teeth, and the last driven contains 120 teeth, thus, $\frac{16 \times 9}{120} = \frac{144}{120}$ or $\frac{12}{10}$, consequently any multiple of 12 or 10, as 48 and 40, &c., will serve. And to prove that this is correct, $\frac{120 \times 48}{16 \times 40} = 9$. This will in most cases be found the readiest method of finding the intermediate wheel, and of course may be relied upon for accuracy.

Various methods of driving the tappets are adopted by different makers, but however driven, whether upon a separate shaft or otherwise, or whatever intermediate wheels may be used, the above system will be found to be substantially correct, the details being varied according to the circumstances of the case.

### PICKING.

We now come to the second movement in the process of weaving, viz., the throwing in of the weft, or, as it is technically termed, the picking.

This movement differs entirely in its character from the shedding. In picking, a considerable amount of force is required to be exerted at a given moment, for the purpose of propelling the shuttle from one side of the loom to the other; but to ascertain the exact amount of force required to accomplish this work is not one of the easiest matters. The question might very naturally be asked, What creates this difficulty? Have we no means of measuring it? In the first place, we have a certain amount of matter to be propelled through a given space in a given time, which time is almost infinitesimal, the whole movement partaking of the character of a blow. The amount of force required to do that might be ascertained, but it would be difficult to ascertain the amount of resistance offered to it in its passage, which resistance varies considerably under different circumstances. That being the case, nothing but actual experiment can give a positive data. Such experiments must be directed to ascertain the amount of force which would be transmitted by a tappet of a given length and shape revolving at a given speed, this amount of force being increased or decreased by the leverage of the picking-stick.

But although it is not easy to lay down an absolute rule, yet an approximate result may be arrived at.

We will take for illustration what is known as the cone picking motion, which is the one most generally used, at least in fast-going looms, and it is in this class of loom that strict attention to the picking movement is most required, for if any harshness of movement exists in the loom it is intensified by the high rate of speed, and the effect of it is injurious to the whole loom.

The cone picking motion is an application of a simple lever, and consists of an upright shaft carrying a cone-shaped stud (from which it takes its name) and a wooden arm, known as the picking-stick, and to which is attached the picker. This stud and wooden arm are the two arms of the lever, and the upright shaft is its fulcrum, the amount of leverage being determined by the relative lengths of the stud and arm, the length of the upright shaft being a matter of no importance so far as its action is concerned, the only condition attached to it being that it shall be sufficiently strong to bear the torsional strain to which it will be subjected.

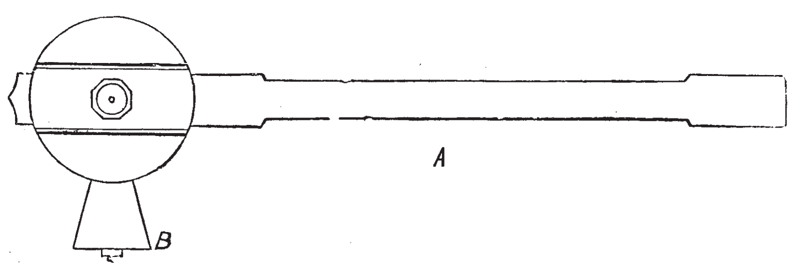


*Fig.* 28.

Fig. 28 is a plan of this motion, A being the wooden arm and B the cone stud upon which the tappet acts, this action being of such a nature as to give the requisite amount of force for the work to be accomplished, but the force must be imparted in such a manner as to render the action smooth and easy. Then to ascertain the nature of this action, we must consider first of all the direction of application of the force and magnitude of such force.

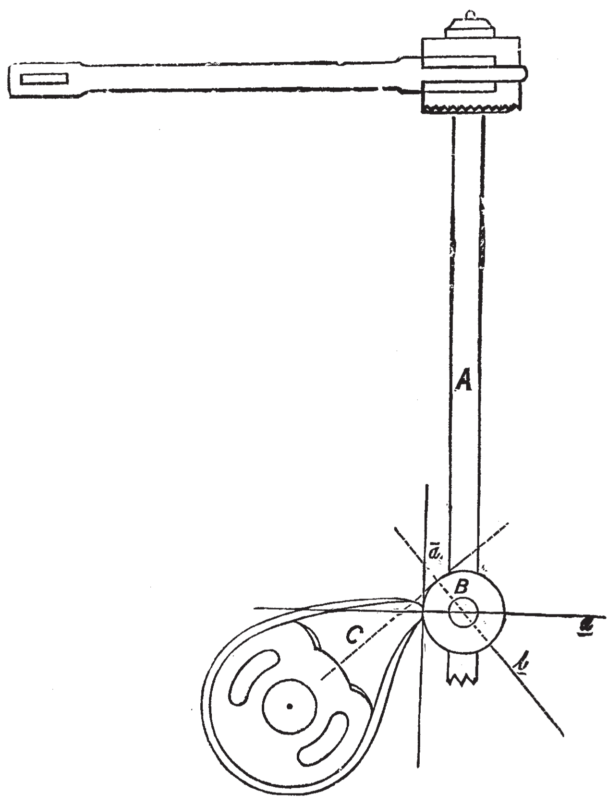


*Fig.* 29.

First, as to the direction. This is determined by the point of contact of the picking tappet with the cone shaped stud, or short arm of the lever, which is provided with a friction roller, upon which the tappet acts. Fig. 29 shows the arrangement, A being the upright shaft, B the cone, and C the picking tappet. The cone being circular, if a line be drawn tangent to the circle at the point of contact with the tappet, as the tappet revolves the direction of force will be at right angles to this tangent, the line *a* will then indicate the direction of the force. Then it must be evident that for the action of the pick to be perfectly smooth the direction of this line should be at right angles (or as nearly as possible) to the vertical shaft A, which is the fulcrum of the lever, and although it is difficult to maintain the magnitude of the force on account of the suddenness of the stroke, and at the same time preserve this line of direction, the nearer the approach to this the more perfect will be the action of the pick. This must be evident almost at a glance. We will suppose for a moment that the point of contact is at *a*; then draw a tangent to the circle at that point, and the dotted line *b* is the direction of force at right angles to it. It requires very little demonstration to prove that a great portion of the force is expended upon the stud, or upon the socket in which the upright shaft works, pushing it downwards, instead of causing the lever to move easily upon its fulcrum; the result is harshness of working, and a certain jerkiness, as well as requiring considerably more force to propel the shuttle, consequent upon the amount of force which is expended upon the stud and socket being lost to the pick.

The direction of force may be regulated by the relative position of the tappet shaft and the cone picking stud, the latter requiring to be placed in such a plane—above or below the plane in which the tappet shaft revolves—as will bring the point of contact in such a position as to give the proper direction to the force. Again, to assist the maintenance of this direction of force the cone and the tappet must be shaped to each other in such a manner that as the tappet, which is a lever, describes a circle upon its centre, and the lever consisting of the cone and picking stick describes an arc of a circle upon its fulcrum, the contact of the two surfaces will maintain the same position throughout, and that contact shall not be with one portion of the surface—or at one point—but it shall be across the whole surface of the tappet, otherwise an imperfect motion is imparted which cannot be remedied in any other manner.

Another question requiring attention is the position of the upright picking shaft. This may be determined by two considerations, first, the length of picking stick or arm necessary to give the leverage required; second, whether the upright shaft is to be placed in the centre of stroke or otherwise. The first determines the distance at which it must be placed from the lay or going part; the second determines its relative position to the tappet shaft, and consequently the diameter of the disc of the tappet, diameter of cone, and length of tappet nose. Assuming that it is desired to place the upright shaft in the centre of stroke, that is, that the centre of the cone stud shall be parallel to the tappet shaft when it has traversed half the distance from one extreme point to the other of its course, and that the positions of the two shafts have been predetermined by other reasons, then the diameter of the tappet disc and cone must be regulated to suit this position. Suppose the distance between the centres of the two shafts to be six inches, and to obtain the requisite power a tappet nose of three inches is required, then the sum of the radii of the disc and cone added to half the length of the tappet nose must be six inches. Thus, radius of cone $1\frac{1}{4}$ inches, radius of disc of tappet $3\frac{1}{4}$ inches, half length of tappet nose $1\frac{1}{2}$ inches, $1\frac{1}{4} + 3\frac{1}{4} + 1\frac{1}{2} = 6$ inches. But the upright shaft, instead of being placed in the centre of stroke, may be placed at or near either extremity of the stroke; that is, it may be so placed that the centre of the cone stud will be parallel to the tappet shaft, either before the force commences to be delivered, or when it is finally expended. In the first case, the sum of the radii of disc and cone must equal the distance between the two shafts; in the latter case it will be the sum of the two radii and the length of the tappet nose. In whatever position the shaft may be, the skew form of the tappet must be arranged to suit that position. Having determined the relative position of the two shafts, and the cone and tappet, we now come to the question of the magnitude of force, and the time occupied in its delivery.

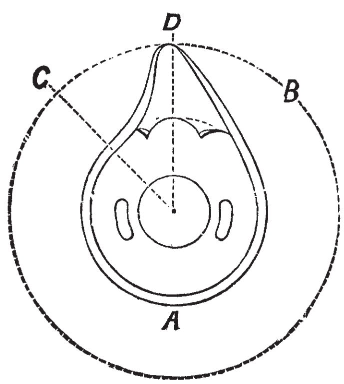


*Fig.* 30.

First, as to the magnitude of the force required. As I have said, it is difficult to lay down a definite rule, yet we can arrive at an approximate result. In the first place, the intensity of the force depends on the length of the tappet from the circumference of the disc, its form, and the part of the circle occupied by the working face. If we refer to Fig. 30, the circle A is the circumference of the disc, the circle B is the circle in which the tappet moves. If we draw a radial line through the point where the tappet rises from the disc, and cut the larger circle at C, and another through the point of the tappet at D, the distance C D is that portion of the revolution which the tappet makes while the stroke is being given. This, in conjunction with the leverage given by the picking-stick or arm, gives us an idea of time and space.

We must then take into consideration the question of momentum. In the construction of this tappet a similar principle must be adopted as in the construction of shedding tappets. The first portion of the rise must be gradual so as to draw up the leather which connects the picking-stick with the picker, and commence to move the shuttle gradually and increase in velocity towards the end of the stroke. This will be increased as the form of the tappet approaches nearer to the radial line

The question now arises as to the length of the tappet. This must be determined in conjunction with the leverage of the picking arm, the length of the shuttle-box, and the nature of the stroke to be given. We have assumed the length of the tappet to be three inches from the circumference of the disc, and suppose the leverage given by the relative length of the picking-arm and cone to be as five to one, that would give a length of traverse to the picking-arm which must correspond with the length of the shuttle-box (with an allowance added for length of leather to take the picker back) ; then as the stroke is required to be slow or quick for the work it has to perform the tappet must be shaped accordingly, that is, the time occupied in the delivery of the stroke must be increased or decreased, and the working face must be made to form a greater or less angle with a radial line drawn from the point of the tappet nose to the centre of the circle. The shorter the tappet the more sudden will its action require to be, and the nearer it must approach the radial line in form. The slower the required action and the greater the arc of the circle occupied by the working face, and the more gradual the rise from the circle.

There is one matter connected with this class of tappet to which attention should be called. It is no uncommon occurrence for the man in charge of looms, when he wishes to increase the force of the pick, or in other words, to give more impetus to the shuttle, to file out the tappet nose, so as to make it resemble a hook in shape, by doing so he apparently gives more force to the final delivery, in reality he makes the movement more sudden, but in doing so he creates bad working, for the tappet instead of acting in such a manner as to preserve the proper direction of force, will, as it were, hook itself upon the cone, and so not only lose its power for a short time, but will act in a very jerky manner.

There is no part of the loom which requires more careful attention than the picking, because from the very nature of the movement there must be considerable re-action in the working parts and accompanied by great wear and tear, and it can only be by a careful observance of the general lines indicated here, along with a proper timing of the pick to the other working parts of the loom (a matter which will be dealt with under the head of general working), that the evil effects can be in any degree mitigated. The easier the movement can be executed, the better it will be in every way for the general working of the loom. Too much stress could not be laid upon the necessity of paying strict attention to this part of the loom. No matter what method of picking be adopted, the very nature of the movement makes it difficult to deal with, and it is no exaggeration to say there is more unnecessary wear and tear produced by bad picking, than by a bad arrangement of any part of the loom, and however perfect the loom may be in its other parts, even a slight imperfection in the picking will neutralize it to a considerable extent.

## BEATING UP OF THE WEFT.

We now come to the consideration of the third of the primary movements in weaving, viz., the beating up of the weft. This is performed by what is termed the lay, which carries the reed dividing the warp threads.

The lay performs two distinct functions, the beating up of the weft and carrying the shuttle. For the first operation a smart stroke of the reed is necessary, and for the latter a somewhat protracted pause, to allow the shuttle time to pass from side to side through the shed formed by the warp. To effect these two purposes it is necessary that the movement of the lay, in its passage to and fro, shall be of a decidedly eccentric character.

Movement is imparted direct from the main driving shaft of the loom to the lay by means of cranks, and it is in the manner in which the continuous circular motion of the crank is converted, as well as in the relative sizes of the crank and crank arm, or connecting rod, that this eccentricity is obtained.

If we take an ordinary crank, and place the connection of the crank arm at its furthest extremity in the same plane as the plank itself, and consider the rod as infinitely long, and let it continue to move in that plane, the motion imparted will be regular in its character, though not moving at the same rate of speed throughout, that is, the regular circular motion of the crank becomes converted into a reciprocating rectilinear motion, a slight pause taking place at each extremity of the stroke of equal duration, and as it approaches those extremities it becomes gradually slower, the highest rate of speed being attained in the centre of the stroke. Take for example the illustration given of harmonic motion at Fig. 24, page 93, there it is shown at what varying rate of speed motion is communicated to any body moving in a horizontal plane by means of a crank, each division on the circumference of the circle is equal, but the perpendicular lines dropped to the diameter are not equal

To carry this further, instead of dropping perpendiculars to the diameter, produce the diameter to an indefinite length, and draw a complete circle instead of a semi-circle,

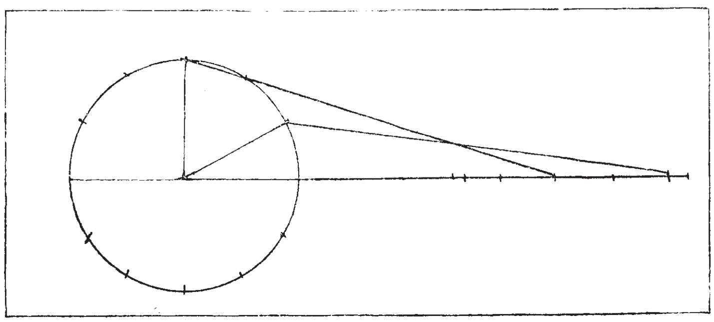

*Fig.* 31.

having divided the circle into any number of equal parts take a distance in the compasses equal to the supposed length of the connecting rod, and cut the produced diameter from each division of the circle as a centre, as in Fig. 31. If the connecting rod be of sufficient length, the divisions at each extremity will be equal, but the shorter the rod the greater the inequality, the divisions at one extremity will become less, and those at the other greater, and a decided eccentricity of movement is obtained.

Another mode of showing it is as in Fig. 32, when the point A is the centre upon which the lay moves; the line B shows the position of the sword or arm of the lay when the reed is in contact with the cloth; and the line C is the same arm at the other extremity of its stroke, or when furthest from the cloth: then in its passage the lay describes the arc of a circle, *b c*. It will be observed that when at the fore part of the stroke, the sword or arm occupies a vertical position, consequently, when at the back extremity the point of connection is brought below the plane which it occupies at the fore part. The circle D is the circle which the crank describes in its revolution, the centre *d* being in the same horizontal line as the point of connection at *b* ; then take any two points 1 2, on the arc

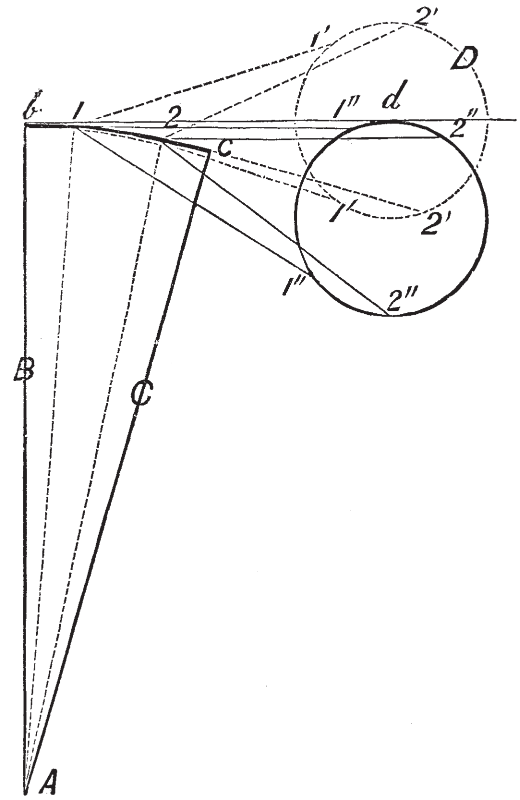


*Fig.* 32.

*b c*, at equal distances from *b* and *c*, find the corresponding points in the circle, or the position which the crank will occupy when the lay is at those points; this may be easily done by taking the distance from *b* to where the horizontal line cuts the circle, which will give the length of the crank arm; then from 1 cut the circle at the points 1′ 1′ and from 2 cut it at 2′ 2′. On examination it will be found that the arc 2′ 2′ is somewhat larger that the arc 1′ 1′ consequently a longer time is occupied by the lay in passing from 2 to the back extremity of its stroke and returning to 2, than is occupied in passing from 1 to the fore centre and back again to 1.

As the shuttle must be passing through the shed when the lay is at the back part of its stroke, the length of pause which is given here might not be sufficient in ordinary cases to allow it to get clear of the warp before it would be caught by the reed, and as more or less damage would result from its being caught, it may be necessary for this pause to be increased. This may be done by altering the relations between the circle described by the crank itself and the length of the connecting rod, because, as already shown, the shorter the latter in relation to the former the greater the amount of eccentricity obtainable.

The amount of eccentricity thus obtainable will be in direct ratio to the diameter of the circle described and the length of the crank arm. The larger the circle described, and the shorter the crank arm, the greater will be the eccentricity obtained. But there is a limit beyond which this may not be carried, else a hesitancy takes place when the crank is passing the back centre of the stroke, which requires a momentum to carry it over that point, and too great irregularity of movement, or jerkiness, is imparted to the lay.

The broader the loom is the longer the time required for the shuttle to pass through the shed, having a greater distance to traverse, consequently the greater the eccentricity that must be given to the movement of the lay. This may be obtained by increasing the throw of the crank, in proportion to the breadth of the loom. This, of course, also lengthens the stroke of the lay as well, but it is desirable to limit this to as small a space as possible, so as to avoid as far as practicable the friction upon the warp threads, caused by the reed passing and repassing over them. A very convenient mode of dealing with this matter is to place the crank in a plane lower than that of the point of connection with the going part, as shown by the lower circle in Fig. 32. By this means a large throw of crank can be obtained, and yet the crank be out of the way of the warp, though the point of connection with the sword may be actually on a line with the warp. By having the point of connection as high as possible, a great amount of leverage is of course obtained, and the throw of the crank, or the circle which it describes being increased in proportion to the length of the connecting rod, the requisite amount of eccentricity is obtained. Of course the traverse of the lay, or going part, must be determined to a considerable extent by the size of shuttle, taking for a medium width of loom, say a traverse of three times the breadth of the shuttle; for broad looms a little more, and for narrow ones a little less. But this must not be taken as an absolute rule, sometimes circumstances altering the conditions.

In determining the length of stroke to be given to the lay, the leverage given by the point of connection of the crank-arm with the lay being below the line of contact with the cloth or otherwise, must be taken into consideration. When the rocking shaft is below and the connection of the sword with the crank-arm at a point between that and the point of contact with the cloth, the lay becomes a lever of the third order, consequently the same rule will apply as to the treadles, that is, as the distance from the centre of connection to the centre of rocking shaft is to the distance from the latter centre to the point of contact with the cloth, so will the circle described by the crank be to the stroke of the lay.

Example.—Centre of rocking-shaft to centre of connecting pin 27in.; centre of rocking-shaft to point of contact with cloth, 33 in.; diameter of circle described by crank, 5 in.; then as $27:33::5:6\frac{1}{9}$, which will be the stroke of the lay.

If the rocking-shaft be placed above and the connection with the crank be placed below the warp line, then leverage will be lost in the same ratio.

It will be observed that the rocking-shaft is so placed here that when the reed is in contact with the cloth the sword is in a vertical position. This is done so that the lay, in its movement, never passes the centre upon which it is working, so as to prevent any vibration which would occur if constantly passing and repassing that centre, and which would interfere in a considerable degree with the working of the loom; and in addition to preventing that vibration, the reed, striking the cloth at right angles, strikes a firmer blow than it otherwise would.

The bevel of the shuttle race is the next matter which calls for attention. When the lay is thrown back for the shuttle to pass through, the race should be bevelled to suit the shed, that is, it should form a similar angle to a horizontal line that the lower half of the shed forms, but the reed and the back of the boxes must form a line directly parallel with the swords upon which the lay works. The effect of this is that the shuttle runs as it were in a dovetailed groove, and consequently runs much steadier and is not so liable to fly out; and the bevel being suited to the shed the warp offers less resistance to the passage of the shuttle, thus producing smoother working and reducing the friction of the shuttle upon the warp to a minimum.

The actual bevel of the race, or more correctly speaking the angle which it forms with the reed, will, in the case of the rocking-shaft being below, be determined by the position of the rocking-shaft in relation to the point of contact with the cloth, and in a slight degree by the length of stroke given to the lay. If we take a given bevel, with the rocking-shaft in a line perpendicular with the point of contact of the reed with the cloth, or at least with the swords of the lay in a perpendicular position when the reed is in contact with the cloth, this bevel will require to be increased as the rocking-shaft, or centre upon which the lay works, is moved towards the centre of motion, because the nearer the centre upon which it works is to the centre of motion the less is the reed thrown out of the perpendicular, and consequently the less angle formed by the shuttle-race with the horizontal line when the lay is at the back extremity of its stroke; the bevel of the race must therefore be increased to compensate for this loss of angle. When the lay is worked from above the length of stroke decreases the bevel of the race in the same ratio as it is increased when worked from below.

## THE TAKE-UP MOTION.

We now come to the consideration of what may be termed the auxiliary motions of the power-loom, motions which are highly valuable in themselves, and without which a power loom would be of little practical use, yet at the same time these motions can only be considered as adjuncts to the three motions already considered, and as assisting them in their operations.

The first and perhaps the most important of these, is the take-up motion, the object of which is to wind the cloth on a beam as it is woven, and by regulating the speed at which it so winds the cloth, determining the closeness of the weft threads, as the warp threads are determined by the closeness or fineness of the reed.

There are two descriptions of taking-up motions, which are known respectively as the drag and positive. The first, as its name implies, being a dragging motion, the cloth beam being weighted by a lever and weights, the amount of weight used being regulated to suit the strength of fabric required to be produced, and during the process of weaving, as the diameter of the cloth beam increases by the winding on of the cloth, the weight must be decreased to compensate for it.

The positive motion is of a totally distinct character, the cloth beam being driven by a feed roller acting on the cloth as it winds round it; by this means it is not affected by the diameter of the cloth beam, the movement being regular throughout, consequently it may be driven by a train of wheels, one of which may be movable, so as to determine the rate of take-up or speed at which the cloth is wound on the beam. By this means much more even fabrics may be produced, and with considerably less attention beyond ascertaining the proper wheel that will be required to give a certain number of picks per inch.

The positive motion is the one now most generally adopted, except for very heavy work, where the teeth or fluting of the feed roller, to be sufficiently effective in carrying down the cloth, would have to be so strong as would probably damage the cloth, or perhaps in such cases as where the yarn is of an uneven character, and it is desired to keep the cloth of as nearly as possible the same thickness.

By the arrangement of the drag, or, as it is sometimes called, the balance motion, the cloth is carried forward a distance equal to the diameter of the wêft inserted at each pick, whereas the positive motion carries the cloth forward exactly the same distance at each pick, no matter what may be the diameter of the weft. Such being the case it is evident that the former is well suited for cloths made from yarns which vary in their diameters very greatly, and when, as nearly as possible, the same bulk of cloth is required, as in woollen goods, and the latter for evenness of texture, and cloths made from yarns of an even character, as worsted.

The rule to find the number of teeth in the change pinion to give a certain number of picks per inch may require some explanation. The train of wheels in all classes of looms is not always the same, but the following is the general arrangement. Fig. 33 shows the wheels and their relation to each other ; A is the feed roller ; B is the feed roller wheel ; into this is geared a small pinion C driven on another wheel D ; this wheel is driven by the change pinion E, which is in turn driven by the ratchet wheel F, being carried on the same spindle. At every

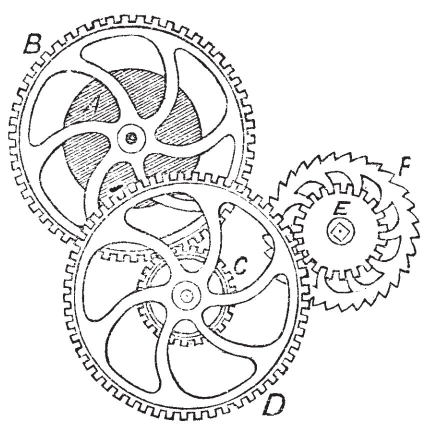


*Fig.* 33.

stroke of the lay the ratchet wheel is driven forward one tooth by a catch or pawl attached to the sword of the lay. Then the question to determine is, having a feed roller of a given circumference, a train of wheels of given dimensions, driven by a ratchet wheel, also of given dimensions, moving one tooth at every pick of the loom, to find the number of picks which will be woven in every inch of cloth with a change pinion of given dimensions ; or, what dimensions of change pinion will be required to weave a given number of picks per inch?

The latter will perhaps be the simplest as well as the most useful way of examining the question, as it is certainly the one most generally adopted.

First of all reduce the first driven wheel, the second driving, and the second driven, or what is termed the feed roller wheel to one number. The dimensions of these we will suppose to be as follows: the feed roller wheel 125 teeth, driven by a pinion of 19 teeth, carried on a wheel of 125 teeth. If we multiply the two large wheels into each other and divide by the small one we shall arrive at this result, thus $(125 \times 125) \div 19 = 822$. If we multiply this number by the number of teeth contained in the ratchet wheel, and divide by the number of picks required in the circumference of the feed roller, the quotient will be the number of teeth required in the change pinion. Then suppose the feed roller is $14\frac{1}{4}$ inches in circumference, the ratchet wheel contains 60 teeth, and it is desired to have 60 picks per inch in the cloth, then $60 \times 14\frac{1}{4} = 855$ picks in the circumference of the roller. The process will then be as follows:—$(822 \times 60) \div 855 = 57{\cdot}682$, but as decimals cannot be taken into consideration in the number of teeth in a wheel, we must take the full number nearest to that, consequently a pinion with 58 teeth will be required to produce the number of picks required.

Or take another example: suppose the feed roller wheel with 107 teeth, driven by a pinion of 12 teeth, carried on another wheel of 107 teeth, then $(107 \times 107) \div 12 = 954$; a ratchet wheel of 50 teeth, circumference of beam $14\frac{1}{2}$ inches, with 60 picks per inch as before, $(954 \times 50) \div 870 =$ 55 (nearly) teeth in change pinion.

Or we may put the matter in a rather shorter manner. Multiply the driven wheels and the ratchet with each other, and divide by the number of picks in the circumference of the beam multiplied by the pinion which drives the feed roller wheel thus 855 picks × 19 teeth = 16,245; then 125 × 125 × 60 = 937,500 ÷ 16,245; = 57·682 as above. The whole of this process simply resolves itself into the rule given in a previous page, viz., multiplying drivers and driven respectively into each other, and dividing one by the other and by the picks required; but I have taken this method of explaining so as to make it easy for young students or those not intimately acquainted with calculations.

But it is sometimes an inconvenient process to go through the whole calculation to ascertain the number of teeth required for any number of picks, therefore it is easier to take one number and calculate all others by this standard. For instance, if we were to take one pick per inch as the standard, whatever number of teeth is obtained to produce one pick per inch, divided by any other number of picks required, will give the change pinion which will produce that number. Thus, as 60 : 3461 :: 1 : 57,682, thus proving again that a 58-teeth pinion is required.

Again, a practice prevails of counting the number of picks by means of a piece glass or counting glass, of given dimensions, and it is desired to ascertain the change pinion which will give a certain number of picks in the space represented by this glass. Then, instead of taking the number of picks per inch, we must take the number per glass. Suppose the glass to be a ¼ inch, to ascertain the wheel which will give a certain number of picks per ¼ inch we will adhere again to the same dimensions, viz., (125 × 125) ÷ 19 = 822, and suppose one pick per ¼ inch, and a 60-teeth ratchet wheel, (822 × 60) ÷ 57 = 865. Then a change wheel having 865 teeth would give one pick per ¼-inch, consequently this number divided by any number of picks required per ¼-inch, will give the proper change wheel; thus, if it is required to put in 60 picks per inch, which is 15 per ¼-inch, then 865 ÷ 15 = 57·682.

The matter may, perhaps be further simplified as follows:—the ratchet wheel, the large intermediate, and the beam wheels are all driven, the change and small intermediate wheels are drivers as well as the beam, therefore leaving aside the change wheels and finding the relation of the drivers and driven to each other, thus $\frac{60 \times 125 \times 125}{19 \times 14\frac{1}{4}} = 3642$. So that if a change wheel could be used containing only one tooth, the loom would weave a cloth with 3462 picks per inch. Or, on the other hand, if the wheel could contain 3462 teeth, the cloth would contain one pick per inch. Again, if we are working to the $\frac{1}{4}$ inch instead of one inch, we have only to divide 3462 by 4, and we have 865 as given above.

It will be easily understood from the foregoing that whatever the dimensions of the glass, or whatever method may be adopted for measuring the number of picks, it is easy to reduce to a simple number the whole train of wheels, which number may be divided by any number of picks on the given space to ascertain the number of teeth in the wheel required, or if divided by a given number of teeth in the change wheel will show what number of picks such wheel will produce. Another matter connected with this will perhaps require some explanation. It will be evident that the foregoing calculations represent the exact speed at which the cloth is wound on the cloth-roller, consequently the number of picks represented is the number which the cloth would count when tight in the loom. But it is a well known fact that every material shrinks more or less when set free, so that if it is desired that the represented number of picks is to be the number which the cloth must count when out of the loom, a percentage must be allowed for shrinkage, more or less, according to the class of material used.

### THE TENSION OF THE WARP.

The regulating the tension of the warp is a subject which requires some consideration, this really accompanying the taking-up motion. Although it might appear that the taking-up motion draws off the warp from the beam, yet this is not absolutely the case, for the warp is really drawn off by the shedding and the stroke of the lay.

The appearance of the cloth depends a great deal upon the tension at which the warp is held. As a general rule the warp should be worked nearly as tight as the strength of the yarn will permit. If it is woven too slack the cloth presents a raw, lean appearance, which detracts very much from its value, and which can very seldon be removed by any amount of finishing. On the other hand the warp may be held too tight, in that case causing considerable breakage of the yarn, and giving the cloth a hard, harsh appearance and feeling.

This is a matter which will require some attention as each warp is put in the loom, but it is not a difficult matter after a little practice to discover the proper amount of tension to be given.

Care must be taken that a uniform tension be preserved throughout the breadth of the warp. To secure this it is absolutely necessary that the beam on which the warp is wound, the feed roller, cloth beam, and the rails of the loom over which the warp and cloth pass, must be perfectly parallel with each other, and also that the warp be wound on the beam with an equal or regular tension, otherwise unequal and uneven cloth will be the result.

There are many ways of regulating the amount of tension given to the warp, which it would be quite unnecessary to enumerate, as each particular method has its adherents, the general method, and the one which stands the longest test is by means of a stout cord round the ends of the beam, one end of the cord being made fast to the loom and the other attached to a lever, upon which are placed weights sufficient to give the required tension. Considerable ease may be given to the warp by what is commonly termed the spring weight; this consists of nothing more or less than, instead of making the end of the friction cord fast to the loom, attaching it to a spring or a light weight just sufficient to prevent the weights on the lever from gradually settling to the ground; by this means at every opening of the shed the beam gives off warp, and as the shed closes it springs back again, thus keeping the warp at a regular tension, and there is at no time any undue dragging.

Whatever means are adopted for holding the warp tight the one condition just referred to should never be lost sight of. As will readily be understood, when the shed is open there must be a greater length of yarn between the warp beam and the cloth than when the shed is closed. Usually the weft is beat up to the cloth at the moment when the shed is closed, or when it has just commenced to open for the next pick, so that, if the warp beam is held rigidly, the warp will be at that moment in a greater or less degree slack. Now it is well-known that to produce the best cloth, at any rate in the great majority of fabrics, the warp should be as tight as possible when the weft is being beat up; therefore to preserve the tension the warp beam must be made to oscillate in a greater or less degree, so that as the shed closes it will draw back the warp, and hold it at least as tightly, or at as great a tension when close as open. The ordinary rope or chain arrangement usually accomplishes this in a sufficient degree, but the spring or balance weight just referred to gives even more elasticity to the movement of the beam.

Some of the arrangements adopted for holding the warp at tension, or as they are termed "letting-off motions," hold the beam perfectly rigid, that is, they give off the warp from the beam at a certain fixed uniform rate, but do not allow any oscillation of the beam. When such is the case some other means must be adopted to compensate for it. This is usually provided for by making the back rail of the loom over which the warp passes oscillate, instead of the warp beam. Of course it is a matter of little moment whether the oscillation takes place in one or the other, so long as the warp is kept regularly at the proper tension, not too tight at one moment and too slack at another, but in many fabrics it is preferred to regulate the tension by means of the beam, rather than by the rail, as the warp in that case by means of friction, or a brake, upon the beam, adjusts itself more readily than when it is let off by any positive motion, and there is therefore less irregularity in the tension.

Whichever arrangement may be adopted, and there are plenty of advocates for both systems, provision must be made for equalization of the tension in as great a degree as possible.

### THE WARP LINE.

While dealing with the warp, attention may be directed to another matter which is of no mean importance in the production of cloth, that is, the line which the warp forms in passing from the back rail of the loom, through the healds, to the breast beam, as it is termed. To the casual observer it will probably appear that this line should be perfectly straight, and for some kinds of cloth that is the case; but in other goods it is not so. This applies more particularly to plain cloth. If the warp forms a straight line, when the healds are all even, as the shed opens both halves of the warp have the same tension, consequently each thread retains its own position in the cloth. The threads being divided by the reed, every division is clearly marked in the cloth. This is sometimes desirable, though more frequently the better the warp threads are spread so as to hide these divisions the value of the cloth is proportionately enhanced. This can be easily accomplished by lowering the warp out of the straight line at the healds; the reason of this is, that when the shed is opened the whole of the tension of the warp is thrown on the lower half, allowing the upper half to be comparatively slack, and the shed for the succeeding pick opening as the weft is being beat up to the cloth, the slack threads are forced

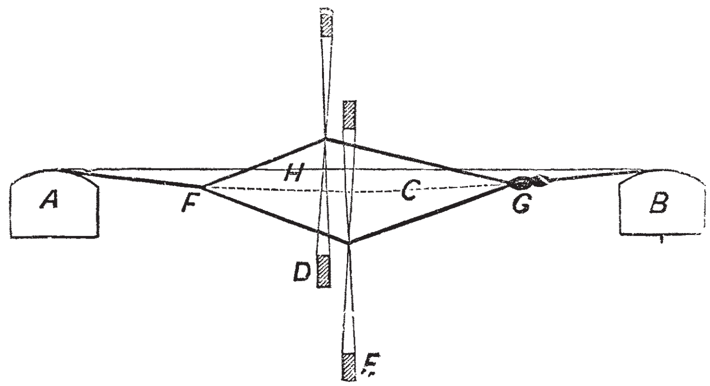


*Fig.* 34.

into the centre of the space between the two which are tight on each side of it. Fig. 34 will perhaps more clearly explain this. A is the breast beam; B is the back rail over which the warp passes; the dotted line C is the line the warp makes when the healds are at rest, which, it will be observed is not a straight line from the breast beam to the back rail, but is depressed at the healds; D E are the two healds; F is the point at which the cloth forms; and G the lease rods. Then the healds being at rest and the warp forming the line C, we depress the heald E and raise the heald D each the same distance from the line C, dividing the warp into two portions, forming the lines F D G and F E G. If we then measure these two lines we shall find the line A F E G B is longer than the line A F D G B, consequently that portion of the warp which is represented by the line A F E G B has to bear all the strain and the other half hangs comparatively slack. But it may not be apparent why this is so. Connect the points A B with a straight line H. A straight line is the shortest distance between two given points, then it must follow that the nearer the line approaches to a straight line the distance must approach the shortest. The line A F D G B is a nearer approach to the straight line H than is the line A F E G B, then the line A F D G B is the shortest, and the more the healds are depressed the greater will be the difference between the two lines. Then it must be obvious that if the lower half of the shed is thus worked at a greater tension than the upper half, the effect must be to force the slack ends into the centre of the space between those which have more strain upon them; and this is assisted by the beating up of the weft; for almost invariably when this arrangement is made the weft is beat up to the cloth after the healds have passed each other, and the shed has begun to open for the succeeding pick; consequently, as the strain is thrown upon each thread alternately, the warp must be spread evenly over the surface of the cloth.

There will be little difficulty in understanding that this arrangement must have a detrimental effect upon the warp in weaving, in consequence of the whole of the strain being thrown upon one half of the warp. Therefore, in weaving tender warps this expedient can only be resorted to in a limited degree, so that any effort to save the warp in this direction must be detrimental to the appearance of the cloth, and all efforts to improve the appearance of the cloth must in some degree affect the working of the warp. Consideration should therefore at all times be given to the quality of the warp for the class of cloth to be produced.

### SHUTTLE PROTECTOR, OR STOP ROD.

This is another contrivance which is of great importance in power looms, its object being the protection of the warp from injury in the event of the shuttle from any cause failing to reach its destination. It requires no great power of imagination to understand that, should the shuttle happen to be in the shed when the reed beats up to the cloth, the result must be most disastrous to the warp.

What is commonly known as the stop rod is designed to meet this contingency. In the back of the box a spring, or lever, is affixed which acts upon a lever A, Fig. 35. Attached to the front of the loom frame is a frog B. The lever is so arranged that when the shuttle is in the box it presses back the spring, and raises the point of the lever—as the lay makes the forward stroke—on the top of the frog B. But if the shuttle does not enter the box, the point of the

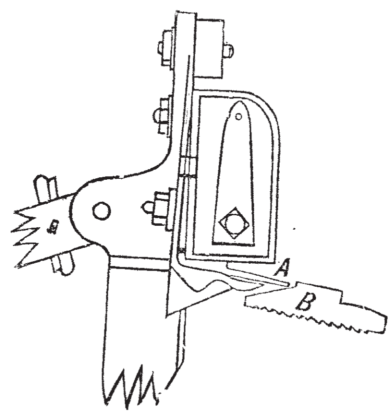


*Fig.* 35.

lever remains down and strikes the shoulder of the frog; the force of the concussion knocking off the loom, by throwing the belt on the loose pulley.

The action of this protector must be in a high degree injurious to the loom if not properly arranged, for the loom is brought to a sudden stop by the inability of the lay to complete its stroke; the crank shaft is stopped in the centre of its revolution; the other parts of the loom are stopped by the concussion of the wheel teeth, thus causing considerable liability to breakage, in consequence of the momentum which the various parts have gained.

The question then arises how to reduce this liability to injury to a minimum, but before anything can be determined it must be clearly seen what is the nature of the injury likely to result. It has already been seen that the sudden stoppage of the loom is likely to cause breakage in the various parts of the loom, this may occur either in the teeth of wheels, in the swords of the going part, or in the stop rod itself. But breakage of those parts is not the only trouble likely to arise from a badly arranged stop rod; it may throw considerably more work upon the picking than is necessary, and so not only produce bad working in the loom generally, but very materially increase the wear and tear of all the parts.

In the first place, as to the breakages which are likely to result direct from the action of the stop rod. It is very evident if the teeth of the driving wheels are not sufficiently geared into each other, that is only touching each other at their points, that the concussion which must result from the sudden stoppage of the loom is very likely to cause breakage, because the greater the clearance of the teeth, the greater the force of the concussion.

Liability to breakage of the swords or arms of the lay, may be occasioned by the position of the stop rod in relation to the connecting pin of the swords with the crank arms. If the vertical distance between those two points is too great, a leverage is given which is in direct ratio to the distance between those points, or in other words the force is applied by the crank at the point of connection with the sword of the lay, and is stopped at the stop rod or protector, then the more the latter is placed below the former, the greater the liability to breakage, because of the increased leverage given to the power as it is applied.

Then as to liability of damage to the stop rod itself, the nearer the frog is placed to the plane in which the stop rod is moving the less the liability to damage to the latter; suppose for a moment that the two are placed in the same horizontal plane, then the arm of the lever which goes up the back of the box, will be as nearly as possible at right angles to that which strikes the frog, consequently the arm is not so liable to be bent or broken, but all the force is exerted directly upon the fulcrum upon which the lever works, but suppose the frog is placed two or three inches below this fulcrum, then the arm A of the lever will be pointing downwards, and forming an obtuse angle with that which passes up the back of the box, the result is great liability to bending of the arm A, and ultimate breakage ; and even if the lever does not actually break, it becomes very soon bent to such a degree, that the shuttle cannot raise it sufficiently high to clear the frog, and as a consequence the loom is constantly being stopped.

Another matter which has considerable influence upon the breakages, and which is very frequently much neglected is the relieving the loom of the power of the belt as quickly as possible. The frog B is usually made so that it will slide for a short distance on the loom frame when it is struck by the stop rod lever, and it has also a projection from it which is intended to strike the handle communicating with the belt fork, and at the same time liberating the brake. Now too much attention cannot be paid to this part of the mechanism, for the sooner the belt is removed from the fast to the loose pulley, and the brake brought to bear upon the brake wheel, the more quickly is the momentum of the loom reduced, and consequently the less violent the concussion of the various parts. In fact if these parts are carefully adjusted, when a loom is running at a fair speed, the belt is actually on the loose pulley, and the brake in full operation, practically, by the time any concussion takes place in the various parts, so that it is robbed as much as possible of its violence.

Then, next, with respect to the second aspect of the question.—The increased work thrown upon the picking.

The swell, as it is termed, or lever in the back of the box, serves a double purpose, it not only enables the shuttle to act upon the lever A B, but it stops the rebound of the shuttle on entering the box. If some provision were not made for this purpose, the shuttle would rebound into the shed, and damage would result to the warp, or the stop motion must be brought into use by some other means. It is obvious therefore, that the shuttle has, on entering the box, a certain amount of work to do; it must press back the swell in the box sufficiently to raise the arm A above the frog B, that being so, if the arm B is very heavy, an unnecessary amount of work is thrown upon the shuttle to raise it, therefore it would have to be sent into the box with a very great force, and having reached there, the pressure upon it would be so great that considerable force would be required to send it out again, so that the power required for picking would be increased. Again, the length of the arm A should be just sufficient to prevent the reed coming so near the cloth as to cause damage to the warp. If it is too long it has a tendency to catch the frog before the shuttle has had time to raise it clear, and thus stop the loom, or the shuttle must be picked across the loom in a less time than would otherwise be necessary, again throwing more work upon the picking arrangement than should be. Again, the arm A of the lever should be raised just high enough to pass over the frog B, and no more, otherwise more work, or power, is exerted than is necessary.

It only requires a brief examination of the loom, and its mode of working, to see at once the necessity for paying attention to these points. The manner in which the shuttle is picked from side to side of the loom, partakes of the nature of a blow, therefore the moment the blow is delivered, the loom is released from the pressure of the work it has been performing, and a reaction takes place in all the working parts; then it necessarily follows that the greater the amount of force exerted, the greater the reaction, and this reaction of necessity occurs at a critical moment, just when the shuttle is being propelled, and may be quite sufficient to divert the shuttle from its course, and with more or less disastrous results, cause it to leave the loom; and even if the reaction alone does not do this, it is certain that the more force a shuttle is propelled with, the more liable it is to be diverted by the least obstruction in its passage, so that even the breakage of a warp thread is often sufficient to cause the shuttle to leave the loom, when more force is exercised than necessary to propel it.

The additional wear and tear, not only upon the picking leathers, pickers, shuttles, and all the parts of the loom connected with the picking arrangements, but upon the loom as a whole, are considerations not to be despised, for it is very evident that the exercise of unnecessary force, must

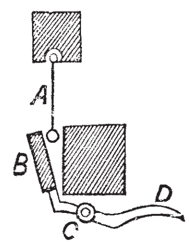

*Fig.* 36.

enormously increase the wear and tear in the picking arrangements, but the great reactions must in great measure both wear out, and tend to derange all the other parts of the loom.

Another method of effecting the object of the shuttle protector is by means of the loose reed. By this contrivance the lower part of the reed, instead of being held in a groove, is held by a loose board behind it, as shown in Fig. 36, where A is the reed and B the board which keeps it in place. This board is attached to an iron rod, which extends the full width of the lay, working upon the centre C and provided with a finger D, so that if the shuttle should stop in the shed the reed is forced back (being only held in position by a spring E, Fig. 37), and is consequently liberated. The arrangement is further shown at Fig. 37. If nothing more were provided than this spring it will be obvious that the arrangement would be very unsatisfactory, because if this spring were very strong the warp would suffer before it would give way so as to liberate the reed, and if it were not strong it would be impossible to beat much weft into the cloth without some other arrangement. This contingency is provided for by the presence of the frog F, which is attached to the front of the loom, and so placed

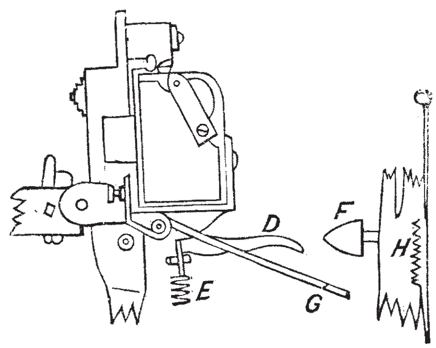


*Fig.* 37.

that if the shuttle has passed through the shed safely, as the going part or lay comes forward to beat the weft up to the cloth, the point of the finger passes under the frog, and so holds the reed firmly in position, while the blow is being given. On the other hand, if the shuttle has not passed through the shed, the point of the finger is raised so as to come in contact with the upper part of the frog, which by its form raises the finger and so assists in liberating the reed, and relieving the warp of the strain which would be thrown upon it by the presence of the shuttle; at the same time the arm G, which is attached to the same rod as the finger, is raised and strikes the front of the handle H, which is connected with the belt fork of the loom, so throwing the belt from the fast to the loose pulley and stopping the loom. Most loose reed looms are now made so that the passage of the finger D up the frog F is dispensed with, and considerable advantage thereby gained, the lever D is produced so as to extend behind the going part, and so make the whole lever something approaching the form of a letter T, the back part of this is provided with a roller which travels, as the lay moves backward, up a bent steel spring. The object of this arrangement is to have the helical spring E as light as possible. When the shuttle is being passed across the loom it presses somewhat on the reed, and in the arrangement shown at Fig. 37, there is nothing but the spring E to keep the reed in position. Now it is obvious that if the warp be a tender one, and the shuttle should be caught in the shed, it would have to raise the point of the lever D somewhat before it could begin to travel up F, and if the spring E is strong enough to keep the reed in position while the shuttle is passing across the shed, it is also strong enough to cause the shuttle to break some of the warp threads; by the extension of the lever, and the use of the steel spring as described, the latter helps to keep the reed in position whilst the shuttle is being passed through, and therefore the strength of the spring E is reduced to a minimum, and should the shuttle remain in the shed, the spring is so light, that, even with a tender warp it will press the reed out of its place without the intervention of the frog F.

The chief objection to the loose reed system is, that it is difficult to make the reed sufficiently firm to give the strength of stroke required for heavy work, consequently it can only be applied to the lighter class of goods.

Recently several new arrangements have been introduced to the trade, by which the reed is perfectly loose until it reaches a point where the shuttle would be pressing upon it were it in the shed, and would consequently throw it out, after passing that point it is held almost as firmly in its place as in a fast reed loom, in fact it is, as it were, a combination of the fast and loose reed—fast when it is required to beat up the weft, and loose when the shuttle is liable to cause damage, so that the objection to loose reed on account of the want of firmness of the blow is in a great measure removed.

### WEFT-STOPPING MOTION.

The weft stopping motion is perhaps one of the most ingenious and delicate, as well as the simplest contrivance of the power loom. In the lay, between the reed and the shuttle-box, is a fixed grate, so arranged as to admit of the three prongs of a fork passing through it at every forward stroke of the lay. On an arm projecting from above the breast beam, and so arranged as to act upon the handle for throwing off the belt, is affixed this fork. The fork is of the form shown at A, Fig. 38, being balanced on the centre A; underneath it is the elbow lever working on the centre B, one end of which rests upon the low shaft of the loom. The top of one arm of this lever is furnished with a catch to correspond with the catch of the fork, the other arm of the lever is acted upon by a cam C upon the lower shaft of the loom, which raises it up, and consequently throws the other arm of the lever back as the lay makes the forward stroke. When the loom is in operation the weft prevents the fork passing through the grate in its natural position by striking the low point of the prongs at *a*, and thereby raising up the hook at the opposite end, thus allowing the arm of the lever in its passage to miss it, but when there is no weft the fork retains its position, passing through the grate, and is consequently caught by the lever, in this manner acting upon the handle throwing off the belt, and thus stopping the loom.

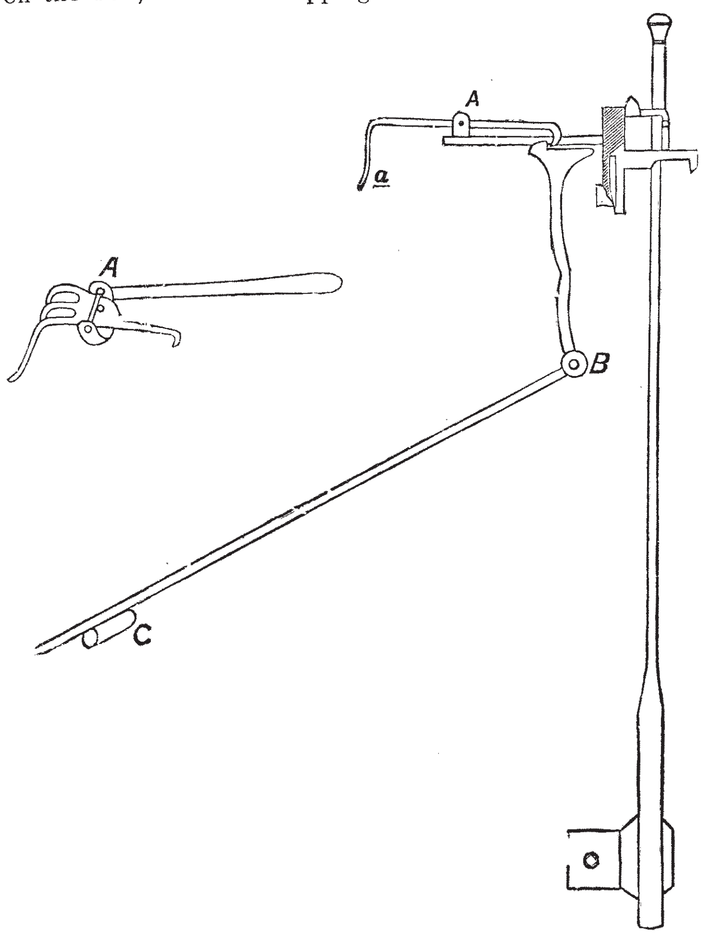


*Fig.* 38.

This motion is one of simple levers acting in unison with each other, and should this unity of action be in any way impaired the effectiveness of the motion will not only be destroyed, but a considerable amount of vexation will be caused by the loom being continually stopped. This shows, then, that the lever must be acted upon at the proper moment, so as to move backward at the moment when the weft should be acting upon the fork. The fork must be properly balanced on its centre so as to keep the hook ready to be acted upon by the catch of the lever, and at the same time not to require more power for the weft to raise it than is absolutely necessary, otherwise when weaving with tender weft the weft will be continually broken by it. The fork must also be in a perfectly straight line with the openings of the grate, so as not to catch the bars instead of passing through.

With due attention to these matters little difficulty will be experienced in the management of this portion of the loom, and it will be found to be a very valuable adjunct to the loom and conduce very materially to the production of a perfect fabric.

### GENERAL WORKING OF THE LOOM.

Having gone over in detail the chief working parts of the loom it only remains to examine its general working and the subjects connected with it. The three primary movements—shedding, picking, and beating-up—having been dealt with, we must now look to their relation to each other in regard to time. As I have pointed out before, the beating up is the last of those three in order of execution, yet it is generally most convenient to take it as the base and regulate the others to it, receiving as it does its motion direct from the main driving-shaft, and the others only receiving theirs through other mediums from the same source.

If we place the lay at the fore part of its stroke, that is, with the reed in contact with the cloth, all parts of the loom are at that moment stationary. As the lay begins to move back from that point the other parts begin to perform their various functions. The first of these is the shedding; the tappets, acting upon the treadles, commence opening the shed, as explained under the head of "tappets," and complete their movement by the time the lay has reached the centre of its stroke, the shed remaining open until it reaches the corresponding point in the return stroke. During this time the shuttle must be passed from one side of the loom to the other, commencing to leave the box at the moment the shed is full open and reaching the opposite box before it commences to close.

There is no exception to this rule except in so far as the shedding is concerned, as previously explained with respect to spreading the warp, where the shed begins to open before the reed comes in contact with the cloth, and in that case the shed is closed and re-opened more quickly and a larger pause given to the open shed, so as to compensate for the earliness of the movement and still allow time for the shuttle to pass through before the closing commences. These three movements being properly timed to each other it becomes quite an easy matter to regulate the other movements to work in harmony with them. The stop-rod motion, being acted upon by the shuttle, its time of action is of course governed by the shuttle reaching its destination, so that there is nothing more to look to than has been already pointed out. If a loose reed, the finger and frog must be adjusted so as to hold the reed firm at the moment of coming in contact with the cloth, or to assist in liberating it if the shuttle has not reached its proper destination. If the loom be provided with changing boxes, the movement of the box must commence the moment the shuttle has entered it and complete its movement before the picker moves for the next pick.

The cam which acts upon the weft fork lever should commence its action the moment the reed comes in contact with the cloth, and consequently after the shuttle has entered the box; if there be no weft, the hook upon the fork will be caught by the hammer, and throw off the belt from the fast to the loose pulley, and so stop the loom.

The taking-up motion being worked by the sword of the lay, its time of action remains the same, but care must be taken that the leverage is properly adjusted, so that it moves the ratchet wheel the proper distance at each stroke, otherwise the effect upon the cloth will be far from satisfactory.

These are the chief matters to be attended to in the working of a loom. There are of course a great many other considerations which require their share of attention, but as the majority of them could only be understood by practical demonstration, and the conditions under which they arise are so varied in their nature that it would be tedious to attempt to detail them all here, I shall only refer to a few of them, and they will refer chiefly to the adjustment of the parts. First, with respect to the picking. As the shuttle is propelled from side to side, the force which is given to it is delivered somewhat in the form of a blow from the picker; then this blow must be delivered as nearly as possible in a straight line with the direction the shuttle is to take. To do this the picker spindle must be parallel with the back of the box, otherwise the course of the shuttle, instead of being directed towards the other box, would be sent either with the tip into the slay, or it would leave the loom altogether, in either case with a result which would probably be more or less disastrous. The direction of the course of the shuttle must be assisted by the box also, so that the front and back of the box must be parallel to each other, and the shuttle must not have too much play or room in the box ; at the same time it must not be held too tight, because it would require more force than is necessary to cause it to leave the box, and when it did leave it would do so with a jerk, which must at all times be avoided as far as possible. Again, the shuttle must meet with as little obstruction and resistance as possible in its passage. This implies two things ; first, that the reed and the back of the box must form a perfectly straight line ; secondly, that the lower half of the shed must lie close down upon the shuttle-race, so that the shuttle can pass easily over it.

If the first of these conditions is not complied with the shuttle will probably fly out of the loom altogether, and if the second be not complied with, the resistance offered to the shuttle would prevent its reaching the box, unless very considerable power were used to propel it, and power should be utilized to the utmost. And even if sufficient power were used to make the shuttle reach its destination, the friction upon the warp caused by it passing over it would be very injurious, causing considerable breakage, and consequent imperfections in the cloth. Another fault would also frequently occur, the tip of the shuttle instead of passing over the warp, would have a tendency to pass under some of the threads, and so cause very serious faults in the cloth.

Too much attention cannot be paid to the adjustment of the sheds, not only so that the warp threads shall touch the race of the lay, but they must not press upon it, and all the healds must be adjusted so that the warp threads all form the same straight line, as pointed out under the head of "shedding," and each successive shed must have the same tension, not have tight and slack threads alternately.

A variety of other causes than those enumerated may combine to interfere with the working of the loom, but I have dwelt now upon the chief ones. With careful attention to these, any others which might occur would be very readily detected and remedied. We have now only a few matters to deal with connected with the power loom; these are speed, gearing, &c., and with these I shall deal very briefly. Any one wishing for more information on these subjects will be able to obtain it in works upon engineering, and numbers of such works may be found in any library in the country. So numerous and complete are such works, that I should have omitted this part of the subject altogether, but I felt that a work dealing with the power loom would be incomplete without some reference to it.

### SPEED, GEARING, POWER, ETC.

The question of the speed of looms is one which is perhaps as important as any subject connected with the loom. The question: What is the proper speed of a loom? is frequently asked, and receives a great variety of answers. The principle of construction adopted in the parts of the loom, and the work it is intended to perform, alter very materially the conditions of speed. And, again, the nature of the material used in the fabric being woven will have great influence in determining the rate of speed at which the loom should run. Great diversity of opinion exists as to the economy of very fast-going looms, and there is certainly more than one side to the question, and considerations which should receive the most careful attention before an excessive rate of speed is determined upon. These considerations are so varied in their character and occur under such a great variety of circumstances, besides some of them being of a somewhat controversial character, that to enter into them or attempt to enumerate them would not only be a great task, but would be also a most unsatisfactory one. They will be best found in actual practice, and at the same time will receive a more satisfactory solution. But an invariable rule may be observed with respect to this question. Uniformity and steadiness in working are essential in all machines, but this applies perhaps in a special degree to power looms, consequently, if the rate of speed at which the loom is being run interferes with or affects this in any degree, the result must be proportionately detrimental. With respect to the working parts of the loom and the material being woven, an increased speed means an increased strain, consequently it must be kept within limits which will not be injurious either to the loom or the fabric. In connection with this question of speed we have to consider not only the calculation of speed of machinery in various parts but also power required for the work to be performed, strength of materials, &c.

It will be as well perhaps to deal first with the calculation of speeds, and then take up the other matters as they arise. The rule which has already been given under the head of calculating speed of tappets is applicable in all cases of toothed wheels. When wheels are applied to communicate motion from one part of machinery to another their teeth act alternately on each other, consequently their relative speed will be to each other as the number of their teeth, and if drums or pulleys are used in the place of wheels the result will be the same, because their circumferences describe equal spaces, or, in other words are travelling at the same rate of speed, consequently their revolutions will be rendered unequal in the proportion in which their diameters differ.

Then from this is derived the rule, viz. : Multiply the velocity of the driver by the number of teeth it contains, and divide by the velocity of the driven ; the quotient will be the number of teeth it should contain. Or in the case of drums and pulleys, multiply the velocity of the driver by its diameter, and divide by the velocity of the driven; the quotient will be the diameter of the driven.

If the velocities of the driver and the driven are given with the distance of the centres, then the sum of the velocities is to the $\left\{\begin{matrix}\text{velocity of driver}\\ \text{velocity of driven}\end{matrix}\right\}$ as the distance of the centres is to the $\left\{\begin{matrix}\text{radius of driven.}\\ \text{radius of driver.}\end{matrix}\right\}$

Example 1.—If a wheel containing 60 teeth makes 42 revolutions per minute, what number of teeth will be required in another wheel to work in it and make 36 revolutions in the same time? $\frac{60 \times 42}{36} = 70$, the teeth required.

Example 2.—A drum 14 inches diameter, making 80 revolutions per minute, is to give motion to a shaft required to make 112 revolutions in the same time. Find the diameter of the pulley required. Then, $\frac{14 \times 80}{112} = 10$ inches, the diameter of the pulley required.

Example 3.—A shaft revolving at the rate of 60 per minute, is to give motion by a pair of wheels to another shaft at the rate of 24 revolutions per minute; the distance of the shaft from centre to centre is 36 inches. Required the diameter of the wheels at the pitch line.

Then, $60 + 24 : 60 :: 36$ inches : $\frac{60 \times 36}{60 + 24} = 25{\cdot}7$ inches, the radius of the driven wheel, which doubled gives $51{\cdot}4$ inches the diameter. Then for the second wheel, 36 inches $- 25{\cdot}7 = 10{\cdot}3$ inches, the radius of the driver, which being doubled gives $20{\cdot}6$ inches, the diameter.

These three examples may be varied to suit any circumstances, and embrace all the phases in which the question may present itself.

The question of the pitch of toothed or cog wheels now comes under consideration. What is termed the pitch (or the distance between the centres of two contiguous teeth) is measured on the *pitch-line*, or circumference of the wheel, and the distance between that line and the centre of the circle is reckoned as the radius of the wheel.

The following rules have been laid down for the diameters and number of teeth for wheels and pinions:

Rule 1.—As the number of teeth in the wheel + 2·25 is to the diameter of the wheel, so is the number of teeth in the pinion + 1·5, to the diameter of the pinion.

Example.—Given the number of teeth in the wheel 96, the diameter of the wheel 24 inches, and the number of teeth in the pinion 16. Then, 96 + 2·25 : 24 : : 16 + 1.5 : 4·27 inches the diameter of the pinion.

Rule 2.—As the number of teeth in the wheel + 2·25 is to the diameter of the wheel, so is the number of teeth in the pinion + number of teeth in the wheel ÷ 2 to the distance of their centres.

Example.—Number of teeth in the wheel 96, diameter of the wheel 24 inches, number of teeth in the pinion 16. Find the distance at which their centres should be placed. As 96 + 2·25 : 24 : : $\frac{16 + 96}{2}$ : : 13·67 inches, the distance of their centres.

POWER OF TOOTHED WHEELS.

Having now dealt with the question of speeds and diameters of wheels, there is yet one other consideration connected with them, viz., the capabilities of transmitting power by wheels or belts. Upon this subject there is some diversity of opinion. Mr. Thomas Box, in his "Practical Treatise on Mill Gearing," says, "The length of teeth and the proportion of wheels, are matters for judgment, experience and taste." With respect to the length of teeth, he says, "With iron-and-iron-toothed wheels, the length of tooth above pitch may be $P \times \cdot 344 = l$, and below pitch $(P + \cdot 344) + \sqrt{P} \times \cdot 125) = L$. This gives the clearance between the point of the teeth of one wheel and the base of its fellow $= \sqrt{P} \times \cdot 125$, which is equal to $\frac{1}{4}$ inch in a wheel 4 inches pitch," &c. With respect to the thickness of teeth, he says of "iron toothed wheels working together with rough surfaces as taken from the foundry, we must allow a certain clearance between tooth and tooth for errors of workmanship and other irregularities. The amount of clearance may be taken at $\sqrt{P}$, ÷ 10, which gives $\frac{1}{10}$th of an inch for one inch pitch and $\frac{2}{10}$ths of an inch for four inch pitch, &c.; hence we have $T = (P - \frac{\sqrt{P}}{10}) + \cdot 5$, &c.," here $T$ = thickness. With respect to width on the face of the teeth he gives a rule as follows "$W = P^2 \times 1{\cdot}8 \div \sqrt{P}$," or put in another from $W = \frac{P2 \times 1{\cdot}8.}{\sqrt{P}}$ In these formulæ $W$ = width in inches, and $P$ = pitch in inches.

Sir William Fairbairn in his "Treatise on Mills and Mill Work," gives an example of a wheel of a $2\frac{1}{2}$ inches pitch, and the teeth of which bears the following proportions.

| | Proportional parts. |
|---|---|
| Pitch ... ... ... ... | 1 |
| Depth ... ... ... ... | 0·75 |
| Working Depth ... ... ... | 0·70 |
| Clearance ... ... ... ... | 0·05 |
| Thickness ... ... ... ... | 0·45 |
| Width of Space ... ... ... | 0·55 |
| Play ... ... ... ... | 0·10 |
| Length beyond pitch line ... | 0·35 |

and from these proportions he gives a very simple mode of constructing a scale which will give the proportions for any pitch.

Unwin in his "Elements of Machine Design," gives the following formulæ, the symbols of which are:—$P$ = Pressure of one wheel on the other; $H$ = Number of horse-power transmitted; $b$ = width of face; $p$ = pitch; $N$ = revolutions per minute; $T$ = number of teeth, then velocity of pitch line in feet per second is $V = \frac{p\ T\ N}{12 \times 60}$.

"For the usual proportions, $b$, $= 2\frac{1}{2}\ p$, and iron teeth $p = 0{\cdot}447\ \sqrt{P}$. But $P = \frac{550\ H}{V} = \frac{550\ H \times 12 \times 60}{p\ T\ N}$

inserting this value $p = 28{\cdot}13\ \sqrt{\left(\frac{p\ H}{T\ N}\right)}$

or inverting we get the number of teeth of a given pitch necessary for strength, $T = 791 \frac{H}{p_3\ N}$"

The same rules will apply to mitre or bevel wheels by taking the average diameter and pitch.

POWER OF LEATHER BELTS

The following passage occurs in Spon's "Dictionary of Engineering."—"Three rules given by practical mechanics vary so much as to give as bases for estimate (without regard to arc of contact) 0·76 horse-power, 0·93 horse-power, and 1·75 horse-power respectively, for the power of a belt 1 inch wide, running 1000 feet per minute." The same work in considering the results of two series of experiments upon the friction of belts, says, "We see that we are justified in admitting that the ratio of the resistance to pressure is :—

1st.—Independent of the width of the belt, and of the developed length of the arc embraced, or of the diameters of the drums, or what amounts to the same, are independent of the surface of contact.

2nd.—Proportional to the angle subtended by the belt at the surface of the drum.

3rd.—Proportional to the logarithm of the ratio of the tension of the strap, and expressed by the formula

$$\frac{f = \mathrm{Log.}\left(\frac{P}{O}\right)}{1\cdot363.}"$$

Where f is the friction, P the power, and O the resistance.

A table is given also of the power transmitted by belts on pulleys one foot in diameter, one revolution per minute, with the arcs of contact upon the pulleys corresponding to the angles ; from which the following is taken :—

| Inches width of belt. | 90° | 120° | 180° |
|---|---|---|---|
| | foot lbs. | foot lbs. | foot lbs. |
| 1 | 102 | 123 | 154 |
| 5 | 508 | 615 | 770 |
| 10 | 1016 | 1231 | 1540 |

The application of this table is to take the known angle of the arc of contact with the width of belt, and multiply by the diameter of the pulley in feet, and the number of revolutions per minute to find the foot-pounds of power transmitted.

A number of experiments are also recorded upon the tensile strength of belts, from which the following deductions are made as to strength per inch of width—

"When the rupture is through the lace holes, 210 lbs.

,, ,, ,, rivet ,, 382 lbs.

,, ,, ,, solid part 675 lbs.

The thickness being $\frac{7}{32}$ in (=·219) we have as the tensile strength of the leather 3,086 lbs. per square inch.

From the above we see that 200 lbs. an inch wide is the ultimate resistance to tearing that we can expect from ordinary belts."

Molesworth, in his "Pocket Book of Engineering Formulæ," gives an approximate rule for single belting $\frac{3}{16}$ of an inch thick, as follows :—V = Velocity of belt in feet per minute. H.P. = Horse-power (actual) transmitted by belt, and W, width of belt. $W = \frac{1100 H.P.}{V.}$

The "Scientific American" in its issue of August 28th, 1880, gives the following formula :—$\frac{W. \ S.}{600} = HP.$

In this formula, S = Speed of belt in feet per minute ; W = width of belt ; and it further says, "with very short or narrow belts, divide by 800 instead of 600." Cooper, in his work on "Belts and Belting," gives some valuable information.

Another rule upon which many work, and which is considered a safe one, is that at a speed of 800 feet per minute each inch width of belt is equal to one-horse power. But such rules as this are very vague, though if made upon a good basis they are very handy.

Unwin, in the work already quoted gives the following rough calculations of the sizes of belts. In a great many cases in practice, the belt embraces 0·4 of the circumference of the pulley on which it is most liable to slip,—that is, the pulley having the smaller arc of contact—and the co-efficient of friction is at least 0·3. Then $\frac{T_2}{T_1} = 2.$

When this is the case the following simple rules may be used:— "Driving force $= P = \frac{550\,H}{V}$"

$$\left.\begin{array}{lcccl} \text{Greatest tension} & = & T^2 & = & 2P \\ \text{Initial tension} & = & T^0 & = & 1\tfrac{1}{2}P \\ \text{Width of Belt} & = & B & = & \frac{2\ P}{f} \end{array}\right\}$$

From these rules he has calculated tables of the approximate widths of belts. "The belt being assumed to be $\frac{7}{32}$nds of an inch in thickness, and carrying safely 70lbs. tension per inch of width," with a velocity of 100 feet per second for

| | | | | | |
|---|---|---|---|---|---|
| 10 | horse-power, | the width | of belt is | 1·6 | inches. |
| 15 | ,, | ,, | ,, | 2·4 | ,, |
| 20 | ,, | ,, | ,, | 3·1 | ,, |
| 25 | ,, | ,, | ,, | 3·9 | ,, |

With the velocity at 25 feet per second, the following is the result—

| | | | | | |
|---|---|---|---|---|---|
| 1 | horse-power, | the width | of belt is | ·63 | inches. |
| 2 | ,, | ,, | ,, | 1·3 | ,, |
| 5 | ,, | ,, | ,, | 3·1 | ,, |
| 10 | ,, | ,, | ,, | 6·3 | ,, |
| 20 | ,, | ,, | ,, | 12·6 | ,, |

It will be seen that although there is some difference in the data given, yet many of them will work out to approximately the same results; and for loom work in particular, from the peculiar nature of the work they have to perform, a safe basis should always be taken. While upon this branch of the subject we may examine

THE STRENGTH OF SHAFTS TO RESIST TORSION.

Fairbairn, in the treatise before quoted, says, "In addition to the lateral strain from transverse forces, shafting is subjected to a wrenching or twisting, from the power transmitted tangentially to its circumference. This causes one end of the shaft to revolve, in relation to the other end, through a smaller or greater angle, known as the angle of torsion; and, if sufficient force be applied, this angle increases till the resistance of the material is overcome, and the shaft gives way." And after examining the subject in all its bearings he gives "The values of the modulus of wrenching $f$ are

For cast-iron about 30,000, for wrought-iron about 54,000. And taking six as the factor of safety if we put the working moment of torsion in the formulæ instead of the wrenching moment, we may put instead of $f$

For cast-iron 5,000, for wrought-iron 9,000.

Hence we get for W, the working stress with solid shafts

$$W = \frac{5000\ h^3}{5 \cdot 1 l} = \frac{980 h^3}{l} \text{ for cast-iron}$$

$$= \frac{9000\ h^3}{5 \cdot 1 l} = \frac{1765 h^3}{l} \text{ for wrought-iron."}$$

Here $h$ represents the diameter of the shaft, and $l$ the length of the lever in inches.

Mr. Thomas Box, in his "Practical Treatise on Mill Gearing," gives the following rules for the strength of shafts, "irrespective of stiffness."

$$\text{"}H = D^3 \times R \div M$$
$$D = \sqrt[3]{(M \times H \div R)}$$
$$M = D^3 \times R \div H.\text{"}$$

In which H = nominal horse-power, D = diameter in inches, and M = a multiplier derived from experience, and varying with cast or wrought-iron, &c.," and for ordinary shafts he gives the value of M for cast-iron at 254, and for wrought-iron at 160.

Spon's "Dictionary," before quoted, gives a formula for the wrought-iron shafts of prime movers and other shafts of the same material, subject to the action of gears, which Francis adopted in numerous cases in practice during the last twenty years and found to give an ample margin of strength.

$$A = \sqrt[3]{\frac{100\ P}{N}}$$

In which P = the horse-power transmitted, N the number of revolutions of the shaft per minute.

For simply transmitting power the formula, used is $A = \frac{50\ P}{N}$."

With respect to the bearings of shafts, Mr. Thomas Box says, "The number and position of bearings must be regulated by the position of the wheels or riggers on the shaft. In all cases the bearings should be as near as possible to the coupling, wheels, &c. But sometimes a long shaft may have no gearing upon it for many feet, and the distance between the bearings must be fixed with reference to the stiffness of the shaft itself. We may admit that a 2 inch shaft, unloaded except by its own weight may have bearings 10 feet apart, and allowing that the deflections may be in all cases proportional to the distance between bearings, we have the rules :— $L = \sqrt{(d \times 16)^2}$, or $L = (d \times 16)^{\frac{2}{3}}$

$$A = \sqrt[2]{L^3} \div 16, \text{ or } d = L^{\frac{3}{2}} \div 16.$$

In which $d$ = diameter of shaft in inches, L = length between bearings in feet." It may be here remarked that a little allowance should always be made for looms on account of the intermittent or reactionary nature of the work.

Unwin, in his "Elements of Machine Design," says that "ordinary mill shafting for textile manufactures" is calculated on a basis which gives the diameter "1·34 times that which would be necessary if they were no bending when as usual it is of wrought-iron," and he gives the following equation - $D = 1{\cdot}34\ B \sqrt[3]{\frac{H.P.}{N}} \qquad = 4{\cdot}414 \sqrt[3]{\frac{H.P.}{N}}$

$$\frac{H.P.}{N} = 0{\cdot}01163\ d^3$$

From this formula he has computed a table, giving the value of $\frac{H.P.}{N}$ for the most ordinary sizes of shaft, from which the following are extracts.—

| Diam. of shaft. | | $\frac{H.P.}{N}$ |
|---|---|---|
| 2 inches | ... | 0·0930 |
| 3 ,, | ... | 0·3139 |
| 4 ,, | ... | 0·7442 |
| 5 ,, | ... | 1·4536, and so on. |

In using the table he "multiplies the tabular numbers in the column $\frac{H.P.}{N}$ by the number N of revolutions per minute, the result is the horses power the shaft will transmit.

Having these rules for finding the capabilities of shafts or gearing for transmitting power, it now remains to find what is the power required to be transmitted.

What is termed a unit of work, is one pound avoirdupois raised vertically one foot; then if $U$ denotes the unit of work in raising $W$ lbs. $h$ feet. $\therefore U = W h$.

Thus the rule to find the units of work in raising a given weight a given height is:

Multiply the height in feet by the weight in pounds (or *vice versa*), the product will be the units of work done.

Example.—Find the units of work in raising 5 cwt. 20 feet high. $\therefore$ U $= 560 \times 20 = 11{,}200$ units of work.

It is important to observe in the application of the above formula to practical cases that the height ($h$) is the vertical distance through which the centre of gravity of the body whose weight ($W$) is raised, consequently the work done in raising a body up an inclined plane or any curved surface is equal to the work done in raising the body vertically through the height of the inclined plane.

What is termed a *horse power* is 33,000 units of work done in one minute. Then the following is the formula, $H$ = horse power; $U$ = units of work done; $T$ = time. Therefore $33{,}000 = \frac{U}{60.\ T}$.

The moving power which is applied to any machine moving uniformly, is employed in overcoming the resistance of friction, and useful work done at the working points of the machine. Hence the aggregate number of units of useful work yielded by any machine at its working points is less than the number received by the machine directly from the moving power by the number of units expended upon the resistance of friction (when the machine moves uniformly.) Then the following general rule will find the work done by any machine.

Find the distance through which the power ($P$) applied to the machine has travelled in one minute, and call this distance ($a$), Find the distance through which the weight ($W$) producing useful work has travelled in one minute, and call this distance (b).

Then $a\ P - b\ W$ = power expended upon friction in one minute, and $a\ P$ = work applied per minute, and $b\ W$ useful work done per minute.

It will be obvious from this that too close attention cannot be paid to the working parts of the loom so as to reduce the friction to a minimum, and so balance the working parts of the loom as to utilize to the utmost the power applied. By doing this not only will the power be economised but the reactionary nature of the movements of some of the working parts will be modified, and thus not only conduce to the general good working of the loom, but reduce in a considerable degree the wear and tear, and so effect an economy in that direction which is not even secondary to the economy of power.

In dealing with the details of the loom it may be that I have overlooked some minor points. My object has been to deal broadly with the subject, believing that the best and only satisfactory course is to deal with the general principles, and only such details as are necessary to make them intelligible, instead of dealing with a number of petty details which may be applicable in one case and inapplicable in another.

I may venture to quote the words of M. Bautain (Vicar-General and Professor at the Sorbonne), who says "If in the teaching of the natural sciences the professor limits himself to practical experiences, to describe facts and phenomena, he will, no doubt, be able to amuse and interest his listeners, youth particularly, but then he is only a painter, an experimenter, or an empiric. His is natural philosophy in sport, and his lectures are a kind of recreative sitting. To be really a professor he must teach, and he can only teach through ideas: that is, by explaining the laws that rule facts, and in connecting them as much as possible with the whole of the admirable system of creation. He must lead his disciples to the heights that command facts; down in the depths from whence spring phenomena; and there will only be science in his teaching if he limit it to some heads of doctrines, the connection of which constitutes precisely the science of which he is the master. He will then be able to follow them in their consequences, and to confirm their theory by applications to mechanical and industrial arts, or to any other use to which they may be applied by man."

## DESIGNING.

What is generally understood as designing for textile fabrics, consists of the arrangement and combination of threads so as to form a pattern on the fabric, whether this fabric be of a plain texture, and the pattern produced by combination of colours, or otherwise. It is not in the mere mechanical act of placing these threads together, but in the arrangement of them so as to produce patterns, whether it be by forming figures with the threads themselves, or in making patterns with threads of various colours, that the skill of the artizan is called forth, and the necessity for technical training made apparent. Any one may be taught to perform the mechanical operation of weaving in a short time, but it is only by careful training and constant attention that the art of weaving can be thoroughly acquired. The arrangement of patterns for weaving is generally performed by one man for a large manufactory, and is dignified by the title of designing, whether or not the class of goods manufactured require any of the skill of the designer, or whether there is anything in the nature of the pattern which can give it any claim to the dignity of a design.

Designing is a part of manufacturing which seems to be generally misunderstood. Given some knowledge of the principles of art and the theory of colour, the one thing necessary to study is the principle of the construction of cloth.

The principle of the construction of cloth may be based upon three distinct classes, viz., plain cloth, figuring, and gauze or cross weaving. (In these three classes lace and knitted cloths are not included). In taking these three principles as the foundation of all weaving, I am quite aware that I am departing from what has been laid down by previous writers, but I will endeavour to justify this departure. Murphy, in his treatise on the "Art of Weaving," lays down six principles, viz., "plain textures, twilling, double cloth, spotting, flushing, and crossed warps or gauze." A recent American writer lays down only four principles, viz., "plain cloth, twilling, spotting, and plain figured double cloth." It will be noticed that this writer ignores entirely the gauze, which is certainly an important branch of textile manufacture, and the construction of gauze cloth is founded on a principle quite separate and distinct from all others.

One of the difficulties of the student in the art of weaving has been the want of classification and

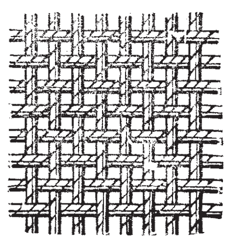

*Fig.* 39.

arrangement of the principles of construction of cloth, and a consequent want of knowledge and system in the combinations to produce the different patterns and effects desired. The student of music had his notes reduced to a system ; the art student had his leading forms and his system of colour,—in these three a similar system is involved ; the musician has his primary and secondary notes ; the artist his primary forms with combined secondaries, and his primary and secondary colours, out of which all others are manufactured. In like manner the weaver may have his primary cloths, out of which he may form secondaries, and from them a multiplicity of combinations and effects.

Having laid down the three principles, plain, figured, and gauze, I will endeavour by going through them *seriatim* to show that they underlie and are the foundation of every description of cloth.

Plain cloth is formed by the warp and weft threads crossing each other at right angles, and passing under and over each other alternately, thus presenting on the surface something like the appearance shown at Fig. 39, and if taken in section it presents the appearance shown at Fig. 40. This is undoubtedly the very first principle in the

*Fig.* 40.

construction of cloth, and was probably practised by the ancients for ages before any attempt was made at ornamentation by forming patterns with the threads. Although this is the plainest and simplest make of cloth, it does not necessarily follow that the cloth must be absolutely plain if made on this principle, but it may be infinitely varied by combinations of colours and materials, and some of the most beautiful effects produced in the simplest manner. Plain cloth is for the strength and quantity of material that may be put in it the firmest and strongest of all makes.

Figured cloth covers a very wide range, although the principle is quite as simple in itself as plain. Fig. 41 is

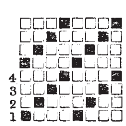


*Fig.* 41.

a very simple form of figured cloth. If a section be taken at the first pick of the pattern, which is represented by the first horizontal line, numbered 1, it will present the appearance shown at Fig. 42. If a section be taken at the second pick, shown by number 2, it will present the same appearance, but the weft not passing under the same end as the previous pick, and so on throughout the pattern. It will thus be observed that the pattern is formed by

*Fig.* 42.

warp and weft threads each passing over and under such a number of threads at a time as is necessary to form the pattern. The number of threads over or under which the warp and weft pass need not be of a limited or a regular character, it may be one or any number. Although this is undoubtedly a figure, it is commonly known as a twill pattern, which is nothing more or less than a figure of a regular description.

It now devolves upon me to prove that every make of cloth which is not a plain cloth, which of course

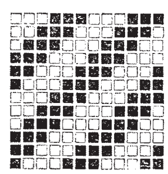

*Fig.* 43.

admits of no variation in its construction, or a gauze cloth, which is constructed upon a totally different principle, must be either a figured cloth or a combination of two or more of the three principles. This I will endeavour to do in as clear a manner as possible.

In Fig. 42 it has been shown that the figure or pattern is formed by the warp and weft threads passing over and under one or more threads at a time, consequently in every pattern where this occurs the same principle is involved. We will take the case of a regular twill, as is shown at Fig. 43.

On examination it will be found that the warp and weft threads each pass alternately over and under three threads; but by the arrangement of the pattern they do not pass over and under the same three threads every time, but move one thread to the right at every pick, thus forming a regular and continuous twill, but this twill is nothing more or less than a regular and continuous figure. We will take the case of another twill, Fig. 44. This twill is also regular

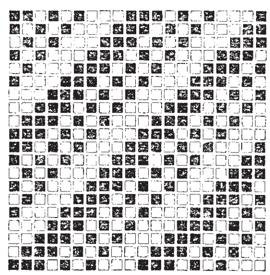

*Fig.* 44.

and continuous, but on examination it will be found that alongside the twill there are four ends that are working plain, that is, the warp and weft threads pass under and over each other alternately; consequently this twill is a combination of the figure and plain principle. Another illustration Fig. 45, will demonstrate this even more fully. In this pattern will be found the continuous twill, a decided figure running alongside it, two ends plain running up the twill and three ends plain running alongside the figure, yet only two distinct principles are found to be contained in it. And no matter how extensive or how elaborate a twill—or, as large patterns of this description are called, diagonals or diagonal twills—may be, only the two principles of plain cloth and figuring are involved, the name of twill or diagonal only signifying that the pattern runs in a regular and particular direction.

Spotting is of two kinds; either the spot is formed by raising the warp or weft, which forms the ground of the cloth, or both, or the spot is formed by a separate colour of warp or weft, or both, which is thrown in for this

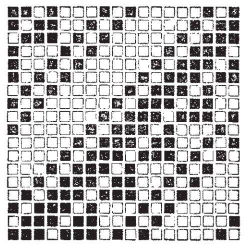

*Fig.* 45.

purpose: but whichever of the two methods is employed the spot must be formed upon the principle shown at Fig. 45, and the ground may be either plain or figured as the case may be, but as in the case of Fig. 45 only the two principles are involved. This will be fully demonstrated in another chapter.

Double cloth may be divided into three kinds. First, double-faced cloth, both faces being formed by warp, all the weft being thrown in the centre between them. In this case the two faces may be of different colours by having the warps different. Fig. 46 shows a section of this kind of cloth, the small dots representing one colour of warp, the large dots another colour, and the waved line the weft—which may be of an indifferent colour—passing between them. It may appear from the section that the weft would appear on both sides of the cloth, and so it would if the cloth were of a thin and meagre description, but if the warp threads are very fine and close

*Fig.* 46.

together, the weft may be entirely hid, because it only passes to the surface of the cloth over one thread, and the threads on each side would close over and cover it. Second, double-faced cloths, both faces being formed by the weft, the warp being in the centre. A section of this is shown at Fig. 47. In this case as in the previous one

*Fig.* 47.

the two faces may be of different colours by using two kinds of weft as indicated in the figure, one for the top side of the cloth and the other for the under side, the warp being of an indifferent colour, the cloth being constructed on the same principle as the previous one, only the weft taking the place of the warp on the surface, and the warp passing to the middle. Third, the two cloths may be separate and apart from each other. A section is shown at Fig. 48 of a double plain cloth. In this it will be

*Fig.* 48.

observed that the two cloths are quite apart from each other, and the question will naturally occur to the student that if a double cloth be made in this manner the two cloths will separate, but to obviate this a very simple precaution is taken. In the process of weaving a thread of one cloth is taken into the other at regular intervals, to bind them together, care being taken to do it in such a manner that it shall not be visible or cause any unsightliness on the face of the cloth. With this I shall have to deal more fully in a future chapter.

Upon this principle of making double cloths there is unlimited scope for making patterns. The two cloths being apart from each other, may be totally different in colour and pattern, or patterns may be formed by having the cloths of different colours, and bringing one cloth through the other so as to form a figure on the face of it.

In the case of double cloths no new principle is involved; it is again a figured effect, a plain cloth or a combination of the two. In the case of the double warp face the effect is produced by the two warps working on the figuring principle, more or less according to the pattern. In the case of the double weft face the effect is produced by the two wefts working on the figuring principle, and in the case of the two separate cloths it is two plain cloths, or two figured cloths, produced by keeping each separate weft to its own warp, no matter whether the two cloths remain separate, or whether one cloth is made to form a figure on the other.

Pile or plush weaving is of two kinds, loop pile and cut pile. The way in which this is produced is by having in addition to the usual warp and weft threads, a third thread which is introduced as warp, and woven into the ground, and formed into loops on the surface of the cloth, by being woven over wires of a length equal to the breadth of the cloth. In the case of a loop pile the wires are simply drawn out, but in the case of a cut pile the wires are cut out by passing a sharp knife along a groove in their upper surface, or by having a sharp knife affixed to the end of the wire, which cuts its way as the wires are drawn out. Fig. 49 shows a section of the wire used for making the loop; the groove on

*Fig.* 49.

*Fig.* 50.

the upper surface guides the knife, which is fixed in what is known as a trevet, and drawn sharply along it to cut the pile.

Fig. 50 is a section showing the structure of a plain or