TECHNOLOGICAL HANDBOOKS.

COTTON WEAVING.

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COTTON WEAVING:

ITS DEVELOPMENT, PRINCIPLES, AND PRACTICE.

BY

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PREFACE.

THE following work, which is complementary to the writer's former treatise upon "Cotton Spinning," was designed at the same time, and originally intended to appear at a comparatively short interval thereafter. Events occurred, however, which compelled the author to lay down the task. When resumed it had to be performed simultaneously with the heavy work of conducting a weekly trade journal, "The Textile Mercury." Had the writer not felt in honour bound to the publishers to complete it, it would probably have been abandoned in the face of more important demands. The task is now, however, finished, and he would take this opportunity of acknowledging the great patience and kindness of Messrs. Bell and Sons in waiting, and that without pressure, until circumstances permitted it to be resumed and carried to a conclusion.

The work is sent forth by the writer in the hope and trust that it will contribute to increase the interest of those whose lives, capital, and energies are practically invested in the cotton trade; and whose welfare, and that of generations of their descendants to follow, are inseparably bound up in the conservation of its interests and the promotion of its prosperity. And beyond this class there is another he would desire to affect, namely, those who care something for the great interests of the State. If any one choose to examine the industrial development of the country, thoroughly, and without bias or prejudice, it will be found that its

eminence in almost everything that makes a nation great, originated in and is maintained by its mechanical industries. And of these the cotton trade was the first, thus becoming the foundation stone of its eminence. There is one lesson that should and will be drawn if the history of the cotton trade be read wisely: it is, that the trade does not belong to the merchants, capitalists, and workpeople of the present generation, but that it is a great national property in which they possess only a life interest. This they are bound by every sentiment of affection for their children and love for their country to pass on to succeeding generations, not only unimpaired, but increased in value. To neglect this duty will be to deprive millions of English people in the future of the means of livelihood, and the nation of one of its most important resources. This would be politically criminal and would do much to depose the country from its eminence in the community of nations. There is also a further duty incumbent upon those whose chief interests are connected with this trade. This is to protect it from external aggression, especially that of ignorant legislators, whose capacities for mischief have been so extensively manifested in the Parliament just dissolved. No more important duty can engage attention than that of the critical examination of the legislative projects affecting it brought forward in the House of Commons, and to give strenuous resistance to every one that will act adversely to its well-being.

The present work is an exposition of the development, principles, and practice of the weaving division of the trade, as the former volume was of the spinning division. In its execution the writer has adhered to the plan of the former work, which has received the emphatic approval of all readers interested in the subject. If there be any difference it will be found in the fuller and more careful exposition of the origin and development of the subsidiary processes, and of the invention and improvement of the series of machines employed in this section of the trade. An effort has been made to clearly define the art of weaving, to trace its development from the primitive germ through all the succeeding stages of its growth to its present wonderful perfection. In the course of the narrative care has been taken to show when and why it has developed tendencies to divide and subdivide, throwing those branches off as separate processes that have become known by other names, though they still are and must ever remain adjuncts of the original parent of the whole, namely, the weaving process. By a careful perusal of what has been written the reader will be able to understand the causes and requirements in which originated not only every part of the loom but of those of almost all the machines employed in the preparatory processes. With this knowledge the intelligent technical reader will easily decide, when further changes or innovations are proposed, whether they are in harmony or conflict with the leading principles embodied in what has already been accomplished, and whether their adoption will prove advantageous or otherwise. All changes are not improvements, and the money spent upon those that are valueless will be simply so much wasted; and the condition of the trade is not such as to admit of waste.

Weaving, of course, is one of the most ancient arts, and cotton weaving in India at least can reckon its history by centuries. In England ~~it~~ is, however, one of the most modern industries, and the development of the English system of manufacturing constitutes one of the most remarkable series of phenomena to be found in human history; and the benefits that have resulted directly and indirectly have seldom if ever been equalled from a single cause. For more than half a century these advantages were almost monopolized by this country, but during the half century which will come to a close in a few years they have been appropriated to a more or less extent by almost every other nation. England can only therefore expect to continue to receive a large share of its benefits by keeping well in front with its inventions and improvements, and for this

she must depend not only upon her present inventors, but upon a further development of the inventive faculty. That this may to some extent be stimulated by the present work is one of the desires of its author.

RICHARD MARSDEN.

MANCHESTER,
August, 1895.

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COTTON MANUFACTURING.

CHAPTER I.

INTRODUCTORY.

The division of the cotton trade into two branches, spinning and manufacturing.—India, its birthplace.—Indian processes; the Institutes of Menu.—Indian competition with the English textile industries the origin of the English cotton trade.—Early tendency of the English trade to divide into two sections.—Temporary tendency to reunite.—Reaction and probable permanency of the division.

THE contents of the introductory chapter of the author's previous work on "Cotton Spinning: its development, principles, and practice," obviates the necessity of any lengthened remarks on the present occasion. But in order to enable the student to thoroughly comprehend the subject and the reasons for the ultimate division of the great cotton trade into two sections, a brief review of its development, considered from a somewhat different point of view, will be not only permissible, but necessary.

As observed in the work referred to above, the best historical evidence obtainable points to India as the birthplace of cotton manufacturing; but when it commenced, how long it remained a pure handicraft, or at what date the first rude mechanical appliances were introduced, are details of its history irrecoverably lost in the mists that have gathered around those long-past times. As far back as ancient records lay bare the history of India, the manufacture of the downy product of the cotton plant is shown to have been generally diffused over that country, employing more or less fully nearly half the population. To quote from the chapter referred to in my previous work: "Cotton was grown in the districts closely adjacent to nearly every village; cleaned, spun, and woven on the spot; each little community producing enough for its own consumption. A rudely constructed roller gin separated the seed from the fibre, and the latter was cleansed from the leaf, dirt, and knots by the bow. The cotton, as left by this instrument in a light fleecy mass, was then taken and, with little further preparation, spun by the women." It will be safe to infer that for a long period the only instrument employed was the rude spindle, and mostly without the distaff, the worker drawing the cotton from loose, fleecy balls, into which it had been formed. Down to recent times, this system of hand spinning has existed side by side with that of the rude wheel still employed for the purpose. The industry being a purely domestic one, was conducted through all its processes and details by the members of one family in their dwellings, or adjacent thereto in the open air. The portions of the processes analogous to those of our present manufacturing system are what mainly concern us and require notice here.

The Indian weaver receives his yarn from the native spinner, as well as from the Indian and European mills, in the bundled form, or in knots or hanks. In this form it is taken and transferred to a pyramidal reel, and thence wound upon short pieces of reed for use in the next process, that of forming the warp. This is done on the plan called peg-warping, not many years extinct even in this country, which will be described in the proper place subsequently. The warp was sized in the most primitive fashion by means of rice water, and it is a curious fact that even in the earliest times malpractices in sizing were

not unknown. The Institutes of Menu, compiled a thousand years before the Christian era, condemn heavy sizing, and declare that a proper allowance shall be made for the added weight, even when sized only for weaving. In Chap. VIII. v. 30, there is the following passage regarding the practice of sizing: "Let a weaver who has received ten palas of cotton thread give them back increased to eleven by the rice water and the like used in weaving. He who does otherwise shall pay a fine of twelve panas." This ancient legislator clearly entertained the idea that sizing should be confined to the legitimate use of rendering the warp more easily workable, and that all beyond should be prohibited. It is questionable, however, whether much more regard was paid to this injunction than is to-day given to moral principles in relation to the same matter.

India from the earliest times exported its cotton manufactures to the countries of Western Asia, whence they were distributed to those of Europe lying along the basin of the Mediterranean, and sometimes to the lands beyond these, though this was but rarely. It was not until after the discovery of the Cape route to the East that the real influence of the manufactures of India upon the Western countries of Europe began to make itself felt. The comparatively low prices at which they now came to be attainable, and their great beauty, caused them to become highly esteemed amongst the aristocracy and the wealthy classes of this country, to the great neglect of the coarse fabrics of home production composed of wool and linen. During the closing years of the seventeenth century, and the opening ones of the eighteenth, the outcry raised against the use of the Indian fabrics led to the passage of several Acts of Parliament having for their object the protection of the native industry. In spite of these, however, Indian goods continued to be worn, and no real or permanent impression was made in the restriction of their use until the weavers of England began to imitate them, which was done in fabrics composed of a linen warp and cotton weft, the English spinners, with their appliances and previous training, being incapable of making a warp yarn from cotton. These productions for a time satisfied the growing popular demand for light fabrics. The true Indian cloths, however, continued to be extensively worn by the upper and wealthier classes.

At this period the earliest symptoms of a separation of the cotton trade into the two branches of spinning and manufacturing began to appear. The invention of Kay's method of throwing the shuttle, called the picking stick and fly shuttle, in 1733—not 1738, as so often given by writers on this subject—had so increased the capacity of the weaver that the members of his own household were rarely sufficient to provide him with the yarn necessary to keep him at work. The demand for yarns became so strong, that in households where no weaving was carried on the younger members were taught to spin, and in a short time, by their earnings, added very considerably to the income of the family. The subsequent invention of Hargreaves' spinning jenny accentuated and increased this movement towards separation, as families whose occupation was mainly spinning, as well as those engaged in weaving, procured the new machines. We thus discover at this early stage the tendency of the industry to separate into the two divisions into which the progress of invention and the development of systematic industry has now more fully led it. The invention of Arkwright's water frame, a machine too heavy and complex to be easily worked for any length of time by human strength, necessitated the introduction of the factory system, and the use of a motor of greater force, which was first found in horse, and then in water power. Hargreaves had founded a mill in Mill Street, near Chapel Bar, Nottingham, and furnished it with his jennies, for which, however, the operative alone supplied the power to work. In near proximity to this, in Woolpack Lane, in the same town, Arkwright, and Smalley, his Preston friend, established their first mill, the machines in which they operated by horses. This mode did not prove satisfactory, and their means becoming exhausted, the assistance of capitalists was secured, and by their aid the mill at Cromford, in Derbyshire, was founded, which substantially became the model of many others established by that enterprising inventor. It may interest the curious to name a few of the mills with the establishment of which Arkwright was connected. Besides those just mentioned, Arkwright built Masson Mill, near Cromford, a mill in Miller Street, Manchester, one at Adlington, near Chorley, and, we believe, several in Scotland. His firm subsequently, we understand, acquired Mellor Mill, Derbyshire, founded by Samuel Oldknow, so picturesquely situated on the Goyt, near Marple. The concentration of the spinning industry in mills which thus took place by this development of the factory system, was a very powerful factor in effecting the separation of the industry into the two branches of spinning and weaving, and the increased capacity of production liberated thousands of operatives for absorption into the weaving branch, in which at that time there was a great demand for workers. A rapid extension of the trade took place, manufacturers purchasing yarn from spinners and giving it out in the form of warp and weft to weavers in the country districts, who returned it in the form of cloth. Thus the separation of the industry into two parts was enforced by the process of growth. The men who thus "put out" yarns, as it was termed, for weaving, were called at first manufacturers, and subsequently hand-loom manufacturers, to distinguish them from the power-loom manufacturers, who afterwards became their formidable competitors, and finally drove them from the field. During the period from 1815 to 1830 there were in Lancashire and the adjoining portions of Yorkshire, Cheshire, and Derbyshire, between 240,000 and 260,000 hand-looms employed. After the latter date there was a rapid decline in the numbers, the improvements effected in the power-loom enabling it to supplant them.

The course of this revolution in weaving seemed at one time to promise a perfect reunion between the two sections of the trade, as the spinners began to put down looms to consume their own production of yarn, whilst, on the other hand, the manufacturers, having acquired wealth, procured spinning plant to supply themselves with yarn. Thus the second series of mills that arose combined both branches of the industry. The power-loom, at its first introduction, and for forty years afterwards, was available only for the production of plain cloth, chiefly known as domestics, shirtings, and printing cloths, for which there was a steady and growing demand. With extending trade and the increasing capacity of the power-loom, the several districts in which manufacturing was carried on began to develope specialities in cotton goods that were hitherto unknown. Stockport, in the early days of the present century probably the greatest weaving centre, made domestics and printing cloths; Preston devoted its energies to long cloths, shirtings, and muslins for the home trade and for India; Blackburn chiefly made long cloths and printing cloths; and whilst Manchester and Radcliffe mainly engaged themselves with coloured goods, fustians, &c., Bury and Rochdale adhered to the woollen trade, making flannels, blankets, and goods of a like description. The remainder of the Lancashire towns had scarcely emerged from the character of villages, and the declining hand-loom trade was chiefly carried on within them. This tendency to recombine continued until about 1850, when the adoption by this country of a free-trade policy in commercial matters gave such an impetus to the trade, that from the last-mentioned date until 1860 an enormous extension of the industry took place. In East Lancashire weaving sheds arose on every hand, and correspondingly, to supply them and meet the expanding foreign demands for yarns, a large number of spinning mills were erected in Oldham and the

adjacent villages, which now rapidly began to assume the dignity of towns. Thus the tendency to divide received a new impetus. To build combined spinning and weaving mills required a large amount of capital not often found in one or two hands; but weaving sheds could be erected for a comparatively small sum. The joint stock system had not then been applied in the cotton trade; it was reserved for the two following decades to witness the application and development of this important principle in connection with it.

Since 1850 the forces tending to divide the trade have been continually in the ascendant, and it would now appear as if they had given a permanent character to its division. The widening of our commerce, and the demands made upon our manufacturers for an increasing variety of fabrics, in substance, quality, and style, almost preclude the possibility of combined spinning and weaving establishments meeting the requirements of the markets economically, whilst upon any other basis the severity of competition precludes business being carried on. Spinning mills must be furnished with machinery fitted to produce either coarse, medium, or fine counts of yarn: they cannot with advantage and economy alternate from one to the other of these descriptions; and weaving sheds attached to them are by that fact, to a certain extent, limited in their range of the market, and deprived of utilizing a certain amount of their capability to meet its wants. With very slight modifications of their plant they could, if free from a spinning mill, change from coarse to medium counts of yarn, or from medium to fine, and back again when circumstances rendered it desirable. But the weaving establishment attached to a spinning mill is compelled to consider the capability and requirements of the spinning section, and in certain conditions of the market may have to decline orders that its untrammelled neighbour can accept. In practical work this occurs oftener than might at first sight seem likely, and, in the course of years, appreciably adversely affects the prosperity of the concern. The conclusion is, therefore, obvious and sound that the division of the cotton trade into the two important branches of spinning and manufacturing is assured and permanent. This being so, it is assumed that the requirements of students will best be met in the following treatise by recognising the fact, and assuming that the practice proposed to be elucidated is that which would be the best for, and the one adopted in, a weaving establishment not connected with a spinning mill.

CHAPTER II.

Early Weaving and the Development of the Hand-Loom.

Weaving an ancient art; definitions.—Its origination in man's necessities.—Classic stories of its invention.—Modern research and geographical discovery show its wide prevalence.—Conjectural origin.—Ancient Egyptian weavers, their looms and materials.—Survival of the purely manual art.—Progress of invention.—Supposed looms of the fourth century, A.D.—Stimulations to further improvements; successive advances.—The shuttle in its incipient stages; its gradual development.—The lathe in its earliest and some succeeding forms.—An equipoise between the several parts of the loom; also between spinning and weaving.—The horizontal loom and its gradual improvement.—The Indian loom; the pacing motion.—The loom as Kay found it; its survival in Wales to the present time.—The Indian loom described; the Indian weaver humidifies his warp.—Loom of Sumatra and Java.—Of Japan.—Of Salomon Islands.—Of New Caledonia.—Of Ashango Land.—Kay's invention of the fly shuttle.—Disturbs the balance between spinning and weaving.—Robert Kay's invention of the drop shuttle-box.

WEAVING is an ancient art that has engaged the attention of both early and modern writers, as quite befits its importance. The former, however, have generally confined their notices to incidental references, that are more valuable from what they suggest regarding its condition and details, than from what they actually reveal. The latter have endeavoured to give an exposition of the art more or less full, and their works have mostly appeared within the second half of the last, and during the course of the present century. The remarkable growth of literature relating to the weaving industry within this period arises from the fact that its greatest developments, and those which have called for scientific exposition, have taken place within its limits.

As might be expected, the art of weaving has been variously defined, and it will be interesting and instructive to the student to have the most important of these definitions brought under his notice. The great lexicographer, Dr. Johnson, with the care, correctness, and ability that usually distinguished his work, thus explains it:—

"Weaving is an art by which threads of any substance are crossed and interlaced, so as to be arranged into a permanently expanded form, and thus to be adapted for covering other bodies."

Consideration will shew that this definition will be difficult to improve upon, and in proof thereof it may be stated that James Yates, M.A., the learned author of the article "Tela," in Smith's "Dictionary of Greek and Roman Antiquities," adopts it in that article, and also in his later work on the same subject, "Textrinum Antiquorum." Unfortunately for the students of the textile arts, the latter work is a fragment—only one volume having been published—which treats of the raw materials, vegetable, animal, and mineral, employed in the industry. Dr. Ure in his "History of the Cotton Manufacture," with some little pedantry elaborates and refines upon Johnson's definition, though hardly to the edification of the ordinary reader, as will be obvious from the following:—

"Weaving is the art of making cloth by the rectangular decussation of flexible fibres, of which the longitudinal are called the warp, and the transverse the woof, or weft."

In the above definition Dr. Ure appears to have imitated Dr. Johnson's definition of lace, which is: "Anything reticulated or decussated at equal distances, with interstices between the intersections." John Murphy, author

of the standard and justly celebrated treatise on "The Art of Weaving," gives no specific definition, neither does Clinton C. Gilroy in his well-known work bearing the same title as the foregoing. The latter, it may be remarked in passing, is distinguished by a remarkable and realistic piece of satirical writing directed against the too common practice indulged in by many people, of alleging that nearly every modern invention connected with the textile industries had been anticipated by the ancients, and that therefore inventors of the present day were entitled to little credit, and consequently to no protection for their devices. This satire composes the introductory chapter to the work, and extends to seventy pages. It has often deceived people who have taken seriously the statements contained in it as veritable history; it is mentioned here in order that its true character may be pointed out. White, a Scotch author, whose work on "Weaving by Hand and Power" was published in 1846, contents himself with a very simple definition, which is as follows:—"Plain weaving consists in the interlacing together of two lines of threads at right angles to each other." Watson, another Scotch writer, whose essay appeared in 1866, gives a still more bald outline, defining weaving as "the making of cloth from yarn or threads." Only another example need be adduced, which shall be from a recent work on "Weaving and Designing" by Mr. T. R. Ashenhurst, late teacher of weaving in the Technical School, Bradford, Yorkshire, published in 1879:—

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

The present writer may be permitted to give a definition:—

Weaving is the art of arranging, at right angles to each other, two or more series of threads of any suitable material, and binding them together by passing each thread under and over, and sometimes partially around one another in regular alternation, or in such other order as may be needed to produce the required effect, by which arrangement they assume and retain an expanded form, rendering the fabric adaptable to many uses.

The origin of weaving can only be conjectured; it is lost in the mists of past ages. History says nothing of its beginning; the earliest mention of the art showing it, comparatively speaking, in an advanced stage of development, and which, judging from its slow growth in subsequent times, could only have been attained through centuries of almost imperceptible progression. Whether it began in Assyria, Egypt, Persia, or India, cannot be gathered, because when first referred to by ancient writers it is inferentially clear from their statements that it was known in all those countries. In lieu of positive knowledge, therefore, we must fall back upon tradition, and when this slender staff fails to give support, we must retire upon the safer deductions of reason, and see if we can glean therefrom a shadowy reflection of the facts.

"Necessity," says an old adage, "is the mother of invention," and the art of weaving, like most other arts, owes its origin to the pressing needs of mankind. Of all animals man is the only one for whom it may be said nature has been at no trouble to provide clothing. It is true that in a very primitive state, and in the warmest latitudes, he runs naked, and feels no necessity for any addition to the scant provisions of nature. But immediately he steps over the boundaries of these districts the lowering temperature develops a desire for clothing. The conclusions of modern science concur with Biblical and other ancient writers, that in the primeval ages men killed the beasts of the field for food, and clothed themselves with their skins. These would differ considerably in suitability for this purpose, though experience would soon teach them to select the best. But the best clothing that could be fabricated from these materials in the then state of knowledge of their treatment, would leave much to be desired in the way of comfort. Hence would result the development of man's inventive faculties. As observed above, however, of the outcome of this as applied to the art of making clothing, we have no positive information. The book of Job is one of the most ancient pieces of writing in the possession of modern times, and every child is acquainted with the beautiful simile it contains drawn from the textile art, in which the patriarch, desirous of expressing the rapidity with which time was passing, exclaims: "My days are swifter than a weaver's shuttle." Of course the shuttle referred to was not the shuttle of to-day, but notwithstanding this, the simile incidentally reveals that the progress attained in the writer's time in this art had been considerable. None of the sacred writers speak of the invention of the art. Wherever a reference to it is made, it is indicative of its being in an advanced stage of development.

The classic writers throw a little more light upon the origin of the art of weaving than do Biblical ones. Amongst the nations of antiquity are several on whose behalf claims have been put forward to the invention. Pliny informs us that "the Egyptians put a shuttle into the hands of Isis, to signify that she was the inventress of weaving." But though I am strongly disposed to think that weaving may have originated on the banks of the Nile, the fact that a shuttle was placed in the hands of this goddess may have indicated more that she was a patroness of those who pursued the art, than of any claim to the invention. Semiramis, the celebrated queen of Assyria, has also been brought forward as a claimant for this honour, but so far as can be ascertained, with no better evidence than that advanced in favour of the feminine deity of Egypt. The habit of deifying or semi-deifying their most celebrated rulers, prevalent amongst ancient nations, led to the attribution to them of the origin of every useful art. This will sufficiently account for the existence of claimants to the invention of weaving amongst nearly all the peoples of the ancient world. This fact strongly indicates that all clue to the origin had even in those early times been lost.

Modern research has shown that the art of weaving was widely prevalent amongst the most celebrated nations of antiquity, and was by them carried to a high degree of perfection, probably as high indeed as manual skill was capable of reaching. The phases of civilization developed in ancient Egypt, Assyria, Phœnicia, Greece, and Rome have all passed away with the peoples who originated them, but their remains still exercise a great influence upon the civilization of modern times, especially on its artistic side, which is the most visible. It will be doing the latter no injustice, nor depriving them of any credit, if it be affirmed also that the origin of many of the most useful arts, amongst which weaving takes a foremost place, must be sought for in the same source, though the course of descent may not always appear on the surface.

Geographical discoveries during the past three or four centuries, amongst the other wonders that they have revealed, have shown that the art of weaving has long existed and been carried to the highest perfection amongst the nations of the far East, whose existence was practically unknown and undreamt of until after the discovery of the mariner's compass. The natives of India, China, Japan, Borneo, and the subjacent countries, were all found to be possessed of this useful art, and, with modifications, to have carried it to a high degree of advancement. In the most recent times the opening up of Africa ("the Dark Continent") has shown the art in a very primitive stage of development amongst its rudest tribes. Crossing the Atlantic to the new world, when the white man first landed upon its shores he found that the various tribes of the natives were experts in manual weaving. It has also since been discovered that it was a well-known art

amongst the ancient races of Mexico, peoples who were unknown even by tradition to those whom Europeans found occupying the country, and whose existence is only attested by the wonderful remains they have left behind them, which demonstrate their possession of a peculiar yet highly-developed civilization. Passing from the mainland of the American continent to the isles of the Pacific, Captain Cook and his successors, in the explorations of these seas, found the natives of the various groups of islands that they discovered quite adepts in the production of simple woven fabrics from the fibrous materials indigenous to their respective countries. And thus it is all round the globe—wherever explorers have gone, they have found amongst every race and nation this useful art in either a primitive, middle, or advanced stage of growth.

It will be seen from the preceding that neither historical research, antiquarian investigation, nor geographical explorations have revealed the origin of the art, the date of its invention, or the name of the first weaver. It takes little intellectual effort to resolve into myths the claims brought to light by the former in favour of certain shadowy individuals of the past. In lieu then of positive knowledge a guess may be hazarded. How came mankind to conceive the idea of weaving? The answer is clear. It must have been to obviate some inconvenience, or secure some advantage. What could this have been? Perhaps a little consideration may reveal the possible, if not the probable, genesis of the idea. The apron of fig-leaves may be dismissed, as also may the thought of any other article of attire. For dress purposes the skins of animals, both wild and domesticated, for many ages would amply suffice for the requirements of the human family in this respect, so that no stimulating inconvenience would be encountered here. Skins would also serve for the construction of tents when mankind began to think it desirable to seek shelter from the heat or inclemency of the weather. Up to that time the natural grasses of the earth had no doubt formed a satisfactory couch on which man could lie down to repose in the heat of the day, or after its labours were over. But when he resorted to tents, which may be supposed to have been made of skins, the grateful floor covering which nature had provided would soon be worn away. The bare earth would not prove agreeable, and it would soon be discovered that it would often be easier to provide a substitute for nature's carpet than to pull down the tent and remove to another plot. The most convenient ones would be resorted to, and thus, in some instances, skins, leaves, grasses, or reeds would be procured as useful substitutes for the growing herbage. These were most probably the first artificial carpets, and it is in connection with the development of this emblem of modern civilization, in the opinion of the writer, that weaving would originate.

Conceding, and indeed affirming, that the balance of probabilities points to Egypt as the country in which weaving was first invented, it may be pointed out that in all past times, as at present, the population of that country has mainly been concentrated upon the lands bordering upon the great river Nile, the old and celebrated stream which a few years ago engaged so much of the attention of Englishmen, and where events of great importance transpired. From the days of the Pharaohs down to the present time the swamps of the Nile have been noted for the abundance of vegetation they produce, and which has been applied to various uses: witness, for instance, the ark of bulrushes in which, in the days of the sojourn of the Israelites in Egypt, it is recorded the infant Moses was placed. What more natural than that the flags from the river should be used for floor coverings? These would be strewn about the floors of the tents and dwellings of the people, as rushes were in this country only two or three centuries ago. It would not be long before Egyptian mistresses and Ethiopian maidens would devise means of utilizing them for decorative purposes; especially as when by so doing their durability would be enhanced, and the comfort obtained from their use increased. Indiscriminately thrown upon the floor they would be trampled up, to avoid which the first plan adopted would probably be to place them longitudinally side by side. In this we get the first step in the art of weaving: a parallel arrangement of reeds or flags. The next, the introduction of transverse ones, would speedily follow, as an ornamental effect would be obtained by laying others across those first placed in parallel order. The second step is thus arrived at: longitudinally and transversely arranged flags; but still no weaving has taken place. As now supposed to be laid, they would be liable to derangement every time a person moved across the floor, which would destroy the ornamental effect. To prevent this it may be assumed that various expedients would be resorted to before it dawned upon anyone's mind that the transverse flags should be made to pass alternately under and over those laid in a longitudinal direction in order to secure a comparatively permanent arrangement to the mass, and such as had never been obtained before. Increased utility combined with a beautiful effect would be the outcome of this disposition of the materials, and it could not fail to strike observers very forcibly. Such would possibly, even probably, be the first woven fabric, and its conspicuous advantages would speedily secure extensive imitation and general adoption. This conjecture, it may be observed, is based on a substratum of fact.

The first webs fabricated in the manner thus supposed would only be of the size that could be made from single flags; when large ones were wanted the longest flags would be selected to produce them. Still, the desire for some of larger dimensions which would arise would remain ungratified until the difficulty in the way was overcome by the discovery of some means of attaching one length to another, which to a certain extent would solve the problem. Before the last-mentioned stage of development the operation would be purely manual, and would need only one individual to perform it. But the increase in dimensions would necessitate the introduction of implements, crude and simple at first, but containing the germs of the wonderfully perfect and complex mechanism of the loom of modern times. The first would most likely be a piece of wood that the worker would lay across his longitudinal reeds to maintain them in position, whilst he lifted and depressed them alternately in putting in the woof, or those that had to occupy a transverse position, which he would push up to the one previously inserted. Here is the beginning of what has now become the cloth beam. His next advance would probably be to place a second beam of similar dimensions and character at the opposite extremity of his loose warp, which would thus be extended and held at both extremities. This would further facilitate his work, as, instead of having to handle all his warp-threads, as they may be called, he would only have to contend with the woof he was inserting transversely, which he would rapidly pass under and over the longitudinal flags thus held down at each extremity.

Amongst the picture writings of Egypt's ruined palaces and temples representations of the ancient methods of pursuing the art of weaving might naturally be expected to be found, and this anticipation has been justified by the discoveries that have been made. Sir Gardner Wilkinson, in his "Manners and Customs of the Ancient Egyptians," has reproduced three drawings from pictures on the walls of Thebes, showing several weavers at work, and illustrating three forms of the loom; or, more correctly speaking, a purely manual process, a rudimentary vertical loom, and a more advanced form of the latter loom. These illustrations are from the tombs of Beni Hassan, which have been fixed by the best authorities to belong to a period 3,000 years before the present era. These representations

were found by Menutoli, and need little description. The framework, if such it can be called, of the first, fig. 1, consists of two transverse bars, which are attached to the pegs secured in the ground. Between these bars the warp is extended, and the weaver sits upon that part of the web already finished, and interweaves his materials without the assistance of anything in the nature of a shuttle. In the original the fabric is shown to be a small, delicately chequered pattern of yellow and green, and from the materials spread around it is inferred that the yarn was dyed in the wool before it was placed in the hands of the

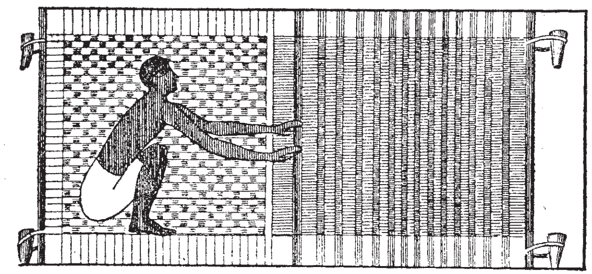


FIG. 1.—ANCIENT EGYPTIAN WEAVER.

weaver. This illustration, if not intended to represent the method of mat-weaving from broad-leaved plants, is evidently very closely derived therefrom, and is so perfectly manual as hardly to show more than the slightest advance upon the stage depicted in the preceding conjecture. The other illustrations exhibit a further development of the loom, and will come under notice presently. The ideal presentation, given in the preceding observations, supported as it is by this Egyptian picture, is offered to the consideration of the reader as affording an approximately correct notion of the genesis of the art of weaving: the earliest stage of an industry that has for untold centuries contributed in a very high degree to the comfort and welfare of mankind.

In fig. 1 we have got the loom in its most primitive form. It is a beautiful illustration, and is interesting because of the support it affords to the most reasonable conjectures that have been formed by students of the natural evolution of the loom from the simple beginnings endeavoured to be pourtrayed here. The weaver sits or crouches upon the part of the web already woven, and as no appliances for shedding are visible, no other inference can be drawn but that the fabric is formed by passing by hand the transverse material alternately under and over the longitudinal threads forming the warp. From the manner in which this material is represented as extending beyond the edges of the warp, it would seem that there was no selvage to fabrics constructed by this method, which would again support the conjecture that the materials were simply flags from the shallows of the river. But if not the same, it requires no stretch of the imagination to conclude that it has been drawn from that source. It may be remarked in passing that the pattern is exactly the one that would result from the interweaving of the leaves of this plant. It is remarkable that flag leaves are still used in Egypt and other lands of Northern Africa for making fabrics of the kind described, which are used for packing the coarser sorts of figs and dates for export to England and other European countries, where they may be seen in our principal markets.

The purely manual form of weaving survives to this day in the art of basket-making, in which it has been carried to a high degree of perfection, especially by the Japanese, fine and beautiful specimens of whose skill may frequently be found in this country. In another, and its very simplest form, it may also be discovered in working men's households, where the careful housewife, in the process of darning hosiery, first extends a number of threads lengthwise of the hole in the stocking, attaching

them to the body of the fabric. These form her diminutive warp. She next proceeds to insert the weft or transverse threads, passing them alternately under and over those of the warp which is extended between her fingers. The needle in this operation performs the function of the shuttle, to the ancient form of which it bears a strong resemblance. It is to be feared that this is a domestic accomplishment of diminishing prevalence. On the Continent, and especially in Germany, young girls are taught the art of darning at school, and become so expert that

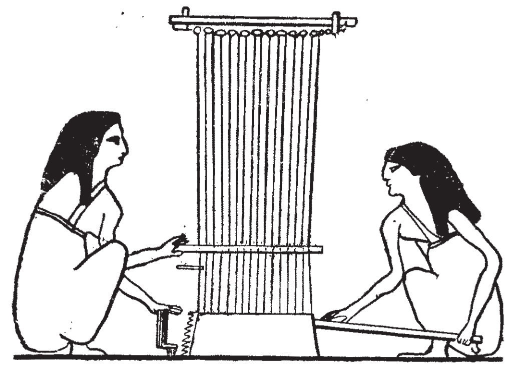


FIG. 2.—VERTICAL EGYPTIAN LOOM WITH TWO WEAVERS.

they often repair the finest woven fabrics with such skill that the place can hardly be discovered. In most of the textile industries, and particularly in cases where the fabric is valuable, repairs of damages are also effected in this manner.

The reason of the next move in advance being made will be obvious. As will be observed from fig. 1, the weaver sits or crouches upon the portion of the fabric already made, and works towards the end of the extended warp in front of him. This constrained attitude must have been exceedingly irksome, and it need not be surprising that the next step should be one that would raise the warp from the ground. Accordingly we find in the construction of the loom as shown in fig. 2, which is derived from the same source as fig. 1, a resort to the vertical arrangement of the warp. Hence comes the high loom retained to this day in tapestry weaving. It really involved little change beyond raising the beam to which the warp is fastened, as seen in fig. 1, and suspending it probably from the roof of the dwelling. This illustration shows one or two points that call for remark. There are two operators who evidently pass the weft or the filling through the warp to one another, the one on the left commencing the operation; the second receiving it, bending and returning it. It will be observed that the filling projects on the left-hand side beyond the edge of the cloth, which indicates that whatever may be the material, in its length it did not suffice to pass more than twice across the warp, thus making one raw edge and one self edge. This is an advance upon the results shown as obtained in fig. 1, where both edges are raw. It may be assumed that two weavers work together as in this instance for the sake of the facility and increased production obtained. In other cases, as in fig. 3, also that of a vertical loom and probably in contemporaneous use with the preceding one, there is only one weaver, who is shown sitting to work. These three figures, all from the tombs of Beni Hassan, sufficiently illustrate the art of weaving as practised amongst the ancient Egyptians. Whether much progress was made by them from this point is not known. If their fine linens such as are found to-day wrapping the mummies were made upon and by these crude means, they afford the most convincing testimony of their great skill.

It is probable, however, that the loom in these forms existed a long time in Egypt, as no evidence exists that we are aware of showing any important advance upon them in this country. In these forms they were probably carried first to Greece, and thence to Italy, as it is in

those countries we next find the earliest evidence regarding the loom. Montfaucon, a French monk and a voluminous writer of the early part of last century, in his great work, " L'Antiquité Expliqueé," says, " It seems, from figures which remain to us of the fourth or fifth century, that they worked at their art with much simplicity. We have some women who are spinning, with others who are weaving; those who make the linen or the cloth of wool are standing. In the ancient Virgil,

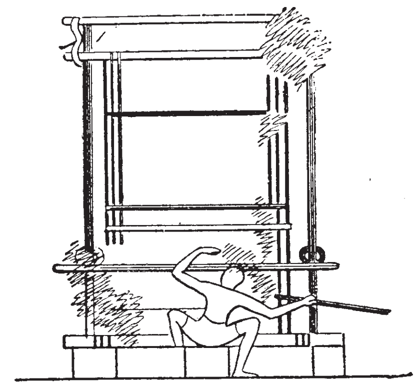


FIG. 3.—SINGLE EGYPTIAN WEAVER AT VERTICAL LOOM.

in the Vatican, which is believed to be of the fourth century, and which formerly belonged to our Monastery of St. Denis, in France, which I have shown in my journal on Italy, we see a woman who works at a piece of linen or stuff, and this woman, who is standing, instead of a shuttle makes use of a long staff (fig. 4). I leave those expert in this art to reason on this manner of working in linen or in cloth of wool." This is simply the vertical loom of the ancient Egyptians that we have already seen. It appears to have been first transferred to Greece, and afterwards to Rome without having undergone much change in its migrations. Very likely the rod was used as both shuttle and batten or lay, but owing to imperfect delineation it has been shown without the hook at the end which was used in drawing the weft through the warp. The old Benedictine Montfaucon with all his wondrous store of knowledge quite failed to observe that the Roman

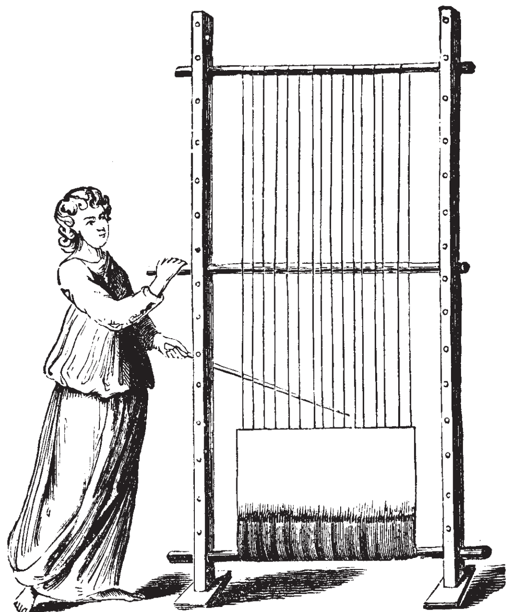


FIG. 4.—GRECIAN VERTICAL LOOM.

and Egyptian looms were practically identical. In using this illustration Dr. Ure, in his "Cotton Manufacture of Great Britain," erroneously terms it a warping frame. But there were disadvantages in the vertical arrangement of the warp that undoubtedly would in some instances cause a reversion to the horizontal position whilst an endeavour

would be made to obviate its defects. This would be accomplished by raising the warp from the position shown in fig. 1 to the height of about three feet at which the weaver could work in a sitting position. To secure this the short pegs would be lengthened until they might fairly be called posts. The strain of the warp, however, in this position, would have a tendency to pull them together, which would be obviated by placing parallel bars between them, first one on each side, then two, and next transverse bars between the beams at each extremity of the warp. With the change indicated a new difficulty would arise. With a fabric of ordinary width, and working from the front as before, with the warp in this position, the weaver could not, if he endeavoured to insert his weft from the side, reach across. Here, probably, may be discovered the origin of two weavers working at one loom, a plan which, under modified forms, survived, even in this country and upon the continent of Europe, until far past the middle of the last century, and which may continue even to this day in secluded districts of the unprogressive countries of the continent and the stationary lands of Asia. This, however, would be an inconvenient arrangement. Many a time two weavers would not be available for one loom, and the other would of necessity be rendered idle until the time his fellow should arrive, when some one more ingenious than the rest would endeavour to overcome his constrained idleness by the invention of a mechanical substitute for his or her absent colleague. What more natural than that he should lengthen his arm, or power of reaching across the warp, by means of a stick? It would have been amusing, even in those days, to see the look of astonishment that would rise on the face of an idle weaver when he returned to work to find that his more industrious and ingenious colleague had been able to dispense with his services, and had finished his task; in fact, it would foreshadow many dramatic pictures of a like kind that occurred in subsequent ages. The stick thus supposed to have been introduced, however, had no hand at its extremity, whereby to hold the thread it had to carry across the warp. The displayed fingers of the hand would speedily suggest a means of overcoming this difficulty by cutting a cleft in the end, which would meet the requirement, whilst subsequently the bent finger would suggest a further improvement in the addition of the hook, which we have already seen was used by the Egyptians. These advances, slight though they may appear, would constitute substantial improvements. This stick, or rod, specially prepared, whilst possessing the functions of the shuttle, was also used as the batten or lay to press the inserted threads successively to the fell of the cloth or edge of the portion previously woven. These improvements, of course, would not be effected in a day: most probably a considerable number of years passed away before they were all accomplished.

It will be obvious that the process of inserting the weft, pushing the rod carrying it alternately under and over the warp threads, exactly as a woman does her needle in the process of darning, was an exceedingly tedious one; and as long as it was followed the labour of the most industrious worker could not be very productive. The want, therefore, most pressingly felt, would be of a more expeditious way of inserting the weft. A brief study of the movements would show that each warp thread was alternately elevated and depressed when the warp was horizontal, and drawn towards or pushed away in its vertical arrangement to allow the weft thread to pass under and over in proper sequence, and that the adjoining thread was depressed when the first was elevated, and elevated when the first was depressed. It would thus become clear that an arrangement by which every alternate thread at one time could first be raised and then be depressed would yield what was wanted, and greatly facilitate the work. Here comes into view the requirement for, and the initial form of, shedding mechanism. How, and by what means, would

it probably be performed? It could only be by some means analogous to a leaf of heddles. Most likely the first attempts at shedding would be by the construction of a leaf of this kind, one of which, in the first instance, would suffice. By its means the threads could be lifted easily, so as to allow of the insertion of the first thread of weft, but more difficulty would be met with in depressing these threads below the level of the unmounted series in order to form a second shed for the next pick of weft. It is just possible that this difficulty may have been the cause of the invention of the vertical loom, in which the heald leaf could be pulled with ease in a horizontal direction on both sides of the warp, whilst the weft could be inserted with equal, if not greater, facility. In the method of working with one series of threads thus mounted, it would be found that they alone would yield to the strain, and bear the wear and tear of the reciprocal action of the shedding process, whilst the unmounted series would show an undesirable degree of slackness. But why not obviate the objection and, at the same time, increase the facility of working by mounting the second series of threads in a separate leaf of heddles, and pulling each leaf an equal distance in opposite directions, by which action the strain would be equalized upon both parts of the warp, and a shed be formed in half the time required with the single leaf? This, when thought of, would be speedily done, and would be found a considerable improvement in both the horizontal and vertical loom, though its advantages would be most strongly manifest in the former. This is what appears to have been done subsequently in Greece or Rome, as is shown in our second illustration from Montfaucon, if we may venture to try to interpret the crude drawings which he transferred to his pages from those of John Justin Ciampini, an Italian writer who died in 1698. Continuing from our last extract Montfaucon says: "Another manuscript of the King's Library, which is a commentary upon the Book of Job, shows us a weaver who works at a stuff (fig. 5). The latter is also working standing. Although this manuscript is of the

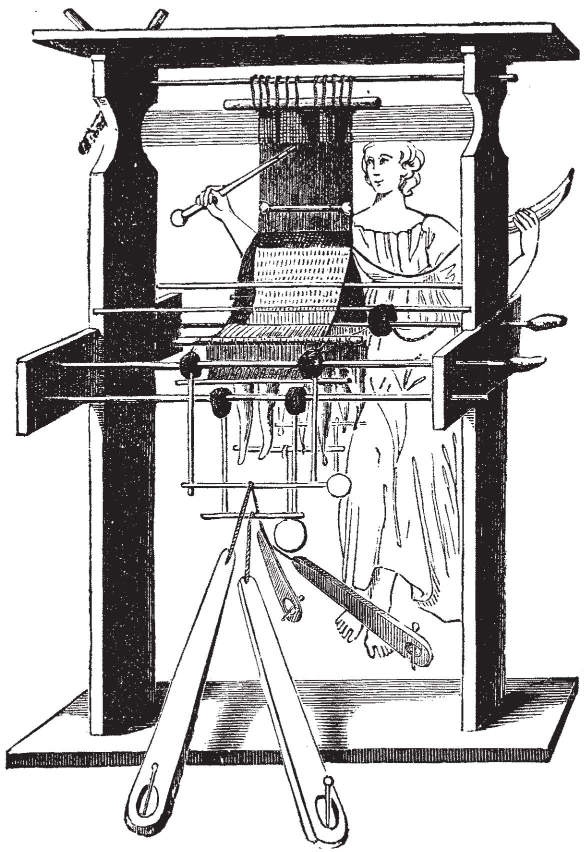


Fig. 5.—Greek Double Loom.

tenth century, the figures in it are drawn from MSS. more ancient: for, as it said in an ancient Commentary,

the oldest specimens of Job had these images depicted, which had been transmitted to the subsequent copies." Such are Montfaucon's observations upon the illustrations in his work of these two looms. Our figure is taken from the pages of Dr. Ure's "Cotton Manufacture," and whilst, generally speaking, it is a good one it has one or two defects. The first is that the figure of the weaver in Montfaucon's work is shown with the left foot upon the treadle just as if about to commence shedding the warp. This brings up the operation much more clearly than as given in this drawing. In the second case, the objects shown as dark balls are really grooved pulleys over which cords pass which are attached to the horizontal heddles. Thus the loom, which appears to be a double one at which two weavers could work at the same time, had its warps shedded by a treadling process assisted by balance or compensation weights that when the weaver removed her foot from the treadle carried the warp back to its proper position. This of course shows a great advance upon our previous illustrations as it brings the feet into action as well as the hands. It must have greatly increased the weaver's capacity of production.

The increasing facility of production arising from the successive improvements here conjecturally outlined would beget a demand for larger fabrics in both lengths and widths than had hitherto been made, or than could be produced in the then existing loom without further modification. Contemporaneous discoveries of, and improvements in, the art of preparing textile fibres, would enable the weaver, when he had supplied himself with the necessary modifications in his loom, to gratify this demand.

The development of the loom frame has already been traced up to a point where it may be regarded as being as large as the requirements of the time and conveniences might be supposed to need it. The domestic establishments of the ancients were not particularly noted for being very spacious, and therefore an enlargement of the frame of the loom, or its extension by any additional projection, would be quite out of the question. One of the bars to which the warp was affixed would therefore be converted into a roller beam and the extra length of warp be wound upon it. This was a simple expedient, but it will be clear that it practically enlarges the narrow limits to the length of a fabric that had existed up to this time very largely indeed. If the warp was thus wound upon a roller at one end of the loom, why should not the woven fabric be wound upon one at the other side, and thus remove another inconvenience? This would be a necessity to get it out of the way of the weaver. Here, then, we have got the warp beam and the cloth beam. In countries where the operation of weaving was carried on out of doors, such as in India, these inventions only came into use at a much later date than in the countries bordering the Mediterranean, to which our remarks apply, and to which all that is known of the early history of weaving specially pertains. In India the weaver planted his simple loom under the shade of a tree (fig. 9), and extended his warp into the distance as far as necessity required. The invention of these beams restored the weaver to his primitive position, that which ultimately became and is now distinguished as the front of the loom. There was, however, as yet, no pacing motion to the warp beam, nor taking-up motion to the cloth beam; these were additions of a much later date. It is probable that the weaver, when he had filled his warp too near the point at which his healds were hung, would go to the back of his loom, roll off the warp, return to the front, and roll the length of woven cloth upon the beam intended for its reception. It will be clear that this arrangement would be inconvenient, and entail much care and trouble before a proper tension could each time again be adjusted. But such as it was, it no doubt endured for a long period before it was further improved. The subsequent illustration (fig. 10) shows both warp and cloth beam and a rude

tension arrangement or pacing motion. It is also shown to be under cover.

Hitherto it will have been observed that no mention has been made of the lathe and the reed. The necessity for the latter had not come to be recognized, and the hooked rod by means of which the weft was inserted combined the functions of both the modern shuttle and the lathe. At this point in the development of the loom the time of separation was approaching. The very early date at which the loom had attained the degree of progress upon which the present remarks are based will be apparent when it is pointed out that it must have been long anterior to the time in which was woven the cloth that modern explorers have discovered swathing Egyptian mummies. Fabrics made by the insertion of short lengths of weft threads would have one, if not both of their edges loose, and consequently liable to ravel off, unless the projecting portions were turned into the next shed, of which, in any of the ancient cloths that have been preserved, there appears no evidence. Neither in any of the mummy cloths, so far as we are aware, are loose edges found. The safe inference from this is, that either the hieroglyphs represent a state of the art existing long anterior to the time when the mummy cloths were woven, or otherwise the weaving of matting from the flags of the river, which might exist alongside of the more advanced form of the art represented by the capability to weave the fine linens with which modern times have been made familiar. The representations of the textile arts amongst the Egyptian hieroglyphs are so few in number and so imperfect in detail, that the latter conjecture is most probably the correct one. The forms portrayed are the simplest ones, such as would invite selection for representation, whilst the more perfect, and consequently the more complex ones, would act rather as deterrents.

It must be remembered that whilst the loom was undergoing the development just sketched, the art of spinning threads from the different fibres was improving in like manner. The possession of a continuous thread would be a great boon to the weaver, not only in the preparation of the warp, but also for use as weft. The rod, which it has been seen, was in use for inserting the weft, would not be adapted for using a continuous thread, and hence the necessity for its modification. It became desirable that the weft carrier should go completely through one open shed and return by the next, continuously repeating its traverse until its cargo of yarn was used. One conspicuous improvement resulting from this method would be the formation of neat, strong, and firm edges that would not ravel off, as by the older plan. These have become in modern times known as selvages, properly self-edges. The passage through each shed of a long rod containing yarn would be found to be a great inconvenience, and the first effort to remedy this would be by shortening it. This would obviate much of the difficulty and accelerate the operation, but would still leave abundant room for further improvement. The load of yarn this germ of the shuttle carried would considerably impede its being passed through the shed, owing to its coming into contact with the threads of the warp, a fact which it would not take long to discover. The provision of a remedy for this would not be easy, and a long time would doubtlessly elapse before it was accomplished. In this rod containing weft yarn will be discovered the germ of the shuttle pirn or cop. The previous use of the long rod for inserting short lengths of weft yarn as picks would have taught these ancient weavers that a smooth piece of wood could with facility be passed between the threads of the warp, but how to get the yarn inside a piece of wood, or enclose it in a sheath of that material, would be the difficulty. It has been assumed all along that the development of the art of weaving, as hitherto traced, occurred in Egypt and the neighbouring countries, though principally in the first-named. An observant

weaver would not therefore have to travel far in order to discover suggestive material for the solution of his difficulty. The art of navigation would have grown sufficiently at the period supposed to be under consideration to have reached to the construction of a rude form of boat for use upon the waters of their famous river. It may safely be assumed also that Egyptian children in the early age would love the flowing waters of the Nile, and delight to play upon its banks, much as English children of to-day love the seashore, and take pleasure in freighting and launching upon the waves their toy-ships. What more likely than that the toy-boat of an Egyptian child first suggested the idea of a shuttle to the swarthy weavers of the Nile valley? At the present day there is a striking likeness, both in form and function, between a boat and a shuttle, and it is well known that there now exists on many of our inland canals a form of boat called a shuttle. The idea once seized upon, the construction would speedily be modified to suit it for its special function. This invention or adaptation would give a wonderful impetus to the weaver's art, because of the manner in which it would expedite production; as, instead of being slowly and with difficulty put through the warp-shed, it could then be rapidly passed from hand to hand. The Greek weaver shown in fig. 5, *ante*, is an illustration of the later Greek loom in which this stage of advancement is shown, the woman represented having the shuttle in one hand and the sword or batten in the other. It is quite possible, however, that in assigning the invention of the shuttle to this early date, and to Egypt at all, the period may have been anticipated, and the honour awarded to the wrong country altogether. Assyriologists of late years have begun to put forward strong claims on the part of Assyria for the honour of precedence over Egypt in the arts of civilization.

This change in the form of the shuttle would induce another important advance. It has been shown that up to that point the function of the batten, lathe, or slay, and the shuttle, had been combined, and that the long rod by which the weft was inserted was used to beat it home. The new form of the shuttle, however, was unsuitable for this purpose, and therefore a rod specially adapted for it was constructed and used instead. The illustration from Montfaucon shows this rod. In some cases a comb, rudely made in the form of the human hand, was used to bring the weft into its position at the fell, after which the spatha, as the rod just mentioned was called, was introduced into the shed to give it the final blow and drive it home. The form of the comb indicates its origin, and points to the early use of the human hand for the same purpose, which has been shown previously. In the comb and the spatha, if the human hand be omitted from consideration, is discoverable the origin of the modern lathe and reed, the functions and actions of which have been conjoined, and have had another added to them, that of preserving the parallelism and equi-distance of the threads of the warp.

Assuming that the development of the loom took place much on the lines here laid down, it will be seen that a point has been arrived at in which there is a sort of rough balance or equality of facility in the performance of the different actions in the process of weaving. The shedding would be done by hand; the shuttle was cast through the warp by the same means; and the weft was driven home by the same instrumentality with the tools just pointed out. The same comparative equipoise existed between the production of yarn and its consumption. It is in positions of this kind that pauses are apt to occur in the rate of improvement. No difficulty conspicuously obstructs the progress of work, and hence ordinary intellects are not stimulated into a manifestation of their skill. The loom might easily continue in this state for ages before any further important advance was made, which would probably result more from the inspiration of a bright mechanical genius, than from the pressure of facts upon ordinary intelligences.

The next step in advance would most likely take place in the horizontal loom, and would consist in an improvement of the shedding appliances, enabling the weaver to operate this part with his feet, instead of hands, as before. This was probably what is still to be seen in the hand-loom of the Hindoo weaver of the present day, merely cords pendant from leaves of heddles with loops at the end, in which the operator inserts his great toes, alternately drawing down one leaf and then the other, whilst the corresponding one rises by which the shed is formed. The facility gained by this improvement would speedily lead to the conviction that the use of the comb and spatha was a slow and cumbrous process of getting the weft into its position in the woven fabric after its insertion by the shuttle. It will easily be seen that an enlargement of the comb, which might be gradual, to the width of the cloth would obviate much loss of time, and expedite the work; whilst the necessity of preventing the entanglement of the warp-threads, and the preservation of their parallel order, would lead to the construction of finer and finer combs, until strips of reed were combined in one frame large enough to reach across the cloth. The use of the enlarged comb would be cumbrous, and its repeated insertion into the warp-threads tedious and slow, until it was found that by pushing it back upon the warp the same purpose would be served, whilst weaving was greatly expedited. The strengthening of the comb by the increase of its weight and length would enable the weaver to drive home or lay the weft in its final position by its means, and thus dispense with the use of the spatha. This would eliminate one operation altogether, and to that extent simplify the process. At first the finest or lightest fabrics would only be dealt with in this manner, but the increased facility of production obtained from this method would soon suggest the strengthening of the reed-frame to fit it for use in the heavier cloths. From this would speedily follow another improvement. The weight of the lay in this form would impede the shedding operations, an impediment to progress that would, in its turn, suggest the suspension of the lay from cords. To make the lay depend from two vertical bars attached to an axle on which it could oscillate easily, was one of the most important advances that had hitherto been made in the construction of the loom. It would probably take some time before it was perfected in its minor details, but these would naturally be added as their want became manifest. This arrangement, shown in fig. 6, would again greatly facilitate production, and in turn would lead to the introduction of the bore-staff for drawing down the warp from the front to preclude the necessity of the weaver's frequent journeys to the back of the loom to unwind it. Here again would be developed another difficulty, which would require further ingenuity to overcome. The draught of the warp from the front would too often leave it slack and unfit for shedding. The frequent interruption of work arising from this arrangement appears to have led, though at what date is not known, to the introduction of a plan to secure a uniform delivery of warp from the beam equal to the requirement of the weaver. This was the pacing motion. The earliest form of this arrangement was the old weight-rope, yet so extensively in use even upon the modern power-loom. This is a rope which passes once, or oftener, round the collar of the beam, and having a weight at one end and a counterweight at the other, or otherwise having the latter attached to a flat spring or to the loom frame. Various modifications of this arrangement took place before it attained the comparative perfection of the present state. In a French work, "Spectacle de la Nature," published in the first half of the last century, and translated and published in English in 1748, a drawing is given of a loom having the pace-weight, which is shown in fig. 7. The drawing is not sufficiently clear to show whether the rope

passes more than once around the collar of the beam, but it is clear enough to show that the action is automatic. A similar appliance is shown upon a velvet-loom, which is also portrayed in the same work.

The development of the loom has now been traced through its various stages up to the point at which it

FIG. 6.—FLEMISH LOOM ABOUT 1560.

remained until the new epoch of invention dawned upon the world. This has been done in order to show that, simple as its primitive form may appear to weavers in these days, there was really much more inventive skill and ingenuity required and expended in its invention and construction than appear on the surface. The sketch, though mostly hypothetical, is not without historic support, as the brief references to the processes of weaving, and the implements used in the industry, that have been given from ancient writers, conclusively show. It will

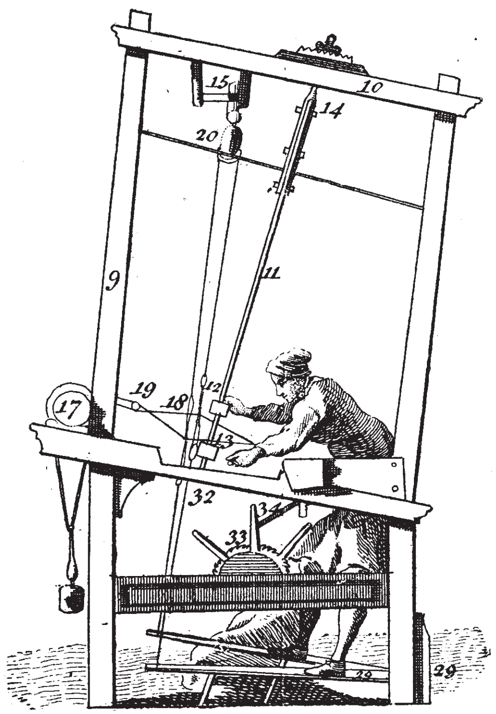


FIG. 7.—FRENCH LOOM, SIDE VIEW; ABOUT 1740.

be useful, therefore, to summarize the progress made, which can probably best be done by portraying the loom as it existed in the sixteenth and seventeenth centuries, and at the early part of the eighteenth, previous to

the invention of Kay's important improvements. Our illustrations are drawn from various sources. The first, fig. 6, is a simple loom, and the figure is taken from Schopfer's "Panoplia," published at Frankfort-on-the-Main in 1568. It needs no detailed description. The next two illustrations, figs. 7 and 8, represent a more advanced loom. They are taken from the French work just mentioned. They represent a side and front view

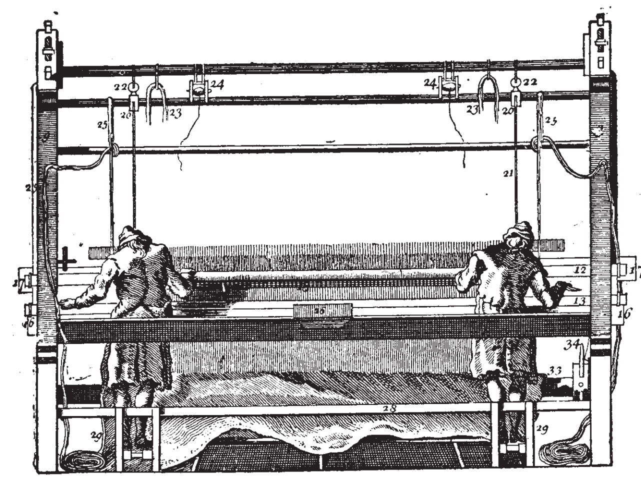


FIG. 8.—FRENCH LOOM; FRONT VIEW.

of a wide loom, which requires two weavers to work it. The frame consists of inclined posts, 9, and cross-pieces, 10. The batten, or lathe, depends from the top cross-bars, where it is carried upon a serrated bearing, by which it can be adjusted within a given range forward or backward, according to the requirements of the weaver, or of the fabric on which he is engaged. The lathe, it will be observed, is composed of its two uprights, 11, carrying its two blocks, 12, 13, for the reception of the reed, the lower one not being furnished with the projection now called the shuttle-race, whilst the top one forms the cap, as in the power-loom of to-day. By means of the cross-piece, 14, the height of the lathe can be adjusted as required. The two leaves of heddles, 18, are suspended on cords, which pass over small pulleys depending from a piece of wood called "the gallows," 15. The breast-beam, 16, is a large block of wood with an aperture in it, through which the cloth passes to the beam or roller, 33, beneath the loom. The warp-beam, 17, it will be observed, has no spike, but rests in its bearing upon its collar. The great amount of friction surface thus obtained dispenses with the necessity of heavily weighting the beam for pacing purposes, this being accomplished by the small weight sliding upon the rope in a manner remarkable in this day of multifarious warp delivery arrangements. In the treading motion it will be seen that the treadles, 29, have their fulcrum at the front of the loom, instead of at the back, as generally obtained in a later form of the hand-loom. The weaver throws the shuttle from hand to hand. The cloth was templed by the old hand temple, 31, composed of two flat bars of wood, having pins at their extremity to enter the selvages. This temple could be shortened or extended, according to requirement. It will be admitted that the loom, as here shown, is a very simple thing indeed, and that it should have taken thousands of years to arrive at this stage of its development implies the existence of a remarkably low degree of the inventive faculty and of mechanical skill amongst the peoples of the various nations to whose comfort the art of weaving had ministered.

It is a remarkable fact, however, and one which forcibly illustrates the strength of the conservative sentiments of mankind, that in this age of mechanical invention, when the loom has been brought to a point of perfection beyond which it is difficult to conceive of its being carried much further, it should yet be found, as here pourtrayed, even

in this country. Five or six years ago the writer, whilst on a visit to South Wales, went to see the picturesque ruins of Caerphili Castle, in Glamorganshire. Leaned against an outer fortification he found a small woollen mill, and, curious to see how the processes of manufacture were carried on there, went inside, and was greatly astonished to find several weavers at work on such primitive looms as here depicted, even to throwing the shuttle from hand to hand. A pleasant chat with these old-time weavers, probably lineal descendants of the Flemish weavers planted in South Wales by Edward III., elicited the information that there were still a considerable number of such looms working in the locality around, and in Newtown and districts in Montgomeryshire.

Perhaps it may be desirable, for the sake of technical students, at this point to give a few illustrations of the loom as it is found to-day amongst Eastern peoples and semi-civilized races, where the art of weaving yet exists in a very primitive form. Of Eastern peoples those of India claim the first notice, chiefly from the early development and the high degree of excellence the art of weaving attained amongst them, the latter of which was due more to the exquisite manual skill of the workers than to the quality of their appliances. So far as can be discovered the Indian loom has undergone very little improvement in the course of many centuries. As it now exists it is probably as ancient as the single-thread spinning wheel of the same country. The illustrations (figs. 9 and 10) will show that it is constructed upon the same principles, and embodies nearly the same parts, as those of the European hand-loom, the development of which has just been attempted to be traced. The slight frame consists of two or four upright posts consisting of bamboo canes, with similar canes extending along the sides at the top, whilst, from a cross-bar between the two sides, the healds are suspended. A similar bar at the back in some instances forms the warp beam, whilst in others the warp is extended its whole length. The cloth beam has in it a groove, into which a strip of bamboo, passed through the looped end of the warp,

FIG. 9.—INDIAN OUT-DOOR LOOM.

is fixed, and thus secured in the groove, precisely as in the English hand-loom, and also as in its successor, the cloth beam of the modern power-loom. The cloth is wound

upon the beam by means of a winch or ratchet-wheel, as in the loom just mentioned. The healds are treadled from beneath by the weaver inserting his great toe in

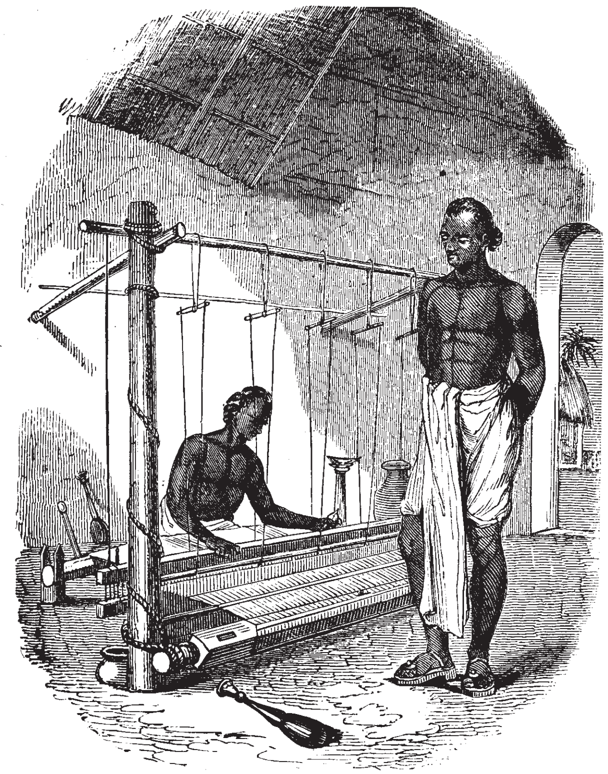


FIG. 10.—INDOOR INDIAN WEAVER.

pendant loops hanging from them. The lay is grooved both in its cap and bottom for the reception of the reed, exactly according to the most modern practice, and the range of its action is controlled by a very simple appliance.

The shuttle bears a great similarity to the English shuttle, though it is somewhat longer and flatter. It is composed of the wood of the betel-nut tree, and is tipped with iron. The eyelet for the passage of the weft is at the side. The cloth is "templed" as in the old manner in this country, the temples consisting of two bars of wood arranged partially parallel, and having pins upon their extremities which are inserted into the edges of the cloth, which is then extended by the rods being pressed down upon it.

In many cases the Indian weaver digs a pit or hole, over which the warp is extended. To weavers in this country the purpose of this pit is not quite obvious, but in the hot climate of India it was of great utility. Its use was, and is now, to secure a degree of humidity for the warp by keeping a well of cool moist air beneath it, the moisture being obtained by the tendency of water to drain into the excavation. In Eastern lands, where the "sizing" was very light, the finer cotton yarns could not have been woven without some such provision during the hot season. Those who remember hand-loom weaving in the cotton trade in this country will know that clay floors in the weaving shops and cellars were very common if not universal, and that in these there was very generally a "treadle hole," into which it was a common practice for the weaver to pour water, especially in summer. Possibly this was a reflection of the system pursued in India, from which it might have been imported when the cotton manufacture of this country was in its infancy. The natural humidity of our atmosphere, however, rendered this provision a superfluous one except on rare occasions, or where the weaving apartments were exceptionally dry.

In the Dutch possessions of Sumatra, Java, and their other provinces, a still ruder form of the loom is used, as was shown at the Amsterdam Exhibition, 1883. This loom consists simply of two bifurcated posts, like a musical pitch-fork in form, which are stuck into the elevated floor

of their dwelling, the open ends uppermost. Into these the beam is inserted, the gears are attached to a post above, and the warp extended by means of a cord passing around the body of the weaver, who follows her occupation with more facility than could be expected from her simple appliances.

In Japan an almost identical loom and method of

FIG. 11.—A JAPANESE WEAVER.

weaving is in use, as may be seen from the accompanyiny illustration (fig. 11). Passing from Japan to the still more distant Salomon Islands, off the coast of New Guinea, there is found a very crude form of loom used by the natives in making grass cloths. It is shown in fig. 12. A portion of woven cloth is shown at A. This specimen was obtained from Santa Cruz, one of the group of islands. For the use of this and the preceding illustration, which are from the "Voyage of the Nyanza," a work by Captain J. Cumming Dewar, published last year, we are indebted to Messrs. Blackwood and Sons, publishers.

The succeeding illustration, fig. 13, is reduced from a drawing in Du Chaillu's book, " A Journey to Ashango Land."

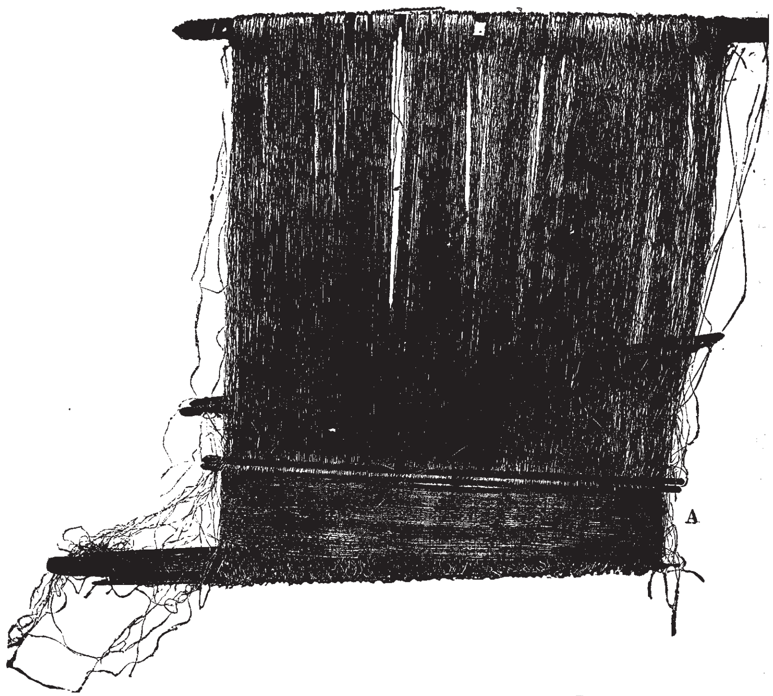


FIG. 12.—LOOM FROM THE SALOMON ISLANDS.

It represents an Ishogo weaver at work making a cloth from the fibres of the palm leaf, which are prepared by the natives with considerable skill, woven into a cloth on the very rude vertical loom shown in the drawing. " In walking down the main street of Mokenga," says the traveller,

" a number of oundjas are seen, each containing four or five looms, with the weavers seated before them weaving the cloth. In the middle of the floor a wood fire is seen burning, and the weavers are sure to be smoking their

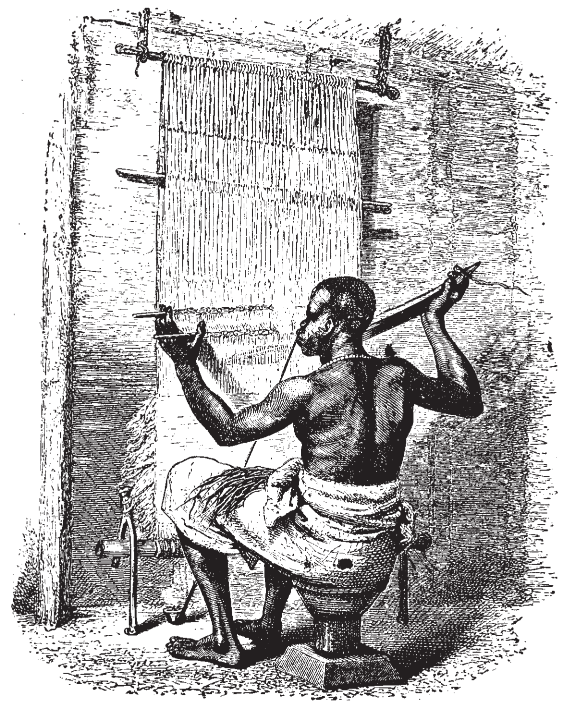


FIG. 13.—AN ISHOGO WEAVER; ASHANGO LAND, WEST AFRICA.

pipes and chatting to one another whilst going on with their work. They are all men, and it is the men who stitch the bongos or pieces of cloth together to make robes of them." This cloth is sometimes striped, or even checked, these effects being obtained by means analogous to those employed by ourselves. The "oundjas," it may be observed, are the workshops of the natives, consisting simply of a roof on posts. They are without walls.

This illustration strikingly elucidates the process of working the Santa Cruz loom, and though derived from lands many thousands of miles apart, the looms are practically identical. The weaver, it will be seen, sits with a supply of grass weft upon his knees, from which to refill his shuttle when exhausted. To those readers to whom Manchester is accessible, we would observe that a loom of the same kind as these obtained from New Caledonia, which is not far from the Salomon Islands, can be inspected at the rooms of the Manchester Geographical Society, 44, Brown Street, Manchester.

It would not be a difficult matter to adduce illustrations to such an extent as to show that the historical development of the loom, as in the preceding pages it has been endeavoured to be traced, could be paralleled on geographical lines: that is, that all the phases through which the loom has passed from its inception to its present degree of perfection, can be found existing to-day, and employed for industrial purposes.

Returning from this digression, the last two advances made in the hand-loom may be noted. At the beginning of the eighteenth century the productive capacity of the spinner and the weaver were in a state of equilibrium: the latter easily consumed what the former produced without the first being overburdened with stocks or the second having to wait for supplies of yarn. But a disturbing element had been introduced into the political, commercial, and industrial relations of England, that began then, and has continued ever since, to exercise the most important influence upon its fortunes and destiny—an influence, of the disappearance of which no sign as yet is visible. This was the foundation of the East India Company during the reign of Queen Elizabeth, and the establishment of numerous commercial factories, and the growth of trade between that country and England. The introduction of Indian cotton fabrics led to a demand which steadily grew, until it had attained such an extent as seriously to alarm those engaged in the textile industries, the dissatisfaction being most concentrated at Norwich, the principal centre of the weaving industries at that time. In 1700 printed calicoes were prohibited by statute from being introduced or worn in the country, but this proved of little avail, as eight years later we find De Foe, in the "Weekly Review," deploring the growing popularity of cotton goods, asserting that it had practically ruined half of the woollen industry of the country. The demand continued to extend, though numerous impediments were placed in the way of its gratification. Weavers also endeavoured to compete with the Indian fabrics by making light goods in both wool, flax, and unions of these materials. The use of cotton was hated so much as to be prohibited in mixed goods. These fine light fabrics could not be woven with the same facility as the rough, coarse, and heavy goods that had been displaced; hence there existed a large and growing demand, that was bound, in the then condition of the industry, to remain ungratified. This may be regarded as the stimulus that led to the next step in the development of the loom—the invention of the fly-shuttle by John Kay, a native of Bury, in Lancashire. Kay was the son of a woollen manufacturer of that town, who had also an establishment at Colchester. After being brought up to the trade in Lancashire, young Kay, who had shown considerable mechanical ingenuity, was sent to the southern town, to take charge of his father's business, and it was while residing there that he determined to accelerate the weaving process, which he accomplished by the invention of his system of throwing the shuttle, and on which his reputation is founded. This important improvement, where adopted, at once quadrupled the power of the weaver, whilst it obviated the necessity of employing two weavers upon wide looms, thus setting a large number at liberty to operate looms for themselves. The invention consisted in the addition to the ends of the batten or lathe of two boxes, for the reception of the shuttle in place of the weaver's hands, previously held out to receive it. In each of these boxes a spindle extending their length was fitted, termed the fly-spindle, and each carried a shuttle-driver, or "picker," as they were technically termed. Between these a cord was extended and attached to each, and affixed to this cord, in the centre of its length, was the peg, or "picking-stick," as it is usually called in Lancashire, by means of which the shuttle was jerked from one box to the other through the open shed of the warp. This constituted Kay's great invention; and simple though it may now appear, few have equalled it in the important consequences that have flowed from it.

The details of a common fly-shuttle loom are shown in fig. 14, which is from Dr. Ure's "Cotton Manufacture of Great Britain." The warp beam, with the warp upon it, is shown at A; the lease rods ought to have been seen at B, but the artist has failed to depict them; the two leaves of heddles are shown at C and D; the reed is carried in the lathe, forming the cross-bar carried by the vertical supports, E, the whole swinging upon the cross-bar, F; G is the weaver's seat, often called "the sitting-tree;" sitting upon which, with his feet he operates the treadles, H, alternately pressing down one and then the other, whilst between each movement he projects the shuttle through the open warp, and then pulls the lathe towards him to bring home the last pick to the fell of the cloth, that is, the pick last laid.

The invention of the fly-shuttle was the initial step of the great industrial revolution constituted by the change from the manual to the mechanical systems of labour, which has been in steady progress through, and will for ever in the pages of history distinguish, the eighteenth and nineteenth centuries from all those that have gone

before, and probably from all that will follow after. It is not intended to place limits to the conquests of the human mind, but it is more likely than not that the chief victories that are to follow will be won in other than mechanical fields.

The balance that had hitherto existed between the spinning and weaving branches was now rudely disturbed. This will be evident when it is stated that in the woollen

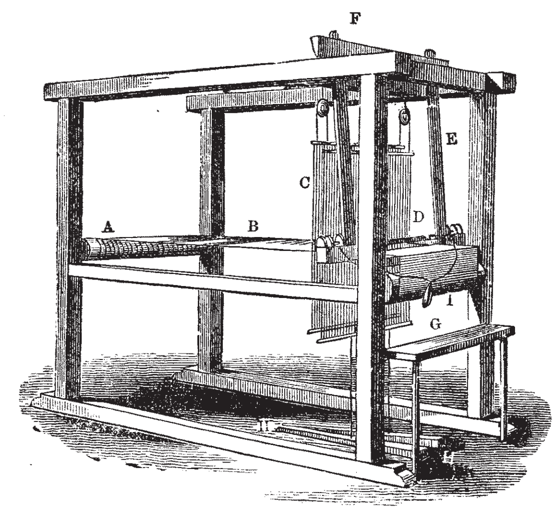


FIG. 14.—KAY'S FLYSHUTTLE LOOM

trade at this time one weaver required, in the other sections of the industry, to prepare for and finish after him, the services of twelve other persons. It may be interesting and instructive to give here a statement from the "case" of a Norwich weaver against Manchester calicoes, published about 1720, and quoted in Mr. Alfred Barlow's "History of Weaving," from which it is extracted. In relation to the rest the weavers, it appears, stood as follows:—

Weavers	100
Wool sorters	4
Pickers	10
Combers	20
Spinners	900
Throwers	4
Twiners of the throwing mill	4
Thread makers	4
Doublers	50
Bobbin winders	12
Back-throw winders	12
Quill boys	50
Warpers	5
Dyers	6
Pressers	6
Total	1,187

Thus it will be seen that an invention like that of John Kay, which quadrupled the capacity of the weaver, and largely increased their numbers by liberating one from every broad loom to weave for him or herself, radically altered the conditions of the industry. The change, however, was not instantaneous, as Kay's invention met with great opposition amongst the weavers of Colchester, where it was first introduced. Kay brought the invention northwards to Lancashire, his native county, where it met with a more favourable reception, and was speedily carried across the borders into Yorkshire, and generally adopted. It is not necessary to inquire further into its effects, or into the manner in which its inventor was defrauded of the reward that was his due. Kay had considerable mechanical ability, as is well proved by his numerous other inventions, and this ability was inherited by his son.

No further development of the hand-loom is heard of until John Kay's son Robert invented the drop-box in 1760. This invention consisted of an arrangement of

several shuttle-boxes at one or both ends of the lathe, whereby the weaver is enabled to introduce with facility into his fabric several colours or counts of yarns, by which the cloth was striped across its length. When the warp was striped in a corresponding manner a checked effect was obtained. The apparatus is shown in the illustration, fig. 15. The cross-bar, A, is sustained upon iron gudgeons on the loom frame, which is shown in section. From this bar the lathe depends by means of its swords, B B. The lathe beam, C, carries the reed. The shuttle-boxes, D D, are shown suspended in their respective frames. The

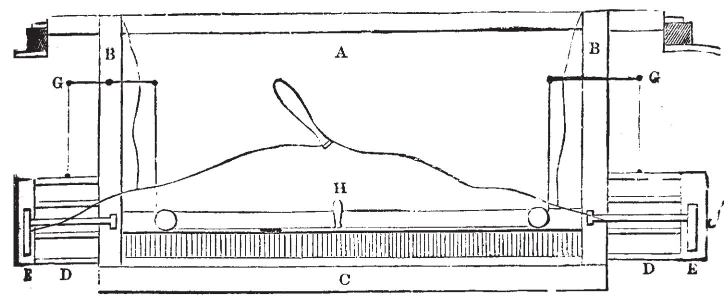


FIG. 15.—ROBERT KAY'S DROP-BOX ARRANGEMENT, 1760.

fly-spindles, each carrying its respective picker, with the picking-cords attached, have the latter rudely delineated at E E. The horizontal levers, G G, moving upon their centres upon the lathe-swords, B B, are connected with the boxes by the means shown, the latter being actuated by the weaver pushing the pin, H, to the right or left upon the lathe-cap or bar, by which action the levers, G G, through their connections, bring any required box opposite the shuttle-race, ready to deliver any shuttle it may contain, or if empty, to receive any that may be directed to it. This may be regarded as the last considerable improvement made in the hand-loom, and it was fit that it should have been accomplished by the son of the man whose inventive genius first gave to the world a fore-gleam of the possibilities of mechanical industry.

This practically closes the chapter of the hand-loom's history. It will be observed that up to this time there was hardly any thought of the loom being made to supersede the operations of the weaver. Nearly all that had been sought, or even conceived, was to facilitate his actions in the labour of weaving. To make the machine imitate and perform these actions equally well, or even better, had not entered into the mind of more than two or three men at the most, so far as appears from any record that remains. But the time was drawing near when the conception was not only to arise, but to be realized by the person to whom the thought occurred. The story of its inception and development will form the subject of the next chapter.

CHAPTER III.

The Power-Loom and its Development.

Poverty of early mechanical science; late development of man's inventive faculty.—The equilibrium in the productive capacity of the spindle and the loom at the commencement of the eighteenth century; deranged by John Kay's invention.—The position reversed by Hargreaves' and Arkwright's inventions.—M. de Gennes' and Vaucanson's automatic looms; failure of both; unfavourable circumstances.—The Barbour Brothers' improved hand-loom.—Cartwright at Cromford propounds the idea of the automatic or power loom.—Endeavours to realise it; his first attempt and failure.—Examines hand-loom weaving and begins anew.—His second attempt, and its wonderful approximation to success; attempting too much the cause of his failure.—Description of his loom.—His subsequent improvements.—Further developments of the loom.—Clark's improved slay.—Gorton's over-pick.—Miller's wiper loom.—Johnson's dressing frame.—John Todd's improvements.—William Horrocks' improvements.—His dandy loom.—Further improvements and alterations by various succeeding inventors.—Richard Roberts and his important inventions and improvements in the loom.—Full description of Roberts' loom.—Automatic stop-motions for warp and weft threads.—William Dickinson's Blackburn loom.—His improvement of the picking motion.—Inventors upon false tracks.—The draught and pacing motions.—Smith's scroll pick.—Kenworthy and Bullough, the Blackburn inventors.—The automatic weft slop-motion; Ramsbottom and Holt's double vertical loom.—James Bullough's double horizontal loom.—Parkinson's disc temple.—James Bullough's improved weft-fork arrangement, and trough and roller temple; description.—Clinton G. Gilroy's claim to the former examined.—The power-loom in principle now a perfect automaton, and an economical success.—Its further improvement by a multitude of inventors.

LOOKED at from the present advanced position of textile mechanics, attained after a century of unparalleled inventive efforts, the slow and halting steps made by mechanical science in the many centuries comprehended in the previous review would justify the conclusion that the inventive faculty of man's nature constitutes a recent development of his intellectual powers, equivalent to the acquisition of a new sense. Even yet the capability is almost confined to two or three European peoples and their descendants in other lands. The great results achieved by these nations have had little or no effect in stimulating the manifestation of the faculty amongst other communities. The skill of Eastern races seems to have spent itself in achieving the most perfect results of which manual processes are capable. The products of Indian, Chinese, and Japanese arts, especially in textiles, in excellence of colouring, variety, beauty of design, and perfection of execution, are something that the mechanical productions of the West are a long way from equalling, but to which they may with advantage aspire. These are thoughts that would lead to some interesting speculations if followed, but such a divergence would be out of place in the present essay, and the temptation therefore must be resisted.

The reader will recall the fact stated in the preceding chapter, namely, that a condition of practical equilibrium existed between the various sections of the textile industries at the close of the seventeenth and the beginning of the eighteenth centuries: that is, the productive power of spinners in supplying yarn was about equal to the capacity of the weavers to consume it. The conjoint labours of the two, however, were unequal to meet the growing demand of the people for finer and better textiles, which began to be supplied from India. The imports from this source were, however, interfered with by legislative enactments, which were passed at the instance of manufacturers. Kay's invention of the fly-shuttle increased the disorder arising from the growing competition of India, and its extended adoption intensified the disorganization to such an extent that one of the most pressing

wants of the time was the weaver's want of weft. The details of this phase of the history of the cotton trade, and the efforts of invention to overcome these difficulties, and which ultimated in the brilliant success of Hargreaves of Blackburn, Arkwright of Preston, and Crompton of Bolton, are given in the writer's former work "Cotton Spinning: its Development, Principles, and Practice," to which the reader who may be interested therein is referred.

The extending adoption of Hargreaves' jenny in the homes of the spinners and weavers; the successful establishment of Arkwright's spinning mills at Cromford, Masson, and other places; and of those of other people in various parts of the country, in which the machinery of the great inventor was worked under a royalty, led to a well-founded apprehension that from a great scarcity of yarn the country was passing to a state of superabundance, that would be even more disadvantageous than the previous deficiency. This idea became in a few minds the parent of another, that the loom ought to be improved; and recent researches into the story of its mechanical development have led to the discovery of several attempts to carry into effect the vague conceptions that, with more or less distinctness, had thus grown up. These must be noticed very briefly.

It is somewhat singular that the first attempt to make an automatic loom yet discovered occurred half a century before Kay invented his fly-shuttle. It appears to have been made by one M. de Gennes, an officer of the French navy, who presented the machine embodying his conception to the Royal Academy of Paris, in 1678, and a description, with an illustration, was published in No. XXXII. of the "Journal des Sçavans" in that city in the same year. It was termed a new machine for making linen cloth without the aid of a workman. Those who may be desirous of learning more of it will find an illustration in the Introduction to the "Abridgements of Specifications for Weaving," Part I. (1620-1859). It is very interesting, and to the student well worth perusal. This germ, however, perished, leaving no influence behind.

The next attempt which has been brought to light was also of French origin, and was made by Vaucanson in 1745. His loom contained the rudiments of the celebrated invention of Jacquard, and also of the friction roller taking-up motion still universally in use. It is curious to observe that both this and the former invention of De Gennes had a shuttle motion, consisting of levers having sockets at their extremities, which passed the shuttle alternately from one to the other through the open shed of the warp. This, on the part of both inventors, was clearly an attempt to imitate the action of the earliest weavers and the function of their hands in passing the shuttle through the shed of the warp. But later weavers threw their shuttles from hand to hand: these levers, if the expression may be permitted, handed the shuttle alternately from one to the other. It will be obvious that the best speed that could possibly be attained would be less than that of the ordinary weaver even of that time. It may be remarked, in passing, that the present writer saw a loom constructed on this plan in the Paris Exhibition of 1878, made by a Swiss machinist. It could hardly have been intended to be more than a mechanical curiosity. Kay's plan of throwing the shuttle had been invented twelve years, but had evidently not come under the notice of Vaucanson, otherwise, as Mr. Alfred Barlow in his "History of Weaving" remarks, "he might have adopted it, and had he done so the power-loom might have made its way half a century earlier than it did." The result in this case was the same as in the preceding one.

At the time under notice, however, there was no strong motive to increase the capability of the weaver, and had any ingenious inventor succeeded at this time in making an automatic loom of a capacity exceeding that of the hand-loom, it would have had small chance of being adopted, as

already the power of the spinner to supply weft was being left in the rear of the weaver's capacity to consume it, owing to the extending use, by the latter, of Kay's invention But the time was drawing near when all this was to change. In 1764 Hargreaves achieved his grand success in the invention of the spinning-jenny, and Arkwright quickly followed in his steps. A few years served to revolutionize conditions, and yarns from being very scarce became relatively abundant. It was this which gave rise to the impression referred to above. The first outcome of the idea was the attempt of "Robert and Thomas Barber, of Billborough, Nottingham, gentlemen," who, in 1774, took out a patent, No. 1,083, for machinery for preparing, spinning, and weaving fibrous substances, &c Mr. Barlow, in the "History of Weaving" before referred to, p. 231 gives both details and illustration, to which the reader is referred. This loom was wonderfully near being a solution of the problem conceived, and had its inventors possessed the persistency of purpose of Dr. Cartwright, there can be little doubt that their success would have been assured, as their device was a much better and more practicable one than the first effort of the clergyman's. Nothing, however, so far as can now be learned, was heard of it further.

These were the droppings, of no significance to blind eyes, preliminary to the showers of the inventive faculty that were about to fall upon the world, and which were abundant and full of meaning and promise for the highest interests of mankind.

The sentiment of which we have just spoken had in no sense been allayed when, in 1784, a party of gentlemen are stated to have met at the dinner table of an hotel at Matlock Bath, closely adjacent to Cromford, the seat of Sir Richard Arkwright's mills, who engaged in a discussion of the prospects of the then infant cotton trade; and, as has oftentimes been done since, debated the consequences that would ensue from the over-production of yarns that was held to be likely to arise from the then existing numbers and prospective increase of the newly invented machines. It was in this discussion that the brilliant idea was expressed that if we made machines to spin yarn we must make machines to weave it. This grand conception was put forth by the Rev. Dr. Cartwright, a clergyman of the Church of England. The company which was thus engaged in conversation included several gentlemen from Manchester, who might fairly be esteemed to be capable judges of the subject. These declared the idea to be quite impracticable, owing to the number and complexity of the movements of a weaver when at work. The rev. gentleman, however, strongly argued in favour of its possibility, and in proof of the position he had taken up, adduced in illustration and instance the automaton chess player, which was about that time attracting much attention in London. Of the effect of his arguments upon his hearers the records tell us nothing, but it is certain that he convinced himself not only of its practicability, but of the great desirability of its being done; and, greatest conviction of all, that he was the man to do it. Had the worthy doctor done nothing more than broach this magnificent idea he would have deserved to he held in grateful remembrance; but as he at once proceeded to carry it into effect his deserts in this respect are all the greater.

Dr. Cartwright returned home, and immediately set about the realization of his novel scheme: novel it may truly be called, because it has nowhere been alleged, nor is there any reason to believe, that either he or any members of the company before whom he projected it had ever heard, in any manner, of the attempts made by the persons whose names have been given before. As he himself subsequently confessed, he knew nothing whatever of weaving, never even having seen a weaver at work. Of the stages of his progress no record is left, but after a few months' struggle he had brought his thought so near to realiza-

tion that he took out a patent in order to secure the large profits he anticipated would accrue from the invention. This was in April, 1785. It is worth while to describe this first device, notwithstanding its crudeness, being, as it was, the parent of the large number that has followed it on the same subject. The illustration, fig. 16, and the

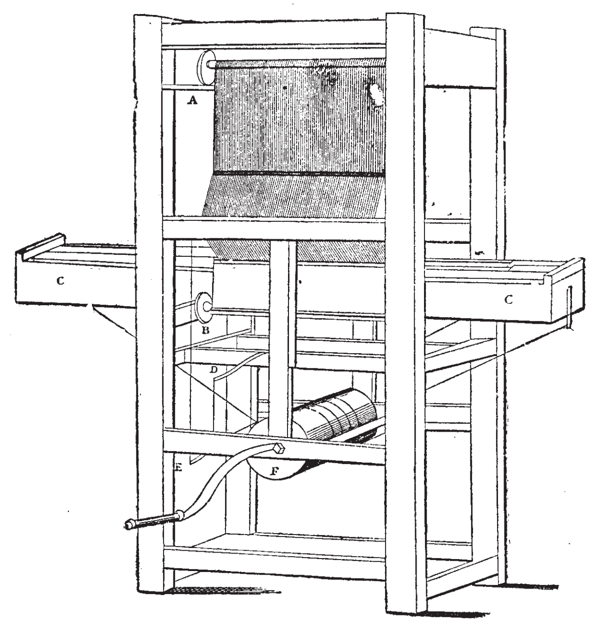


Fig. 16.—Cartwright's First Power Loom, 1785.

details are from the patent specification, wherein it is thus described by the patentee:—

"It is worked by a mechanical force. The warp, instead of lying horizontally, as in the common looms, is in this machine (which may be made to hold any number of webs at pleasure) placed perpendicularly. The shuttle, instead of being thrown by hand, is thrown either by a spring, the vibration of a pendulum, the stroke of a hammer, or by the application of one of the mechanical powers, according to the nature of the work and the distance the shuttle is required to be thrown; and, lastly, the web winds up gradually as it is woven.

'A is the warp beam; B the cloth beam; C C the boxes containing the springs that throw the shuttles; D is a lever, having a corresponding one on the opposite side for elevating the reed or comb; E a lever, having a corresponding one on the opposite side for reversing the threads; F the cylinder which gives motion to the levers. N.B. The warp is kept to a due degree of tension by the counteraction of either a weight or spring. The web is made to wind by a like power, though in an inferior degree, and is prevented, as the stroke of the reed or comb brings it down, from unwinding by a ratch-wheel and click."

It is curious to observe that this is a vertical loom The reverend gentleman's ignorance of the art of weaving, and the appliances common in the industry, from a contemplation of the nebulous result of his first effort, will be very obvious to all modern readers. When he had, as he thought, completed his task, he condescended to see how other people wove. He went to watch some hand-loom weavers at work, and was surprised to find how easily and with what little expenditure of energy they performed their task. His loom could only be worked by two strong men, and that for only a short time at once. His lathe for beating up the weft fell with a weight many times greater than necessary, and with such force as must tear all his warps to pieces. It was an instructive lesson, and was not lost upon him. He returned home with more knowledge and wisdom, and resolutely set himself to devise a fresh solution of the problem.

In his new design Dr. Cartwright adopted the common wood frame of the hand-loom, and with it the horizontal arrangement of the warp. In doing this he acted wisely,

because the general prevalence of this form of the loom, which was the outcome of the experience of nearly all ages and countries, was an incontestible demonstration that it was the best. But he did, or at least attempted, much more than this. A study of the art of weaving, as he saw it practised, revealed to him many details, of which he was before entirely ignorant. It is curious to contrast the enlarged and comprehensive conception of his task, as exhibited in the ample and widely different details of his second specification, with the meagre and crude notions embodied in his first. In the latter he overshoots the mark quite as much as before he fell short.

In the domestic form of the industry the weaver performed many tasks for himself that, with its advancing improvement, have successively been detached from his charge and have become separate pursuits. Some of these may be mentioned, as warping, beaming, and sizing; all these processes, besides the movements incident to weaving merely, Cartwright attempted to combine and perform in his automatic loom. And when it is added that he included a positive taking-up motion for the cloth and letting-off motion for the warp, and also a broken-weft stopping motion, and a broken-warp-thread stopping motion, the reader will conclude that he attempted too much, and no wonder will be felt that he failed. As it is on his foundation that the wonderfully perfect automatic loom of the present day is built, it will be interesting to the student to examine the embodiment of the inventor's idea in some detail, means for which is afforded in the annexed illustration, fig. 17, which is a reduction of the drawings accompanying his specification of October 30th, 1786. We may premise that the drawing is crude and imperfect, showing a want of skill in mechanical drawing. The view given is, however, accompanied by a number of drawings of details, but the task of combining them in one machine must have been very difficult. The language in which the specification is drawn is as crude and incomprehensible as the drawings,

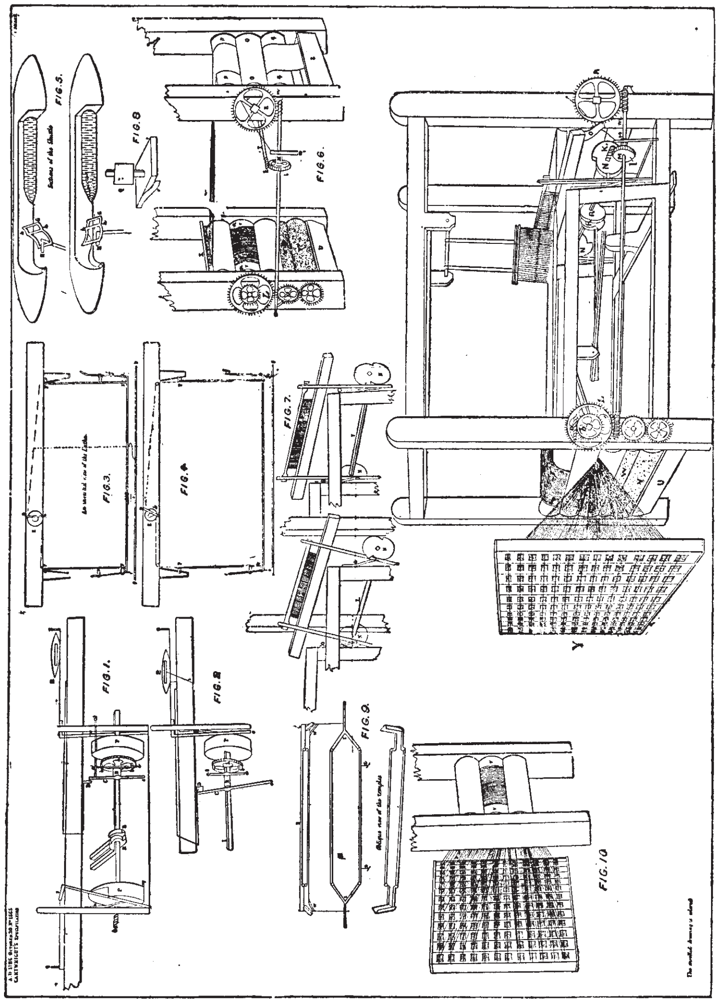


FIG. 17.—CARTWRIGHT'S SECOND LOOM AND DETAILS, 1786.

and would need the expenditure of much more time and patience than the average reader would be likely to give to get approximately near its meaning. This being the case, the writer prefers to submit a paraphrase of it, which he hopes will remove most of the obscurity in which Dr. Cartwright's meaning was hidden, whether intentionally or otherwise it is not necessary to inquire.

It will be observed that the inventor has adopted the ordinary hand-loom frame. Instead of the common single beam for the warp, he has substituted a yarn bobbin frame, from which the cloth can be woven, he says, "without the trouble of winding, warping, or beaming." It will be remembered that it was customary for the hand-loom weaver to size or "dress" his warp in the loom in lengths from near the healds to the warp beam. This practice the learned doctor endeavoured to obviate by inventing the automatic arrangement shown in the illustration, which consists of a trough extending across the loom at the back to contain the sizing mixture, which it may safely be presumed was of much lighter consistency than that now ordinarily used. The first dotted cylinder above the trough represents a brush working in the size mixture, and conveying it in the course of its revolution to a second brush next above it and similarly delineated, which in turn gives it to the roller above, while the latter conveys it to the warp in its passage. The first-named roller may be called the sizing roller, and the top one the compression roller. Passing between these two the warp returns over the latter and passes upward over the carrier beam and onward to the healds. Over the top of the carrier beam a flat dry brush was arranged for working the "dressing composition into the yarn, and laying the filaments of it smooth," but this is not shown in the illustration. The latter is also defective in not showing the taking-up arrangement, given in one of the detail drawings, which consists of three "cylinders" or rollers placed one above the other, the middle one acting as the motor. The cloth as woven passed over the first, around the second, coming back between the latter and the third, and instead of being wound upon the last-mentioned was delivered into a box or trough beneath.

We now come to the mechanism of this remarkable loom. The "slay" or lathe, instead of depending from the upper cross rails of the frame, as in the ordinary hand-loom, has this arrangement reversed, and oscillates upon two standards or primitive "swords," and, it may be presumed, a rocking-rail at the bottom. This arrangement was necessary in order to actuate it conveniently. The main or first shaft crosses the frame in front of the lathe, and carries the two cams which operate it, also the two cams that actuate the under-pick picking-sticks, and in the middle the tappets for shedding. All these are in one way or another eccentric. The shedding tappets and the lathe cams are shown in the illustration, but those working the picking arrangement are left out, it apparently having been beyond the skill of the artist to show one cam behind another. The shuttle was projected through the shed by springs compressed into position by the revolving cams, and acting upon the picking-rods, when released from the detent of the cam. The picking, shedding, and the actuation of the slay being all performed from the first, and indeed the only shaft, for there is no shaft in the loom analogous to the second shaft of the modern loom, it will be obvious that the cams employed needed to be of a very peculiar construction, and, as shown, may be termed double eccentrics. It will be clear also that the movements that could be obtained from such arrangements would at the best be unsuitable for the purpose, as they must have been hard, harsh, and to use the next word in its strictly literal sense, shocking. There could be nothing in it of the easy gliding from one position and one movement to another, so necessary to the preservation of the yarn and the durability of the machine, and which is so characteristic of the almost perfect loom of to-day.

Keeping to the details shown in the illustration, the next movements calling for notice are the taking-up and letting-off motions. These are both of the positive order, and are directly connected. It will be observed that on the extremity of the first shaft there is a projection, carrying a worm gearing into a wheel upon a cross shaft, which extends from the front to the back of the loom frame on the outside. On each extremity of this shaft is a worm, that on the front gearing into a wheel on the taking-up roller, and that at the back into a wheel on the warp delivery roller, and also operating through a pair of wheels the two sizing-brush rollers. By changing the sizes of one or both of the two first-mentioned wheels the inventor altered and regulated the number of picks he put into his cloth. It hardly needs pointing out to any one familiar with the loom that he would experience a considerable amount of difficulty in doing this to his satisfaction by such appliances. It may be also observed that it was, probably, owing to Dr. Cartwright's unfamiliarity with weaving operations that he ignored the excellent warp-pacing or letting-off arrangement of the rope and weight which had long been in use in his day in the hand-loom, and upon which inventors have found it difficult to effect any improvement.

There was also incorporated in this loom an automatic stop-motion for stopping the loom when the weft broke. The principal mechanism for effecting this was a swivel plate inserted into the shuttle. This in form somewhat resembled a buckle of three bars, and had its pivot in the centre one. The bars were not, however, equi-distant, the one nearest the shuttle-eye being further distant from the pivot-bar than the one nearest to the shuttle-peg. The weft-thread was passed through the openings in this buckle, and the tension upon the weft while at work maintained it in a horizontal position. Immediately upon the breakage of the weft the larger end dropped down, and on emerging from the shed caught upon a hook, and thus, through suitable mechanism, brought the loom to a stand.

So far as we can make out this was a very imperfect embodiment of an excellent idea, which has since been perfected in an ingenious and beautiful manner.

But even this did not satisfy the comprehensive mind of the reverend inventor. He endeavoured to construct an automatic stop-motion which should stop the loom on the breakage of the warp-threads. It will suffice to say regarding this, that though probably quite ineffectual in this instance, and serving only to unnecessarily complicate the loom, it has since been perfected and embodied in the modern self-stopping beam warping mill, in which the essential part is the drop-wire. The doctor was also, in this instance, in advance of the time; this part of his self-imposed task even to-day, so far as commercial success is concerned, remaining an unsolved problem as applied to the warp in the loom. It has been solved, but not yet with sufficient simplicity and economy to obtain the wide adoption of any of the methods yet invented. It may be observed, in concluding this notice of Dr. Cartwright's loom, that no means of connecting it with any motive power, is shown in either the full or detailed drawings.

Such are the leading features of this important invention. Its minor details it would serve no useful purpose to describe. The three subsequent patents of the same inventor refer to improvements in various points which bring the several details nearer in principle to modern appliances than they were in their original form. It may now be well to trace succinctly and as briefly as possible, compatible with justice to the subject, the further development of the loom until it is found embodying all the principles and details necessary to render it a perfect automatic machine.

The idea of mechanical weaving having thus been broached, and demonstrated to be practicable, progress, though slow, was steady for some years, as many inventors entered the new field thrown open for the exercise of their ingenuity. Contemporaneous with Cartwright was

"Thomas Clark, the Younger," who, in improvements patented in 1788, advances the lathe by pulleys revolving in arms fixed to a square piece of wood upon the driving-shaft, and brings it back by wood springs. This is apparently the beginning of the "wiper" principle. The same inventor introduces the warp-pacing arrangement of the hand-loom, the lever and weight ropes, which Cartwright made a mistake in not adopting at once. He wisely discards the latter's attempt to make a warp from a creel of bobbins. He also makes provision to prevent the breakage of the warp by the trapping of the shuttle, to obviate which it may reasonably be suspected Dr. Cartwright had found to be one of his greatest difficulties. Clark's method is to suspend the warp carrier beam from cords passing over pulleys, balancing it by weights. In the event of a shuttle being caught in the shed, the strain upon the warp would draw down the beam and slacken the warp to such an extent as to prevent its being broken. It is not many years since inventors abandoned plans on this principle for obtaining the same end.

In 1791 Richard Gorton introduced the old over-pick, in which the picking-stick is attached to a stud on the lathe, and is connected by cords to a picker on each side of the loom, in this imitating the action of the hand-loom weaver, using John Kay's invention of the picking-stick, by which the weaver threw the shuttle alternately one way and then the other by a forward and backward jerk of the hand. This system is still in existence in some of the old woollen and worsted power-looms in Yorkshire, but has long ago disappeared from the cotton trade. He also furnished the shuttle-box with the swell spring to retain the shuttle, and the stop-rod and frog, both of which are still extensively in use. He adopted Cartwright's plan of sizing the warp by means of trough, brushes, and roller.

Robert Miller, of Glasgow, in 1796, introduced the improvement of taking up the cloth as woven by means of two rollers worked by a ratchet-wheel and catch, "fastened to a lever worked by a cam on the main shaft." The first part of this improvement is in universal use to-day, the only change that has occurred being in the means of actuating the rollers. In the same specification the inventor brings forward another excellent appliance in the lever-picking motion, which subsisted with improvements until about 1855. Other devices were included, but from the description given of them it is safe to infer that they were substantially impracticable. This was the celebrated wiper loom.

Seven or eight years passed before any further advance was made, which then came in the shape of an invention by Thomas Johnson, of Stockport, in 1803, of the dressing-frame, which finally emancipated the weaver from the task of sizing his warp in the loom. This necessity and complication of the weaving process had been a great stumbling-block to the progress of the improvement of the loom. It is not necessary to describe this invention in this place; neither, as sizing now branches off into an independent industry, is it requisite to note its further progress in this review of the development of the loom.

In 1803 John Todd, presumably of Burnley, introduced the heald roller, placing it on the top of the loom, and attaching the healds thereto by cords, working them by treadles actuated by cams upon the second shaft. The lathe is moved by a crank working in a slot in the lathe swords. The stop-rod for the latter, as described before, is included. This heald roller and the new shedding arrangement constituted a great advance.

The improvements of William Horrocks, of Stockport, patented also in 1803, brought the power-loom appreciably nearer to being a commercial success, though still leaving much to accomplish. In this case the old wooden frame of the hand-loom was retained, and the lathe was pendant from the top cross-beams, and was operated from cranks on the first shaft, the shedding being performed by tappets on the second shaft. An improved taking-up

motion for the cloth was introduced, which was said to be a piracy from one invented by William Radcliffe, also of Stockport, the year previous, and brought before the trade embodied in that inventor's well-known "dandy loom." This was a remodelled and greatly improved hand-loom; it was substantially the last attempt to improve it.

After the above date there was much labour, but little achievement of value, for the space of twenty years. As the inventions that were patented during that time have left little or no mark of a permanent character upon the structure of the power-loom, it will serve to enumerate their principal objects, as these will show the directions in which the inventive genius of the time was labouring. In 1806 Peter Marsland introduced a slow movement of the lathe during the passage of the shuttle. This was obviously to overcome the difficulty induced by a poor picking arrangement. It was, however, beginning at the wrong end. In 1807 Thomas Johnson set aside the principal experience of ages, and constructed a vertical loom, thus reverting to an ancient form. Little was heard of this, so far as can now be gathered. In 1810 William Cotton adapted, as a pacing or letting-off motion, the principle of an invention for another purpose. Peter Ewart, in 1813, first introduced the pneumatic principle into the loom, which he applied for actuating the lathe. Many others since his time have struggled with this principle, though chiefly with a view to utilizing it in the projection of the shuttle. All have hitherto failed to produce any arrangement of commercial value. In the same year William Horrocks patented a plan by which he almost brought the lathe to a stand whilst the shuttle was passing through the shed, thus accenting the principle introduced by Peter Marsland. The waste of power involved in this arrangement will be obvious. In 1815 Joseph and Peter Taylor invented the double-beat foot-lathe, for use in weaving heavy cloths, an invention which has survived in improved form until to-day. It is still in extensive use for certain fabrics. In 1821 William Horrocks again comes to the front with a plan for wetting the warp and weft during working. This was obviously to overcome the defects of the system of sizing then in use.

We now come to a celebrated name on the roll of English inventors, that of Richard Roberts. Roberts had for five or six years been settled in Manchester, and had achieved a considerable reputation by his inventions in other fields of mechanics, when the firm, of which he was a principal, turned their attention to textile machinery. Roberts' improvements in the loom constituted in their day a very distinct step forward. The most important of these, embodied in the patent grant of 1822, is an improved arrangement and actuation of the taking-up gear, consisting of a toothed wheel placed upon the axis of the cloth-roller, which was actuated by a pinion fixed on the axis of a ratchet-wheel, which was moved by a click jointed to a lever worked by the lathe. This is substantially the taking-up gear of to-day. A positive warp-delivery motion, worked in connection with the taking-up arrangement, is included, the means employed being "a screw and worm wheel, or other similar contrivance." There are several other improvements included in the same specification, relating mostly to the means for the production of fancy cloths and to small-wares in swivel looms. The only one we need notice is an improvement in the means of shedding in cases where more than two shafts of healds are employed. The tappet-wheel he makes to "consist of a number of small rollers or tappets, arranged in the circumference of a circle or revolving wheel, and adapted to operate upon a system of levers, one half of which are elevating levers for the purpose of raising the shafts or heddles, and the other half are depressing levers, for the purpose of depressing the shafts or heddles." This is almost the cylinder-shedding arrangement, well known in the production of fancy fabrics until about the year 1855, when it began to be superseded by

improved appliances, which will duly come under notice hereafter.

Richard Roberts took the power-loom as left by William Horrocks, and upon that built his modifications and improvements. The loom of Roberts occupies a position about midway between that of Cartwright and the comparatively perfect loom of to-day. It will, therefore, be useful to the student if the position at this point be reviewed, and an opportunity be afforded him of measuring the progress made in the interval from Cartwright's laying down his task to the time it was taken up by one of his greatest successors in the same field of invention. The following illustrations and descriptions of Roberts' loom, from Dr. Ure's "Cotton Manufacture," enables this to be done with facility.

"Figs. 18 and 20 are two side elevations, and fig. 19 is a front view.

"Those parts in the engraving marked with the letter A compose the frame-work of the loom. B is the usual outrigger, or fast and loose pulleys, upon the principal or crank shaft. C is a small fly-wheel, for equalising any casual irregularities of motion in the machine.

"Upon the other end of the main shaft is a wheel, D, figs. 19 and 20, driving another wheel, D′, with double the number of teeth, upon the shaft, E, which makes, therefore, only half as many revolutions as the main, or crank shaft, B. The shaft, E, is called the tappet, or wiper-shaft; it raises and lowers the treadles, and throws the shuttle, while the shaft, B, by means of its cranks, F, figs. 18 and 20, drives home the weft towards the finished cloth, or works the batten.

"The cranks, F, are connected with the two levers, G, G, called the swords of the lay, to which the batten, H, is made fast, which carries the reed in its middle, to the shuttle-boxes, *h, h*, at its end. See fig. 19.

"I is the warp-beam. The warp-yarns pass from it over the roller, K, through the heddles, L, through the reed, *l′*, over the breast-beam, M (having now been changed into cloth). This is finally wound upon the roller, N, or cloth-beam. This roller bears at one end a toothed wheel, *a*,

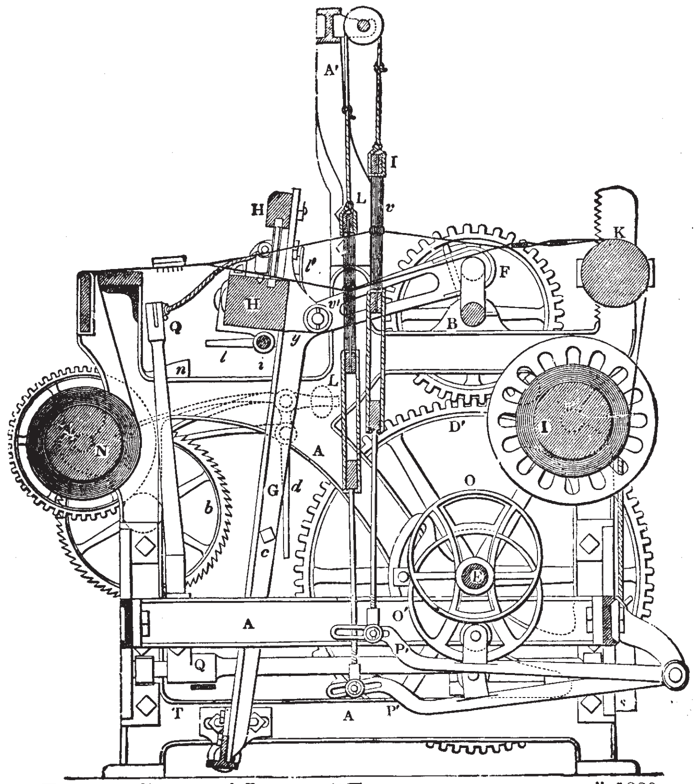


Fig. 18.—Roberts' Loom. "First side elevation;" 1830.

which is moved slowly by a small pinion, *u* (fig. 18), upon the axis of the ratchet-wheel, *b*. This latter wheel is turned round a little after every throw of the shuttle, or shoot of the weft, by means of a shed, *c* (figs. 19 and

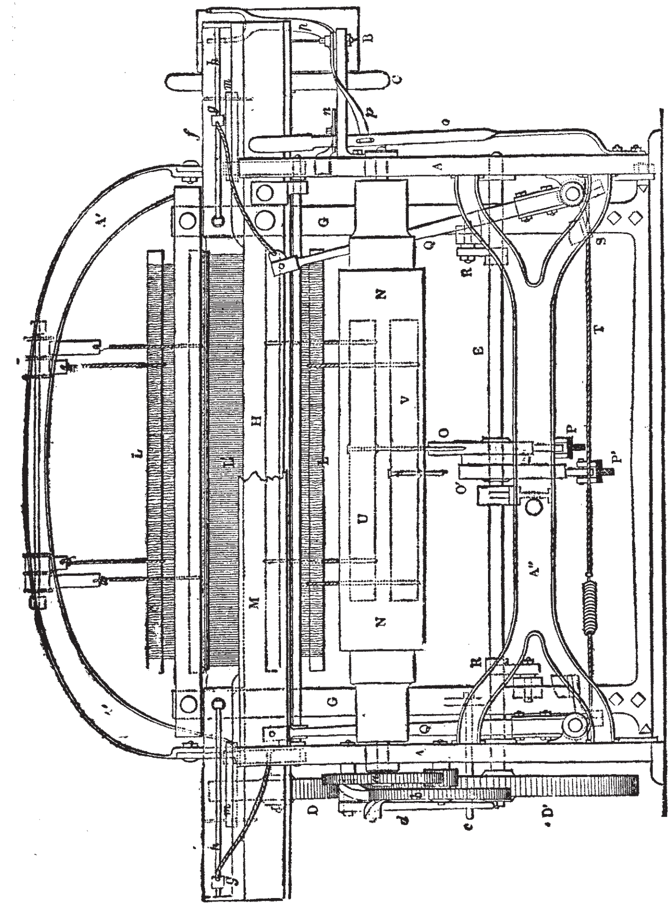


Fig. 19.—Roberts' Loom. Front view.

20), fixed upon the side of the lever, G, and pressing against the other lever, *d*, with which a click is connected. The degree of motion of the ratchet is regulated according

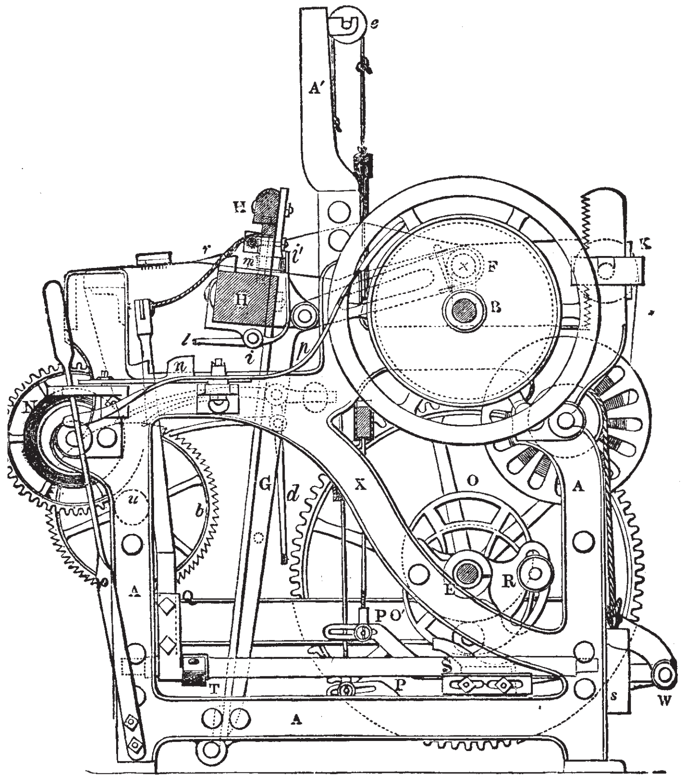


FIG. 20.—ROBERTS' LOOM. SECOND SIDE ELEVATION.

to the quality of the cloth, by fixing the click in different holes of the (dotted) lever, *d*. The lifting of the heddle, L, is performed by two eccentric tappets or wipers, O, O′,

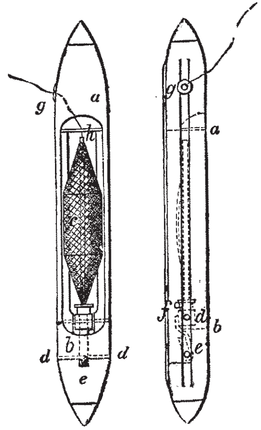
upon the shaft, E, which press the treadle-levers, P, P′, alternately up and down. These levers are connected by strings or wires with their respective heddles, which are in their turn placed in communication by straps which play over the small rollers, *e*, *e*, at the top of the loom.

"In fig. 19, the levers, P, P′, have been shown in section, in order to explain the way in which the eccentrics, tappets, or cams work through the intervention of two small friction rollers, made fast to the levers.

"The shuttle is thrown by the two levers, Q, Q, which are alternately moved with a jerk of the rollers, R, fixed by arms on the shaft, E, and working upon cams, S, connected with the shafts of the arms, Q, Q. These arms, which represent the right arm of the hand-loom weaver, are united by the pecking-cord, T, which is mounted with a spring of spiral wire, so that either arm may be brought to its proper relative position.

"The shuttle is lodged in one of the boxes, *f*, *f*, of the batten, H, and is driven across along its shed-way by one of the pickers, *g*, *g*, which run on the two parallel guide-wires, *h*, *h*, and are connected with the peg-arms, Q, by strong cords. See fig. 19.

"If by any accident the shuttle should stick in the shed-way, the blows of the lay or batten, H, against it, would very soon cause the warp to be torn to pieces. In order to guard against this misfortune a contrivance has been introduced for stopping the loom immediately, in case the shuttle should not come home into its cell. Under the batten, H, fig. 20, there is a small shaft, *i*, figs. 18 and 18, on each side of which a lever, *l*, *l*′, fig. 18, is fixed. These two levers are pressed by springs against other levers, *m*, *m*, which enter partly into the shuttle-boxes. They act there as brakes to soften the impulse of the shuttle, and allow also the point of the lever, *l*, to fall downwards into a line with the prominence at *n*, provided the shuttles do not enter in and press the spring-point, *m*, backwards, and thereby the upright arm of the bent lever, *l′*, onwards, so as to raise its horizontal arm, *l*, above *n*. When this does not take place, that is, when the shuttle has not gone fairly home, the lever, *l*, hangs down, strikes against the obstacle, *n*, moves this piece forwards, so as to press against the spring-lever or trigger, *o*, *o*, which leaps from its catch or detent, shifts the fork, *p*, *p*, with its strap, from the fast to the loose pulley at B, fig. 19, and thus, in a twinkling, arrests every motion of the machine. See figs. 18 and 20, at the right-hand sides.



Figs. 21, 22.—Roberts' Loom Shuttle; Plan and Side Views.

"The shuttle is represented (fig. 21) in a top view, and fig. 22 in a side view. It is made of a piece of boxwood, excavated by a mortise in the middle, and tapered off at its ends, the lips being shod with iron points to protect them from injury by blows against the guides and the bottoms of the boxes.

"In the hollow part, *a*, *b*, there is a skewer or spindle, *c*, seen in dotted lines. One end of this skewer turns round about the axis, *d*, to allow it to come out of the mortise when the cop is to be put on.

"*e* (see the dotted lines in fig. 22 is the spring which keeps the spindle, *c*, in its place by pressing against one of the sides of the square ends of the spindle. *f* is a projecting pin or little stud, against which the spindle, *c*, bears, when laid in its place. *g* is a hole in one side of the shuttle, bushed with ivory, through which the thread passes, after being drawn through a slit in the centre of a brass plate, *h*. In that side of the shuttle which is furnished with the eye-hole, there is a groove extending its whole length for receiving the thread in its unwinding

from the cop. The under surface of the shuttle, which slides over the warp-shed, is made smooth from end to end by means of two wires, which abate the friction.

"Thus we see that in the power-loom there are eight points to be considered:—

1. The framework of the machine.
2. The mechanism connected with the warp.
3. The movement of the healds, or heddles.
4. The movement of the lathe, or batten.
5. The movement of the shuttle.
6. The mechanical arrangements of the whole machine.
7. The mode of action, or working of the several parts.
8. The methods of throwing the loom out of gear.

"1. The *framework* is of cast-iron, and is composed of two sides, each being cast in a single piece, marked A in the three figures, in which are seen an upright at each end, a cross-bar at top and bottom, with a curved bar diagonally placed. Upon the front of the uprights in fig. 19, immediately above the letter A, there are notched brackets for supporting the iron axes of the cloth beam, N. On the back uprights of the loom there is a slot-bar for supporting the axes of the warp-beam, I. See fig. 18. Towards the middle of the top rails of each side the vertical prolongation terminates in the arch A′.

"The cross binding-rails which unite the two faces and the two ends of the loom are,—

1. The great arched rail, A′, fig. 19, shaped like a basket-handle, which is made fast by screw-bolts and nuts, of which the heads are seen under A′ in fig. 18. This arc is destined to support the heddles, *e*, *e*.

2. The front cross-rail, A′, fig. 19, bifurcated at the ends to afford a greater extent of binding surface with the uprights.

3. The back cross-rail (not seen in these views), perfectly similar to the front one, A′.

"The frame-work is exceedingly substantial, and stands steadily upon four large feet. The floor which bears it should be free from tremor; a stone or brick floor on the ground storey being the best.

2. *Arrangement of the Warp.*

"The warp is wound, as we have said, upon the cylindric wooden beam, I, figs. 18 and 20, from which it passes over the guide-friction roller, K, whereby it is brought into a horizontal plane suited to the play of the shuttle and the lathe. The cloth being formed at *r*, figs. 18 and 20, progressively slides over the strong breast-beam, M, and is wound upon the cloth-beam, N.

"It is essential to good work in the power-loom, that the warp and the cloth be uniformly stretched to the proper tension during the whole process of weaving; for if it become at any time greater, more force will be required to move the heddles in opening the shed, the yarns will get broken, and one shoot cannot be driven so close home upon another as when the tension is less. On the other hand, if the web be left too slack, the shoot of weft will be driven too far into the shed, and will thereby ride, in some measure, over the warp. It would not be difficult to give the chain the requisite degree of tension for the particular style of goods, were it not necessary to maintain it at the same pitch all the time that the cloth is winding, and the warp unwinding, about their respective rollers. The warp-beam, I, has at each of its ends a large wooden pulley (one is seen in fig. 18), which are fixed by screws upon the disc iron plate; round that pulley a cord makes two or more turns, and then hangs down with the tension weight at its end (see fig. 18); a light counter-weight, not seen in this view, hangs interiorly from the other end of the cord. The weight, *s*, consists of round plates of cast-iron, and it may, therefore, be modified at pleasure by increasing or diminishing their number.

"The roller, K, may be raised or lowered upon its rack-work upright, as shown in fig. 18.

"The surface of the breast-beam, M, slopes slightly, and is made very smooth to facilitate the sliding motion of the cloth in its way to be wound upon N.

"The cloth-roller, N, bears upon one of its iron axes prolonged, the toothed wheel, *a*, which works into a pinion (seen in dotted lines, *u*, in fig. 18) upon the axis of the ratchet-wheel, *b*. Hence if the ratchet-wheel be turned round, it will turn the pinion, *u*, and the wheel, *a*, on the shaft of the cylinder, N, so as to wind up the cloth as it is made. The click-lever on the top of the ratchet-wheel makes it hold whatever it has got, and thereby prevents the cloth from unrolling.

3. *Movement of the Heddles.*

"These are of the usual construction in this power-loom; they are shown in section at L, L′, fig. 20, and in front view in fig. 19. The loops or eyes, *v*, fig. 20, through which one-half of the threads of the warp passes, lie in two ranges; as also the loops, *v′*, of the other heddles, which transmit the other half of the threads. The loops are arranged in two ranks, and in different planes (on different levels), in order that the warp-yarns in passing may be brought closer together. Thus the even numbers of threads, 2, 6, 10, &c., which belong to the heddle L, pass in the loops of the first or upper range, and the numbers 4, 8, 12, &c., in those of the second range; and the odd numbers of threads, 1, 5, 9, &c., which belong to the treadle L′, pass in those of its upper range, and the numbers 3, 7, 11, &c., in those of the second.

"With the same view there are two heddle-sticks at L, L′, so that the threads which belong to the first range loops may be received over the two front rods above and below, and the threads which belong to the second range may be received over the two back rods. In fig. 20 the line of division is shown in the middle of the section of the heddle-rods at L. The same takes place with the other heddle, L′.

"The rods of the first heddle-leaf are each attached above to two cords terminating in leather straps, *e*, *e* (fig. 19), the ends of which are nailed to the wooden pulleys, as shown in section at *e*, figs. 18 and 20. The rods of the second heddle-leaf are in like manner attached by two cords, with two leather straps nailed to similar pulleys. The last two pulleys have a smaller diameter than the first. Both systems of pulleys are fixed upon an iron shaft, which turns in the notch-bearings of the bracket projecting from the point, A′, of the basket-handle rail (as shown at *e*, fig. 18).

"At their under part, the heddle-leaves are also attached by two cords to two strong wooden bars, V, V, to the middle of which are fixed the iron rods, O, O, which are jointed to the treadle-marches, or steps, P, P′. These are connected by screw-joints (fig. 19), so that the point of attachment may be varied according to circumstances.

"We must now show how the treadles or marches, P, P (figs. 18 and 20), are raised and lowered, and how they effect, at the same time, the elevation or depression of the heddles.

"In figs. 18 and 20 are seen the two bent lever-bars, P, P′, which turn upon a fulcrum at W, and which are prevented from deviating sidewise by upright fixed bars, which pass through slits in their middle, as shown in fig. 20. When the march or lever, P, is pushed down, depressing the front heddles, the lever, P′, necessarily rises, because the one leather strap cannot roll round the pulley, *e*, without unrolling the other, and reciprocally. In order to shed the warp alternately, first in one direction and then in another, nothing is required but to depress, in succession, each of the treadles or levers, P, P′, taking care not to obstruct the motion of the rising one.

"The movements, 4, of the baton, and 5, which throws the shuttle, are essentially a little complicated, not so much from any difficulty of giving them the requisite velocity, as from the necessity of making them start precisely at an instant, dependent not merely on the position of the heddles, but on that also of the batten.

6, 7. *The Communication of Motion, or the Train of the Working Parts.*

"The driving-shaft, which puts the whole machine in motion, is represented by B, figs. 18 and 20. It is supported by the upper cross-rails, which extend beyond the side-frames, to carry upon the right hand the toothed wheel, D, fig. 20, and to the left the pulleys or outriggers, C, fig. 18, upon which the steam-belt runs. Inside of the frame, opposite each of the swords, G, of the batten, there is a crank mechanism, B, F, upon the driving-shaft, to which the links, F, *z*, are adjusted which move the batten. It is therefore evident that for every turn of the fly-wheel, C, or the steam pulley-shaft, the batten must make a complete vibration to and fro, advancing each time so as to beat up the shoot of weft at exactly the same point. Hence, if the main shaft make 120 revolutions in the minute, the shuttle must pass 120 times along the shuttle-rail.

"The toothed-wheel, D, figs. 19 and 20, making as many turns as the fly-wheel, works in the toothed-wheel, D′, of double diameter, and, therefore, communicates to it half its own velocity. This wheel, D′, is made fast to one of the extremities of the tappet, or wiper-shaft, E (figs. 18, 19, and 20), whose two bearings are in the curved diagonal rails, X, fig. 19. This shaft, E, is moreover supported in the middle by a clamp-collar, between O and O, fig. 19, in order to guard it against the least flexure, in consequence of the heavy strains it is exposed to in moving the treadles.

"The eccentrics, O, O′, are mounted upon the shaft, E, and, turning with it, impart alternate pressure to the marches or treadles, P, P, as well as to the pecking-arms, Q, Q′. The effect of these eccentrics may be readily conceived from their being of a spiral form, but with their curves placed in opposite positions. Hence, if from the common centre of the two eccentrics any radius be drawn to the two circumferences, the sum of the two portions of it, intercepted by the centre and each circumference, will be a constant quantity, which is the essential condition to be fulfilled by these eccentrics to give equal alternate impulsions.

"The ratio between the greater and smaller curvature of these eccentrics depends upon the extent of the opening or shedding of the warp for the shuttle-race. In the figures here engraved the measurements are $\frac{1}{4}$ and $\frac{1}{2}$ inch, which, by the scale of 1 inch to the foot, gives 3 inches and 6 inches; and as the bottoms of the upright rods which move the heddles work in the levers, P, at a great distance from the fulcrum, W, one-half greater than the eccentrics, O, or as the fraction $\frac{3}{2}$; the movement of the heddles will be $\frac{3}{2} \times 3$ inches $= 4\frac{1}{2}$ inches. In order to open the shed still more the lower ends of the heddle-rods would need merely to be removed by the slots and nuts farther from the fulcrum, W, that is, nearer to the points of the treadles, or tappet-wheels, O, O, of a greater eccentricity may be used.

"It is obvious that there should be a certain relation between the position of the crank elbows, B, F, figs. 18 and 20, and the position of the eccentrics, O. Thus, in figs. 18 and 19, the main shaft must make one-quarter of a turn before the crank, F, with its link, F y, can strike the batten, H, against the shoot of weft. During this quarter of a turn, the tappet-shaft, E, moving with one-half the speed, will make only one-eighth of a turn. The position of the eccentrics must be nicely adjusted upon their shafts to that of the crank, and firmly fixed in that position, so that the batten may strike home the shoot upon the closed

warp, or upon the warp still partly shed, as may be thought preferable. In the position shown by the figures, the lay will strike somewhat before the closing of the shed; for the eccentric or tappet-shaft, E, will make one-eighth of a turn, equivalent to one-quarter of a heddle-stroke, while the crank-shaft, B, will make the quarter of a revolution requisite to drive home the lay upon the shoot.

"We may now readily apprehend in what manner the double arm throws the shuttle at the proper moment. The two levers (figs. 18 and 19) which produce the pecking motion are actuated by two friction-rollers (one of which is seen to the right of R, fig. 18) attached to the eccentrics or tappets, and diametrically opposite the one to the other. By shifting the position of these projecting rollers in the curved slot of the eccentric, R, the throwing of the shuttle, effected by their striking down the pecking lever, may be adjusted to any point in the revolution of the tappet-shaft, which moves the heddles. As the shuttle can be thrown, however, only when the warp is open in a considerable degree, the screw-bolts which carry the wiper-rollers cannot be moved beyond the space included within the extremities of the great arcs of the eccentrics. And since there are two rollers diametrically opposite, it is obvious that in each complete revolution of the eccentrics the shuttle must be thrown twice; and as each of these revolutions corresponds to two revolutions of the crank-shaft, or two strokes of the batten, there will result, as there ought to do, one stroke of the battens for every passage of the shuttle.

"I have seen this power-loom weaving at very various speeds, from 100 pecks or shoots in the minute, up to 180. The average number in the most improved loom-shops for weaving calico may be reckoned 120.

"Near to each of its ends the warp-beam has two square-grooved large wooden pulleys, which are fixed by screws upon the cast-iron discs. These discs have a hollow socket in their centres for receiving the ends of the beam; and they are also fixed by four screws, which pass down through this socket into the wood. To give them a firmer hold, the sockets have a projecting feather or wedge within, which fits into a square groove or mortise cut in the side of the roller. Round the smaller pulley a cord makes two turns, carrying upon its inner extremity a light weight, and upon its outer one a much heavier weight. Round the larger pulley, at the other end of the warp-beam, a similar tension-cord passes, but it makes four turns, bearing analogous weights to the former pulley. One of these weights is seen at *s* (figs. 18, 20).

"When the warp has been made fast, by securing its ends in the longitudinal groove of the beam, and by forcing the wedge-rule down upon the threads, and when it has been led over the guide-roller, K, and the breast-beam, M, and is tied in several little parcels to the cloth-beam, N, held by its ratchet-wheel, it will be stretched to a degree determined by the difference of the above pulley-weights.

"Let us recapitulate the train of its decussating operations, beginning at the moment when the shed is closed—that is, when the two heddle-leaves are at the same level, as well as the tappets of the treadles, which are now pressed by the intersecting points of the tappet-wheels. The batten is likewise at the limit of its advance, in the direction of the cloth, namely, striking home the shoot of weft. Supposing the loom to make 120 pecks in the minute, it will make, of course, a single peck in half a second; hence the fly-shaft makes a turn in half a second, and the tappet or eccentric-shaft makes a turn in a whole second. In moving from the above positions the tappet-wheels must make one-twelfth of a revolution in order to open the warp-shed completely, during which movement one-twelfth of a second will elapse; it remains open four-twelfths of a second, and takes again one-twelfth of a second to close, so that six-twelfths, or one-half, of a second elapse between the moment when the warp begins to open, and the moment of its closing, while it remains completely open four-twelfths of a second.

"The shuttle is thrown at the moment when the tappet-roller at R strikes the bent lever at P beneath it, but the warp must be not merely opened for the shuttle to be thrown; the batten must be then at its utmost limit towards the heddles, in order to give the shuttle "ample room and verge enough." This is the condition which determines the place of the tappet-rollers upon the eccentrics. As the batten arrives near the heddles after three-twelfths of a second, it is obvious that the said roller should strike its lever a little before three-twelfths of a second have elapsed, or a little before the middle of the great arc of the eccentric; thus the shuttle starts before the batten has receded to its utmost limit towards the heddles, and it should have run through a little more than one-half of its race when the batten reaches that limit, so that it may arrive in time at the other end.

"When the shuttle completes its race, the batten has already passed the limit of its excursion towards the heddles, and is on its return to strike home the shoot of weft newly placed between the two portions of the opened warp. It has now its maximum velocity, because the cranks, B, F, are at nearly right angles to the links which move the swords, G, of the battens. This velocity diminishes in order that when the dents of the reed, borne along by the lay, come in contact with the weft to drive it home, they may act by gentle pressure rather than by a blow, so as not to injure the yarn. The warp being closed at the same instant, the pressure does not affect the loops of the heddles, but is exercised upon the warp and the cloth wholly in a longitudinal direction."

The foregoing description and illustration will clearly exhibit to the student the progress made in the construction and improvement of the power-loom in the interval between the time when the first inventor, Cartwright, laid down his task and the time when Roberts in relation to this machine followed his example. We may now proceed to examine and describe the contributions of succeeding inventors, which have helped to make it the perfect automatic machine of to-day.

A company of inventors, Stanfield, Prichard, and Wilkinson, join in a patent for automatic stop motions, for stopping the loom on the breakage of the weft or warp-threads. These, however, need not be described, as neither of the principles embodied in their plans have come into use. In fact, no satisfactory and commercially successful method of stopping the loom on the breakage of a warp-thread has up to the time of this present writing been invented, though electricity amongst other agents has been tried.

The next great step in the improvement of the power-loom is one which does not appear to have been patented at all, so far as the writer can discover. This was the invention of the modern overpick-loom, probably best known as the Blackburn loom. Perhaps, to avoid all risk of confusion with the old overpick-loom, which, in an antiquated form, still survives in some of the woollen and worsted districts, it will be best to call this the horizontal side-pick. This well-known loom, which is now almost universal, was the invention of Mr. William Dickinson, of Blackburn, who at the time he worked out this great improvement was the manager for Messrs. Davison and Price, ironfounders and machinists, who then carried on business at the Eagle Foundry, Blackburn. This loom was, and still, of course, is, a very perfect mechanical reversion to the actions of the old hand-loom weaver, who threw his shuttle from hand to hand. The picking arrangement was very simple and efficient. It consisted of two tappet-bowls carried, one on a fixed arm at the end of the tappet-shaft, and the other attached to the arms of the spur-wheel upon the opposite end of the same shaft. The revolution of the shaft brought these bowls alternately sharply against two vertical levers attached to the loom-frame by, and pendant

from, pins on which they were pivoted. These levers were of a peculiar form, suited to yield the effect desired. To the bottom of each a leather band was attached, which extended to a sector on the bottom of a vertical shaft, to which it was attached. These shafts were fixed inside the loom-frame, about midway between the back and front, and carried upon their tops the picking-sticks horizontally extending over the shuttle-boxes. Connection with the pickers was established by picking-bands in the ordinary way. The two vertical shafts were also connected by a band called a "back-strap," really a check-strap, attached to small sectors on each shaft. In operation the bowls on the tappet-shaft in their revolution struck each picking-lever alternately, forcing them back from a vertical line and through the bands connecting them with the upright picking-shafts, sharply drawing the latter about one-third of a revolution round, causing the picking-stick upon its top to make a sharp movement, which, though describing an arc of a circle, gave a lateral movement to the picker, and thus projected the shuttle through the shed to the opposite box, whence, in the same manner, it was immediately returned. This is identically the same motion as that in vogue to-day. It will thus be seen that the picking-sticks, in this arrangement, very closely represent the arms of the olden time weaver, and simulate his action. This picking motion became very popular, and remained unchanged for about twenty-five years, when, about 1853, an improvement was effected in its details by the substitution of the cone-tappet, at present in use for the lever and bowl described above. This was also by Mr. William Dickinson, who had before this time founded the still existing firm of loom makers known as William Dickinson and Sons, Blackburn. Of this type of loom in its original and improved form, probably ten times as many have been made as of any other. Its details will come under notice subsequently.

Our review has now carried us to about the year 1830, and it may be desirable to remark that the inventions to which references have been made are not more than one-tenth of the total number devoted to the improvement of the loom. The purpose of the writer has been, and will continue the same throughout, to notice only those improvements that have introduced principles, in however crude a form, that have maintained their position, and, with improvement in their details, have become integral and valuable portions of the loom of to-day, and with which there can be no thought of dispensing. It may be observed, however, that during the ten years from 1820 to 1830 there is visible an increasing effort to add two valuable features to the loom, namely, first, an automatic stop-motion, to stop the loom on the exhaustion or breakage of the weft; and second, an automatic, or self-acting temple. It is very curious to note with what persistency inventors went upon a false track in their endeavour to accomplish the former object. This was to devise an arrangement which, on the breakage of the thread, should prevent the shuttle entering the box to which it was proceeding. In the then existing arrangements of the loom this could only operate with disastrous effect upon the warp, which would be liable to be "smashed" every time the loom was thus stopped. Unquestionably the evils that would thus be produced would be greater than those endeavoured to be cured, and this, no doubt, was the reason that ultimately led to the abandonment of the attempt to solve the problem in this direction. In the matter of templing, the most various devices were resorted to, some of which, looked at in the light of present appliances, are exceedingly ludicrous.

Two other matters may, at this point, be referred to as greatly exercising the faculties of inventors. These were the taking-up and letting-off, or warp-pacing arrangements. As has already been shown, the true principles of these had been discovered and applied, but ill-considered attempts to improve upon or supersede them were numerous, and, as might be expected, quite futile.

In May, 1833, an American invention of a self-acting temple, an ingenious but complex device, was patented in this country, and appears to have met with a considerable amount of favour as being the most successful attempt to construct a self-acting temple that had been made. This is described and illustrated in Dr. Ure's "Cotton Manufacture," vol. ii. page 317, to which the curious reader is referred. Its principle is not one which could be approved.

In 1834 we find the record of an invention by Luke and John Smith of an improved picking arrangement, which has held its own to the present time. "Instead," say the patentees, "of operating upon the picking-levers, or picking-sticks, by gear or other mechanism heretofore employed, we fix upon the periphery of each fly-wheel certain inclined curvilinear projections which we denominate inclined planes, and each of these inclined planes is made to operate upon its respective picking-stick at every second revolution of the crank shaft." This is the old and well-known scroll-pick yet in use in heavy looms for cords, moles, ticking, and other heavy fabrics.

In May, 1834, two notable Blackburn names first appear in the inventors' list for improvements in looms. It would seem from the specification, and from a previous one of another inventor, that the taking-up roller was still used also as the roller on which to wind the cloth as it was woven. The consequence was, that as the cloth was wound upon it its diameter underwent enlargement, and its capacity for drawing down the warp correspondingly increased, the cloth gradually becoming thinner or receiving less picks as the weaving proceeded, which if permitted to continue would have resulted in a very great deterioration of the quality of the cloth at the end of the piece. Various plans were tried in order to obviate this result. One inventor borrowed the complex differential arrangement of the cone drums from the slubbing and roving frame, and the Blackburn inventors endeavoured to solve the problem by the use of the disc arrangement for the same purpose. The ordinary method of overcoming the defect, and which perhaps was better than either of these, though troublesome, was to frequently change the pinion on the taking-up gear. It is strange that inventors should go to such trouble when the problem had been perfectly solved some time before by the introduction of a friction cloth roller, which was actuated by surface contact with the taking-up roller, thus winding on the cloth as it was woven without affecting the diameter of the taking-up roller at all. Reference is made to the Blackburn patent, however, more especially to note the first appearance of the "vibrating, or fly-reed," which was introduced in connection with a system of levers for stopping the loom on the breakage of the weft. Probably little conception was entertained at this time of the real importance of this loose reed, and of the great part it would afterwards play in developing the capacity of the loom. Though the Blackburn patent appears in the names of Messrs. Hornby and Kenworthy, the proprietor and the leading manager of Brookhouse Mills in that town, there is good reason to believe they were greatly assisted in devising their improvements by the celebrated inventor James Bullough, then in their employment, and whose own name first appears in the list of inventors the following year.

We now arrive at the date which marks another important invention, and which constituted a great step forward towards rendering the loom perfect. This was the simple and beautiful automatic weft stop-motion. This first appears in a specification granted to John Ramsbottom and Richard Holt, of Todmorden, July 12th, 1834, No. 6644. The specification mainly relates to an ingenious double vertical loom, an attempt to improve that of Thomas Johnson invented in 1807, the details of which it is not necessary to describe, as it did not take very long to demonstrate it could not succeed. A part of this invention consisted of the new automatic weft stopping motion just mentioned.

Though somewhat crude, the essence of the more perfect conception is there, and is very clearly defined. The contrivance consisted of levers, which the patentees call "hands and fingers." These were attached to rods extending across the loom and turning in bearings on the side standards. At each end of the reed there was an aperture in the shuttle-race, covered by some slight wires, set sufficiently apart to allow the fingers of the hands to pass through when not supported by the weft. To the rods were attached levers provided with notches, which levers were again connected to a sliding bar, so that when the fingers were not supported by the weft the notches on the levers were struck, and the levers and sliding-bar were raised by the lay, so as to allow a spring to act upon the driving-strap and traverse it from the fast to the loose pulley, at the same time bringing a nib on the sliding-bar in contact with a nib on the fly-wheel of the loom, which stopped it instantly. When the shuttle did not reach its box, a pendant lever was acted upon by a swell in the shuttle-box, so as to cause a catch upon it to come in contact with an arm extending from the sliding-bar, which was thereby raised and the loom stopped as before described.

On October 1st, 1835, James Bullough, of Blackburn, appeared in the Patent Office with an invention of a double horizontal loom having two beams, two slays, and two sets of healds, with the other necessary appendages. This was evidently suggested by the preceding invention, but was worked on different and better lines, and had all the merit of novelty. Included in this patent is an improved weft stopping motion and taking-up and letting-off arrangement. This specification affords another illustration of how clay and gold, so to speak, are mingled together, the double loom being radically wrong in principle when considered from an economical point of view. The only valuable points in this invention are those relating to the three automatic motions just mentioned.

In 1836 Andrew Parkinson patented "an improved stretcher, or temple," which consists of a circular disc, or wheel, the periphery of which is studded with pins. It is arranged horizontally near the edges of the cloth, and its revolution keeps the latter stretched to its proper width. This was a meritorious invention, and has not even yet been altogether discarded.

Though numerous inventions in connection with the loom continued to be made and patented, these related more to details or adjuncts than to the essential parts of the loom itself, and but little of a real advance was made in the next five years following the above-mentioned date.

In 1841 we come upon two important improvements embodied in one patent specification. These were, first, the trough and roller-temple, that in templing marked the introduction of a new principle, which, with improvements in details, has held its own ever since, and is probably, in connection with power-looms, the most universally used of all temples. The second of these was a great simplification and improvement in detail of the fork and grid weft stop motion, first introduced by Ramsbottom and Holt, as mentioned previously. The patent containing these improvements was granted to William Kenworthy and James Bullough, of Brookhouse, Blackburn, two names as well known as any in the roll of inventors in connection with the loom.

"This stop-motion," say the inventors, "consists in a very simple additional apparatus, which may be readily applied to looms in general, and may be termed the weft-watcher, or detector, as it points out with unerring certainty the breakage or absence of the weft-thread by the instantaneous disengagement of the taking-up motion, and entirely stopping the ordinary evolutions of the looms. As the object is to be accomplished by the absence of the weft-thread, we are enabled to give it sufficient strength or power, when in its place in the loom, to act

upon the throwing-off motion, by causing the thread to intersect a small forked lever which protrudes through the reed at every stroke of the slay or crossing of the weft, which will cause such forked lever to rise when the thread is present and to fall when absent, and thus to be placed in combination with another detector-lever, which is kept constantly vibrating or moving with the beating up of the slay, and by a proper arrangement and order of their motions will form an escapement, by which we are enabled to stop the taking-up motion and all other actions of the loom simultaneously merely by the absence of the very first pick of weft."

Here at last, fifty-five years after the invention of the power-loom, was an improvement which had been its chief desideratum from Cartwright's days. Without it the power-loom never could have entirely displaced the hand-loom, or have become the important machine it is to-day. As it was, before this improvement was effected, it required the closest and most unremitting attention of the weaver to prevent the warp being drawn down without its filling of weft, by which it was frayed and seriously injured. The cloth too was frequently damaged by "galls" and "cracks," or long and short spaces without weft. One loom was as much as many weavers could undertake the charge of, whilst the most skilful weaver of the time could not venture upon more than two, and these working at a speed of only about 120 to 130 picks per minute. This affords a great contrast to the picture presented to-day, in which it is a common practice for a weaver to take charge of from four to six looms, running from 220 to 260 picks per minute. This improvement rendered the loom an almost perfect automaton. As before observed, the first idea of this arrangement appears in the specification of Ramsbottom and Holt, of Todmorden. A second reference and description of the principle of this invention appears in a patent (a communication) granted to Moses Poole, November 12th, 1839, No. 8270. In the Abstracts of Patents on Weaving, this is described as follows: "The ninth part of this invention relates to a method of stopping the loom when the weft is expended or broken. A "fork or grid," are placed at each side of the lay; the forks are connected by a rod which works in bearings. A curved lever is attached to the rod, which by coming in contact with a stud, or pin, causes the forks to be lifted out of the way of the shuttle as the lay goes back. When the weft is broken, the forks enter the grids, and actuate a balance lever, carrying a small projection, or knob, which comes directly in front of the stop-lever."

On the strength of this notice Clinton G. Gilroy claims to be the author of this invention. In a foot-note on page 416 of his well-known "History of the Art of Weaving," first published in New York, 1844, he makes the following statement:—

"This motion originated with us, in the beginning of the year 1831, at which period we applied it to a power-loom for weaving *Marseilles quilts;* and the patents obtained in England by Mr. Bullough and Mr. Ramsbottom, for modifications of it, of course, belong to us. We made still further improvements on the motion in the years 1836 and 1838, for which we obtained patents in November, 1839, in the name of Moses Poole, of the Patent Office, 4, Lincoln's Inn, Old Square, London. We also secured patents for the same invention in France and Belgium, through Harry Truffant, Esq., patent agent."

We regret, however, to say that in our opinion it would be injudicious to give unlimited credence to the claims of Clinton G. Gilroy, without obtaining therefor strong confirmatory evidence beyond that tendered in his book. In the above extract, his assertion that he "originated" this motion in the early part of 1831 is not supported by a tittle of evidence, whilst his own work affords evidence that he was a careful student of English patent specifications, and of the work of Dr. Ure on Cotton Manufacture, published in 1836, in which Ramsbottom and Holt's patent

is noticed. The improvements he asserts he made as above and patented in 1839, as will be observed from the description, scarcely carry the matter the smallest space beyond the point at which it was left by the Todmorden inventors, and it was far from attaining the simplicity and perfection reached by James Bullough in the invention of 1841.

The power-loom at this point of development had become in principle a perfect machine. The various motions necessary to form cloth: shedding of the warp, picking in the weft, driving it home, taking up the woven cloth, and giving out of the warp as needed, were all automatically performed, and, what is more, these movements were harmoniously combined and correlated, so that the result of their united action was a woven fabric produced without the intervention of human labour, at less cost and better in quality than that as a rule obtained from the work of the hand-loom weaver. It was thus not only a mechanical, but an economical success. In saying this, it is not meant to assert that it was perfect in its details: such was not the case; much ingenuity has since been expended in improving these during the last fifty years, and in order to bring it to its present stage of perfection.

A very brief glance only at a few of the most important inventions contributing to this result will be sufficient to give the student the necessary insight into its further advance and improvement, as they will all in their aggregate come under review subsequently.

The first invention of this kind calling for notice is that of the loose reed, by James Bullough, in 1842. This was practically the first of a series that has almost doubled the working capacity of the loom, enabling it to be run at a speed quite unattainable with the fast reed. In 1845, John Sellers, of Burnley, invented the first loom-brake, which became known as the "Burnley brake." This also was followed by a long series of improvements upon it by various inventors, the effect of which has been to attain with it a degree of perfection that leaves little to be desired. In the same year a very useful little device, the continuous check-strap, was patented amongst a number of other small improvements, being included in a specification granted to William Eccles, William Crook, and William Lancaster, of Blackburn. The invention of the original check-strap, which probably was not continuous, is claimed for the late Mr. Robert Pickles, of Canton Mill, Burnley, who made it whilst an operative weaver between 1835 and 1840, the actual date being probably in the year 1838. The next improvement of importance was the introduction of the present method of picking by the cone and bowl in looms constructed on the Blackburn principle, or the modern over-pick, otherwise sometimes called the side-pick. This occurred about the year 1852, and, appropriately enough, originated in the establishment of the original inventor of this loom. Singularly enough, like the loom itself in the first instance, it does not appear to have been deemed of sufficient importance to be patented. At all events, no record is discoverable of either in the Abridgements of Specifications on Weaving. It was, however, found so superior to the older form of the lever-pick then in general use, that it quickly displaced it, being easily substituted.

Contemporaneously with the development of the power-loom, which in this chapter it has been endeavoured in its essential principles to trace, there were many hundreds of improvements in details, and many hundreds more of attempted improvements, but which in practice did not sustain the claims made on their account. These it has not been necessary to notice, though much that is curious and interesting to the technical student could have been found in them. Useful lessons might also have been deduced from them, as very often failures are more pregnant with instruction than instances of success.

CHAPTER IV.

Weaving and the Construction of Woven Fabrics.

The principles of weaving.—Its simplest form.—The variety of weaves.—Texture of plain cloth.—Healds and reed.—Weaving with one shaft of healds.—Ornamentation of plain cloth.—*The plain weave*, and its variations.—*The three-shaft twill;* designs and drafts.—*The four-shaft twill;* designs and drafts.—*The five-shaft twill;* designs, etc.—*The six-shaft twill;* designs, weave plans, and drafts.—*The seven-shaft twill;* designs and weave plans.—*The eight-shaft twill*, and variations.—*The nine-shaft twill.—The ten-shaft twill*, etc.—*Double and multiple cloth weaving;* description.—The fundamental principles of double-cloth weaving; numerous illustrations.—The laying out of fancy double cloths.—*Crimped cloths;* how to get the best effects; illustrations.—*Gauze or Leno weaving;* description.—Best expression of the gauze weave.—Light and elaborate effects.—*Cords, velvets, velveteens, plushes, moleskins;* descriptions and illustrations.—*Jacquard harness;* the London and Norwich ties.—The hooks of the jacquard machine.—Building the harness.—*Damask weaving;* the shedding capacity of the jacquard machine.—Designing for the jacquard.—Design or point paper.—Simplicity of jacquard drafts.—"Casting out" hooks and mails.—*The analysis or dissection of woven fabrics;* points to be noted, and method of procedure.

THE principles of an art may be called its foundation stones; and the natural consecutive developments from them the successive courses of the building contributing to the formation of the structure that, in its finished state, becomes a thing of utility, beauty, and a joy for ever. Some people may regard this as exaggerated language to apply to the somewhat homely and prosaic art of weaving, as they are accustomed to regard it. But such opinions, where they exist, may safely be attributed to an imperfectly developed capacity of observation, rather than to the absence or deficiency of beauty in the thing observed, when that is the art of weaving. The primary object of the art is the provision of raiment for mankind, and for use in their dwellings. The fabrics devoted to these purposes may be plain, or be slightly or elaborately decorated. These, in their corresponding degree, call into requisition the simple, medium, or the most complex principles and mechanism of the art in order to produce the desired results. This chapter will, therefore, be devoted to an attempt to expound these principles, leaving the mechanism for subsequent review.

The writer has already, in a previous chapter, defined weaving as "the art of arranging, at right angles to each other, two or more series of threads of any suitable material, and binding them together by passing each thread under and over, and sometimes partially around, one another in regular alternation, or in such other order as may be needed to produce the required effect, by which arrangement they assume and retain an expanded form, rendering the fabric adaptable to many uses."

This definition might very properly be enlarged as not being sufficiently inclusive, as it does not bring in several classes of textile fabrics that can be made from a single thread. As instances of these we may point out knitted fabrics, nets, and point lace. Besides these, of which some people may doubt the appropriateness of the classification when brought within the category of textile fabrics, it is possible, and not only possible but a common practice to make fabrics in this manner from single threads. When in the production of these classes of fabrics the number of threads is increased, as they may be in knitting, netting, and the making of pillow lace, it is usually done to facilitate production, or to obtain a greater variety of results. As, however, it is not within the purpose of this work to give an exposition of these phases of the textile arts, but of the principles of weaving as ordinarily understood, they will not require more than a very slight reference.

In the interests of textile students, however, before leaving this point, we may observe that a properly woven fabric as ordinarily understood, and including warp and weft, may be made from one single thread. As an experiment to prove this, let the student take a needle and a length of cotton thread, and, using it singly, pass it backward and forward, say through two pieces of paper kept an inch apart, for about twenty times, placing the thread at each passage alongside and parallel with the one put in before. This will give forty warp threads. Next turn the needle to the side of these, and pass it under and over each thread in succession until the needle passes out at the opposite side, drawing the thread close up. This done, reverse its direction, and alternate the interlacing until it emerges near where it first entered. Repeat this process until the thread in the needle is used up, or the warp threads are filled. In both cases take care that the threads are placed parallel and close together. It will then be seen that a perfect piece of cloth has thus been made, and if done skilfully it would not be easy for other than experts to say that it had not been produced by ordinary appliances. This is the irreducible simplicity of weaving, and as thus described is often used to effect repairs to fine linens and other fine fabrics in Germany, where the women are exceedingly skilful in such work. In England it is occasionally seen in the woollen districts, and in humble homes resort is had to it for mending hosiery, when it is familiarly known as "darning." With these observations on the elementary principle we may proceed to a more methodical exposition of the subject.

Weaving is the name given to the art of constructing textile fabrics. It is of the most simple, or the most elaborately complex character, according to the requirements of the articles sought to be made. The simplest form, as ordinarily understood and practised, requires the employment of two series of threads only. These are respectively termed the warp and the weft, or, as the latter is sometimes termed, the woof. The last name, however, is an archaic form of the word. The warp consists of the longitudinal threads, or those which extend in the direction of its greatest length. The weft threads are the transverse ones, or those that pass under and over the warp threads from side to side. The warp threads may be of any length according to requirement or convenience; the requirement being that they shall not be less than is necessary to make the piece of cloth long enough for use for its intended purpose; and the convenience being that they shall not be longer than in the aggregate form of the warp can be conveniently handled or dealt with in the process of weaving. The minimum length of the weft threads is that required to go across the warp. In practice, however, they are always much longer, being formed into pirns, placed into shuttles as large as can conveniently be used, and so drawn off and left in the warp as the shuttle makes its rapid successive passages. Thus in the cotton trade each warp thread may be anywhere in length from 500 to 1,500 yards or even more; and each weft thread from 200 to 1,000 yards or more, according to the fineness of the counts being used, or the capacity of the shuttle to carry it.

If the almost countless methods and combinations of methods now in vogue in weaving be carefully analyzed they will be found capable of being reduced to a very small number of weaves. The following are the principal:—plain, twill, satin, spot, flush, cross-warp, and double-cloth textures. These each and all give their own simple results, and by combination they can be made to yield an almost infinite variety of complex ones. Simple and complex are alike obtained by the variations in the order by which the threads of the warp are lifted and depressed for the reception of the weft. This action is the shedding process, and correspondingly the means employed to produce the effects rise from the most simple to the elaborately complex shedding power of the modern Jacquard machine. The fact also ought to be noted here that this capacity for producing variety is enormously

increased when allied to the power given by the use of the system of multiple shuttle boxes of either the rising or revolving order.

The plain texture may be regarded as the foundation of all others, and therefore first calls for description. Let the student obtain and examine a piece of common calico, the coarser the better for his purpose, only taking care to obtain it of the full width. Examination will show it to consist of two series of threads, longitudinal and transverse ones. It will be observed that the warp threads lie parallel to each other in a common plane. The weft threads, it will be seen, intersect those of the warp, passing under and over them in alternating succession. Fig. 23 shows this construction plainly, the vertical threads, A, B, being warp threads, and the horizontal threads 1, 2 being weft threads. The detached portion of the figure at the top is a section, enlarged a little to show the construction clearly. The student's sample will show the manner in which the weft threads are returned at the edges, the cloth making what is termed the selvage. In the actual process of construction the warp threads are maintained in a more or less tense condition, so that they are taken into the web of the cloth apparently in a straight line. But this is not actually so, as there is always more or less deflection into a more or less waved form, according to the thickness of the weft thread being inserted, and the degree of tension upon the warp. A similar deflection occurs in the weft threads, and when

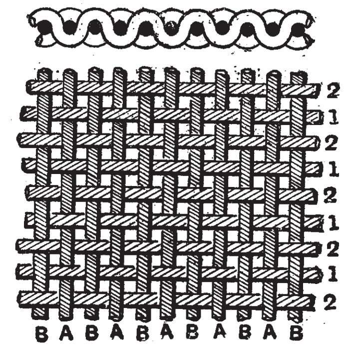


FIG. 23.

the giving way in this respect is mutual and about equal, the two series of threads are bedded together in the best manner. At the option of the weaver, and according to requirement, this flexure may be thrown into either the warp or weft threads. In the section given in the figure it is shown in the weft threads.

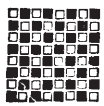


FIG. 24.

The design of this plain weave cloth, placed upon what is termed " point " or design paper, would appear very much like the squares of a chess-board. It is shown in fig. 24. Let it be assumed that the warp threads are white, and the weft threads black, and that the former run in a vertical direction, and the latter in a horizontal one. In the intersection of the threads which this represents the white squares show where a warp thread is uppermost, and the black squares where the weft

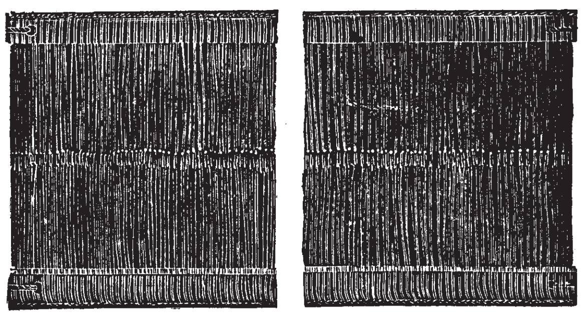


FIG. 25.—SHAFT OF HEALDS (BROKEN).

thread is on the top, and the warp thread down. The order of this alternation shows a plain weave, in silk weaving called a "tabby."

To obtain this result the weaver requires to have a certain control or command over the threads of the warp, in order to depress or elevate them in the manner re-

quired. This he gets in his shedding apparatus, the immediate instrument in this case being the heald, into which the warp threads are drawn.

The heald or heddle is composed of a cord formed of several strands of cotton, worsted, linen, or silk, but those used in the cotton trade are now in the main made of cotton, though still occasionally of worsted. A shaft of healds is shown in fig. 25, and a section of a set for weaving plain cloth in fig. 26. Healds are made upon a beautiful automatic machine exceedingly ingenious in construction, but space for a description here is not available. The eye in the centre, and through which the warp thread is drawn, is knitted into it when being made. The eye is formed of what is termed a mail, which may be made of steel, brass, or glass. The knitted eye is, however, the form in almost universal use in the cotton trade. These healds are mounted upon and stretched between two wooden laths, as shown in fig. 25, to the number of from 200 to 700, or more, according to the fineness or width of the cloth to be

FIG. 26.

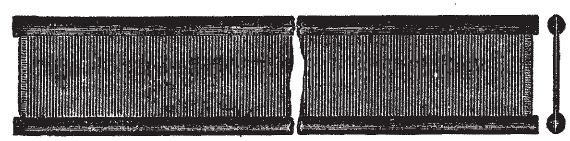


FIG. 27.—REED. SECTION.

woven. So mounted they form a leaf or shaft of healds or heddles, and a number of these, from two to ten, or even more, constitute a set of healds, the number of shafts varying according to the character of the weave intended to be employed. Two are all that are really required for a plain weave, but owing to the greater facility obtained in the way of condensing the warp, or bringing its threads together, and minimizing friction upon the warp when being woven, four are generally used. Fig. 26 shows this arrangement. The two front leaves ascend and descend in the shedding together, and the two back ones in a similar manner alternate with them; that is, when the front ones are up the back ones are down, and *vice versâ*. The draft or order in which the threads are entered into the healds is as follows, reckoning from the front or the shaft of healds nearest the reed of the loom, and commencing on the left-hand side of the healds:—the first thread is drawn in the heald on the first shaft, and the second thread upon one in the third shaft; these two threads go together into the first dent or space in the reed; the third thread is taken into the first heald on the second shaft, and the fourth thread into the first on the fourth shaft. This order is repeated and continued with the remaining portion of the warp until it is all drawn in. It is usual, however, in commencing the draft to draw two threads through each heald instead of one, for the first dozen healds or so, and to finish off in the same way. These double threads are called selvage threads, properly self-edge threads, and are purposely made stronger by doubling to resist the drag of the weft upon them, as it is returned into the shed. Sometimes the two outer threads are made threefold, and again, in very good fabrics, special selvage threads are introduced of twofold twisted yarns.

At this point it will be appropriate to describe in a very brief manner the reed, the ever-present adjunct of the healds. It is so named from having been originally composed of split reeds, the vegetable product of that name. It is now made of iron or brass, but mostly of the former. Wire of the required gauge is rolled and flattened to proper dimensions, highly polished, and run on a reel. It is then transferred to a reed-making machine, another of the wonderfully ingenious machines, adjuncts of the textile trades. The reed machine is furnished with the parts of the reed termed the reed back, composed of two strips of

wood each for the top and the bottom. The machine is also supplied with two reels of pitch twine. Being set in operation, a strong or terminal dent is first put in, when the machine begins to cut the flattened wire into short lengths, and to place them successively in position with their ends between the two pairs of strips forming the backs. When one of these short lengths, or dents, as they are called, has been pushed forward, it is immediately secured in position by the machine wrapping a turn of the pitch-band close up to it around the two strips. Another strip is then advanced and the operation repeated, and so on until the reed is made of the required length. It is then finished off with another strong and broad dent. Fig. 27 gives an illustration of a front view and section. The more openly these dents are set in the reed the coarser or lower are its counts; and the closer they are the finer it becomes. This is all that is necessary to state in this place regarding it. The remainder will be more properly told in another section.

Before leaving this point, we may observe that since writing the above, the author has been informed by a textile expert that, in his young days, when on a visit to Ireland, he saw the rough frieze being woven with a single shaft of healds. This is a fact that will be interesting to the student, as it singularly and most remarkably confirms the theoretic elucidation of the progress of invention in the art of weaving given in Chapter I., pages 26 and 27. It would be highly interesting to learn whether this primitive method is still anywhere followed in Ireland.

It must not be assumed that ornamentation cannot be put into a plain weave cloth. There are several methods of effecting this. The first is by making what are called tape stripes parallel with its length. These are made by drawing-in the warp in double threads similar to the manner of the selvage threads, and doing this according to any given design. Many fabrics are made in this way, though not so many now as was once the case. Sometimes the effect is obtained by the use of two counts of yarn in the warp, fine and coarse, the latter to form the tape. Another variation can be introduced by using two counts of wefts and a two-shuttle loom. In this case a cord weft is introduced for a few picks at regular distances, making a stripe across the cloth. The first-described are termed "stripes," really parallel stripes; the latter are called "cross-over stripes," to distinguish them from those parallel. A further variation is obtained by the employment of these two methods in combination. This produces a class of fabrics termed "tape-checks." A great variety of these can be made, and formerly they were a very popular fabric. Another line of variation is obtained by the introduction of cords, as seen in the familiar instance of handkerchief borders.

It will be obvious that many other combinations and variations in ornamentation can be made by the introduction of coloured yarns in the warp and in the weft and in both. These need not be further enlarged upon, as an almost endless number will suggest themselves. The whole class of ginghams are types belonging to this division.

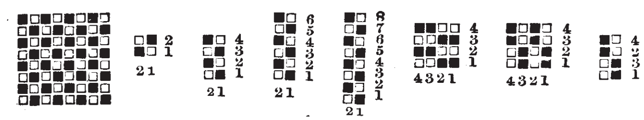
The Plain Weave.

A more technical exposition of the various weaves may now follow: the plain weave naturally comes first. Let the reader bear in mind that all the black squares in the design and weave plans given in this weave and its variations show weft intersections in which the weft rides upon the top of the warp threads; and that the blank or white squares indicate that the warp in that position is uppermost, and the weft below. If the weft did not interlace with the warp in this manner all would be blanks and the formation of a woven fabric impossible.

Fig. 28 gives the design as already explained. This consists of two warp and two weft threads crossing each

other at right angles. In coarse, open cloths, such as canvas, etc., two heald shafts would be sufficient. The draft or weave plan, which means the order in which the warp is drawn into the healds, would then be represented in A. The numbers on the right-hand side indicate the draft of the warp threads through the healds on the shafts in the order of their arrangement; and the figures at the bottom show the order of the weft picks. As explained before, where a great number of warp threads require to be dealt with, and concentration is necessary, as in fine cotton, worsted, and silk fabrics, four, six, or eight heald shafts are introduced in order to secure a better distribution of the warp threads, thus diminishing the crowding, reducing

FIG. 28. A. B. C. D. E. F. G.



PLAIN CLOTH, WITH THE DESIGN, WEAVE PLANS, AND VARIATIONS.

the friction, and lessening the breakages of the threads that would otherwise occur in the weaving of closely compacted fabrics. In these cases the drafts B, C, and D would represent respectively the use of sets of healds of four, six, and eight shafts, and the order of warp drafts for them. In such drafts the shedding is easier as the threads pass each other with less friction, and both yarn and healds are opened more easily to take up broken threads when these occur.

Whilst two, four, six, or eight shafts are commonly used for plain cloth, any even number will give the same result, providing the warp threads are drafted in consecutive order, and the odd numbers of the shafts can be lifted together for one shed, and the even numbers together for the alternate one.

Some observations have already been made upon the methods of ornamenting plain cloths, and a few more may be permitted, as it is quite a mistake to suppose that the plain weave is incapable of yielding ornamentation. It has been shown how tape stripes and checks, both in plain and coloured goods, can be produced. These will yield some very effective patterns for muslins and light zephyrs, whilst mock gauzes, in which a series of reed dents are left without warp threads, form another interesting class in plain weave fabrics, the beauty of which can be further enhanced by the introduction of coloured yarn.

The draft E shews a warp cord, and the draft F a weft cord or rep. The thickness of the cord in the warp may be carried to any extent by increasing the number of threads that form it, or it may be obtained by introducing a second warp of coarse yarn. The weft cord, or rep, by introducing catch cords at the selvages may have any number of picks put into one shed, and these can be bound down by one or more picks in the alternate shed. Of course in the power-loom this implies the introduction of an intermittent shedding arrangement. As in the warp cord so in the weft, coarse and fine counts may alternate to give the effect. By a combination of warp and weft cords squares of basket figures or checks can be produced in endless variety, which make not only useful but beautiful fabrics. A plain weave also forms a secure basis or ground for Jacquard figures.

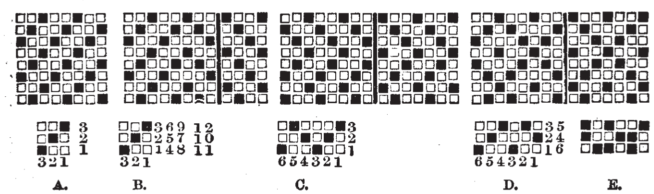
In the interweaving of coarse and fine yarns of warp and weft it is necessary to exercise judgment and care in proportioning the quantities, and particularly in cord effects.

Calicoes and nearly all ordinary plain cloths are woven with what is technically called a skip-shaft draft. This is shown in the draft G, which has been explained before. The four heald shafts rise and fall as if they were two only as will be seen on a glance at the marginal figures.

The Three-Shaft Twill.

The three-shaft twill next comes under notice. This weave is known by many names, such as drill, regatta, Jean, Jeanette, Llama, etc. It is the first departure from the plain weave and is the simplest weave after it. It is worked, as its name indicates, by three shafts of healds which work independently of one another, rising and falling in regular sequence in the order of their arrangement from the front, 1, 2, 3, 1, 2, 3, in continuous repetitions. Its effect is to throw up distinct ridges of weft that run diagonally across the cloth, ascending from left to right. This is caused by the weft always passing under

FIG. 29. FIG. 30. FIG. 31. FIG. 32.



THE 3-SHAFT TWILL, WITH DESIGNS, DRAFTS, ETC.

two warp threads and then over the next, as shown in the design (fig. 29) and its draft, A. It would appear from a casual glance at the design that it would not admit of much variation. It is, however, capable of considerable ornamentation, as is shown by the succeeding designs (figs. 30, 31, 32). Their respective drafts accompany them. In fig. 32 an alternative draft is given. A very bold twill figure, the diagonal rib, can be obtained by the employment of heavy yarns, and a fine effect by the use of fine yarns and closely set reeds. This twill is extensively used for light fancy lining cloths, and it generally forms a base for thicksets, velveteens, cords, and heavy fabrics. As a simple form of decoration, without colour, it is one of the most useful weaves in the whole list for diaper, herring-bone styles, and other goods. When employed in the woollen trade it is sometimes called the prunella twill, and it is known in the Bradford worsted trade as the Llama twill. By introducing coloured yarns and arranging them one and one, say black, blue, and white, the diagonal stripes may be crossed and form a series of checks or hair lines, giving a result that cannot be obtained from any other twill weave. In design, fig. 30, is shown an alternated reversal of the weave, forming what is called a herring-bone twill, from its supposed resemblance to the backbone of that fish. The next design (fig. 31) shows a transverse herring-bone; that is, the former design is made to have its line of direction across the cloth instead of, as before, along its length. Design fig. 32 is a diaper, its plan and draft being given in D. Weave plan E is that of a double twill, by which distinct colours can be obtained on each side of the fabric; for instance, with a white warp and a brown weft the warp would be thrown up, giving the fabric a white face, whilst the weft being thrown down would give a brown back. This may be regarded as a mock double cloth in which the backing is weft.

The examples given will show that this weave may be made a very useful one in the weaving-shed if a little judgment be exercised in its application and in the selection of suitable materials and colours. With these aids a great number of excellent effects may be obtained from this apparently comparatively inflexible weave.

In extensive designs of floral treatment, or other figures, this twill forms a good firm ground as a binder of either warp or weft threads.

In plain cloths it was stated that the yarns used in making them gave the best effects when the twine or twist was in the same direction, because yarns thus constructed imbed themselves better in each other, and so produce a more level and closely compacted cloth, which is the object sought. In twills, on the contrary, the development of the figure is a principal object sought, therefore the angle of direction of the twill should be in opposition, and not coincidence, to that of the yarns used in order to prevent the bedding effect of the alternate course, and so help to develop a clear and bold effect in the line of the twill.

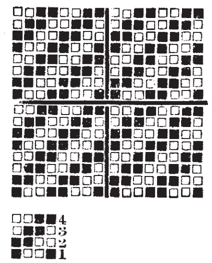
The Four-Shaft Twill.

The next step brings before us the four-shaft twill. It must be borne in mind that every step forward made by the addition of another leaf of healds gives increasing capacity of figure production to the weaver, enabling the weaver, to borrow a metaphor from the church belfry, to ring an additional number of changes upon his instrument, the loom.

The four-shaft twill is variously known as the cassimere, kerseymere, serge, blanket, florentine, swansdown, crow, etc. It is in almost universal use in the weaving world, entering more or less into the composition of fabrics of every known textile fibre. It can be adapted to any counts of yarn and produce satisfactory results. In the fustian trade it is extensively used for plain-backed Genoa velvets, velverets, thickset cords, and an endless variety of patterns for suitings, trouserings, etc., in woollens, worsteds, fine hair lines, warp face figures, etc. It is impossible to enumerate in any reasonable space all the changes that can be made by the weave and draft of a four-shaft twill either alone or in combination with other weaves. The examples given herewith will, however, serve to point out to the student a portion of its capabilities, and indicate the lines upon which he may develop others for himself. The first design shown (fig. 33) is the ordinary disposition of this twill as seen in its common use. It is accompanied by its weave plan and draft, A, as usual. In the next (fig. 34) is shown the herring-bone or ticking stripe, a design much used in making bed-ticking and pillow-case fabrics. The draft is shown at B, the weave being the same as A.

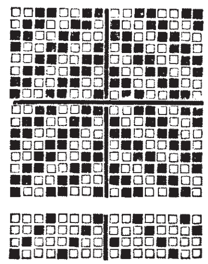
The next design (fig. 35) shows a check formation which may be extended to any size by repeated drafts and

FIG. 33.



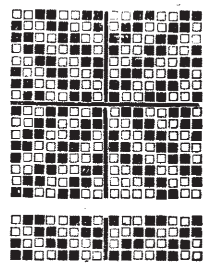
A.

FIG. 34.



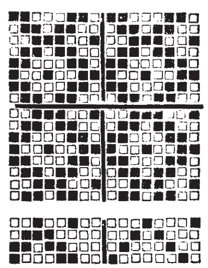
B.

FIG. 35.



C.

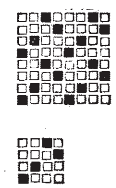
FIG. 36.



D. D1.

FIG. 37.

FIG. 38.



E.

THE 4-SHAFT TWILL: DESIGNS, WEAVE PLANS, AND DRAFTS.

threads. The weave plan appears in C, whilst the draft is a repeat of B, fig. 34. Many beautiful effects can be produced by this weave and method of drafting.

The following design (fig. 36) is one for a diaper cloth, and its weave plan and draft are shown in D and D′.

The next design (fig. 37) is that of a double twill. In

this the face may be made very fine, and the back be weighted with much coarser material. It is mostly used in cotton quiltings and mixed goods of cotton warp and woollen wefts. The amount of material put into the fabric will, to a certain extent, govern the application of the rule previously laid down regarding the direction of the twist of the yarns used. Where the warp is used in the production of the face cloth, the same regard to the direction of the twist is not imperative; it is when the warp and weft are equally balanced in counts that the observance of the rule becomes important.

In design fig. 38 the satin twill is delineated with its accompanying weave E. This form of twill though not perfect, is used for the bulk of cloths having the greatest portion of either their warp or weft brought to the surface.

The Five-Shaft Twill.

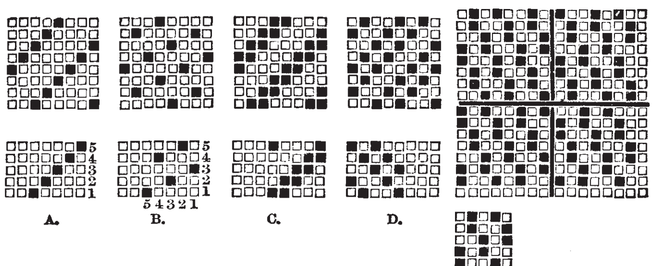
The five-shaft twill is the next on the roll. This is used for heavy fabrics, such as drills, sateens, doeskins, damasks, etc. In fancy diaper cloths it affords great scope for the production of varieties. It is the first perfect satin twill, and it yields many derivatives. Satin twills give a peculiar angle when formed by warp threads. They yield greater strength in the lengthway of the fabric than most other weaves of this type. The reader must here be guarded against the possible confusion that may arise between the terms satin and sateen. The former is the weave employed in making the silk fabric termed satin, in which the weave effect is obtained by throwing the warp to the surface, thus showing the threads running parallel with the length of the fabric; in the sateen weave the weft is thrown to the surface, and the line of the visible threads upon it runs across the cloth from side to side. When the sateen or weft twill is used, the satin or warp twill is simply thrown to the back of the fabric, and *vice* *versâ*. This principle governs both of these weaves whenever they are employed.

In the design fig. 39 is given the ordinary weave of the five-shaft twill; A shows its weave plan and draft.

In design fig. 40 the satin weave is given, and in B its plan and draft.

In design fig. 41 a fancy twill is given, and in C its weave is shown. As will be seen by referring to A (fig. 39) there is merely an additional black square introduced and placed below each of those in the original plan. This

FIG. 39. FIG. 40. FIG. 41. FIG. 42. FIG. 43.



THE 5-SHAFT TWILL DESIGN, ETC.

makes two each in the run where there was only one before. An excellent effect is obtained from it.

The design shown in fig. 42 will give a very firm weave, in which there will be no risk of the threads of the fabric slipping. It is very suitable for linings. Its plan appears in D.

Design fig. 43 is derived from that shown in fig. 40, and is obtained by the introduction of another dot for each of those in the former design. Its plan is shown at E.

All the drafts in these examples are straight-over drafts. Numerous other weaves might be brought forward to show the wide range of usefulness of this twill, but those given are their foundations and the ones from which they are derived. The combinations that can be

made of these yield many interesting results, and the exercise of developing them would be most useful to the student.

As a ground for figured effects the five-shaft twill is much used by designers for all kinds of silk, cotton, linen, woollen and worsted goods.

The Six-Shaft Twill.

This is deservedly a favourite basis for almost every class of fabric, and with colours in warp and weft will give numerous combinations.

In design fig. 44 is given the basic arrangement of the weave, showing equal flushing of warp and weft. The weave plan, A, it will be seen from the figures on the margin, is a straight-over draft.

Design fig. 45 is also a form of twill very frequently seen; in this there are more warp threads brought to the surface. The weave plan, B, shows it to be a straight draft.

The next design (fig. 46) divides the diagonal figure into two portions, bringing a warp thread up between the floating weft threads. In this design, instead of floating three and sinking three, they float two, sink one and float one. This arrangement increases the firmness of the fabric from that of fig. 44, but sacrifices some capacity for a display of colours. The weave plan is C, a straight draft.

In design fig. 47 is given a variation, suitable and in use for diaper patterns. In the weave plan, D, the draft is shown by the figures at the margin.

Design fig. 48 exhibits a satin as made on six shafts. The weave, E, shows it a straight draft. This is termed one of the imperfect satins, though largely used as a ground for figured effects.

There are numerous derivatives from all regular twills, producing the effect of several portions of a twill combined in one weave. The six-shaft twill under notice affords numerous examples, one of which, with the explanation of its formation will suffice to show how others can be con-

FIG. 44. FIG. 45. FIG. 46. FIG. 47.

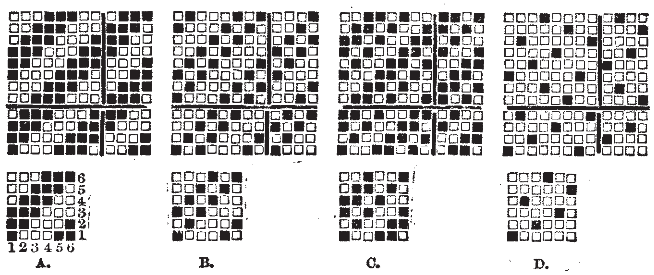
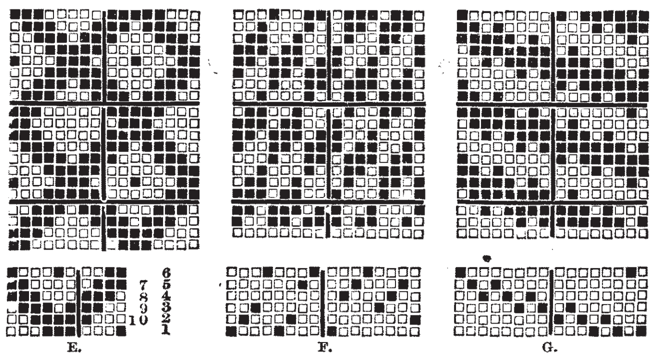


FIG. 48. FIG. 49. FIG. 50.



THE 6-SHAFT TWILL: DESIGNS, WEAVE PLANS, AND DRAFTS.

structed. For this weave plan A (fig. 44) may be taken as a foundation. The number for counting off determines the number of threads to be used in each part before changing. The number to be left out shows the number of threads to be skipped, and also gives the number of the thread on which the next change will take place.

As an illustration, design fig. 49 is given. The number of threads used in this are three for each change, whilst two threads are left for each skip. By referring to the figures given at the bottom of the weave plan, A (fig. 44), the arrangement of the threads in the design can be easily followed by observing this rule. The full repeat is shown, F being the draft.

Design fig. 50 is another form of construction, G being the weave plan. In these drafts the warp threads are evenly distributed over the shafts, no shaft being overloaded. From a weaver's point of view, this is a great advantage in weaving many fabrics composed of fine, tender yarns. The number of threads used for a change may be increased, as, for instance, a design may be constructed from the weave plan, A (fig. 44), by counting six and skipping two. In fact, the capability of changing is almost inexhaustible, and offers a fine field for study to the textile student. In every twill, whatever may be the number of shafts, this system can be utilized with the most satisfactory results. These remarks will obviate the necessity of going over the same ground again in other examples to be brought forward. They will also be found sufficient to convey the necessary practical information for developing new ideas and obtaining fresh and useful weaves.

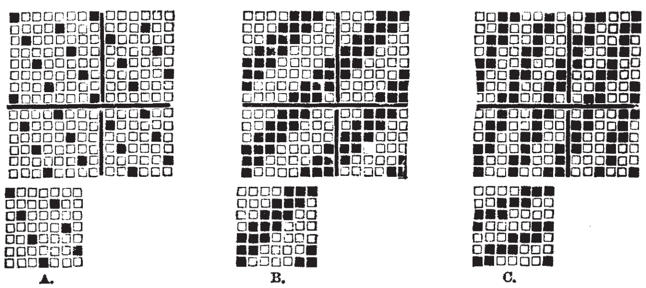
The Seven-Shaft Twill.

The seven-shaft twill, which we now proceed to notice, conducts the student another step forward in the path in which he obtains increased capacity. The first design given (fig. 51) is a satin, A being the weave plan. This is a perfect satin, as we may observe, in passing, are all satins that are formed by an odd number of threads in the straight-over draft, or in the number required to form a complete pattern. There are many rules given for the placing of the wefts dots or intersections in a satin weave, but the simplest method is the best. This is to take the first number after one that is not a measure of the shafts or repeat threads. Thus three would be the first number in seven after one, therefore this may be used to count with as follows:

1, 6, 4, 2, 7, 5, 3.

The dots represent the seven shafts or threads. This gives one plan of intersections by the use of three as a measure. But four may be used also as it is not a

FIG. 51. FIG. 52. FIG. 53.



THE 7-SHAFT TWILL: DESIGNS AND WEAVE PLANS.

multiple of seven, and this would give the following arrangement:

1, 3, 5, 7, 2, 4, 6.

Upon this principle the intersecting dots of any satin may be found; and on reference to design fig. 51 it will be seen how these latter figures have been practically applied.

Design fig. 52 is a regular seven-shaft twill, with its accompanying weave plan, B, a straight draft.

Design fig. 53 is a derivative twill with a more vertical

figure, obtained from the satin arrangement of fig. 51. Its weave plan is given in C.

The remarks made about the six-shaft twill apply with equal force to this and all other twills, so that there is no need to increase the number of examples, as, by following the instructions given, any number can be constructed with facility, whilst by combinations with other twills, reverse drafts, and colours, the capacity for obtaining variation of effect will be found to have hardly any limit.

The Eight-Shaft Twill.

The eight-shaft twill is again richer in its effects and variations than the preceding. In design fig. 54 is given the ordinary eight-shaft twill, straight draft and weave plan, A.

Design fig. 55 is a fancy broken twill, formed from the weave plan, A, fig. 54. The draft is given in B, and the extended weave plan in C. This example will prove a good study for the student, because a further fresh disposition of the draft would bring out another formation equally useful and ornamental.

Design fig. 56 is a diaper arrangement constructed from the V draft D, its weave plan being given in E. It will now be quite obvious that any other eight-shaft weave with the same draft would give further novelties.

Design fig. 57 is a satin with its weave, F, the draft being straight over.

Design fig. 58 is a combination on eight shafts of design fig. 54 and its satin arrangement, which will give a stripe effect. Naturally it will be evident that the width of the stripe can be increased by an extension of the draft given at G. The weave plan is the same as A of design fig. 54.

It would be quite impossible to give any adequate conception of the number of changes that can be brought out

FIG. 54.

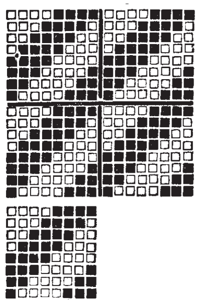


FIG. 55.

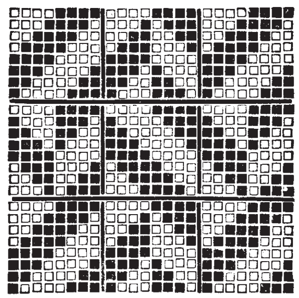
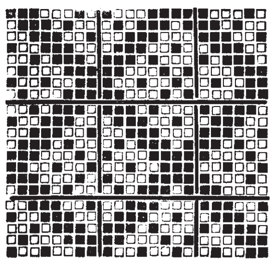
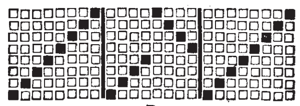
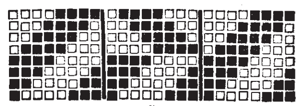


FIG. 56.

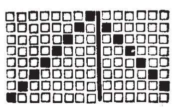




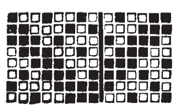
B.



C.

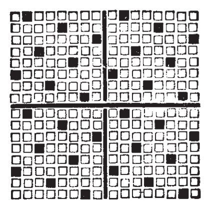


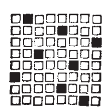
D.



E.

FIG 57.



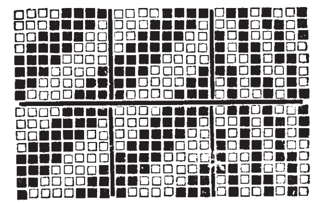


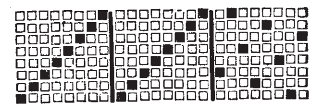
F

THE 8-SHAFT TWILL AND VARIATIONS.

from the drafts, etc., but the examples given will serve to represent the main features. As foundation weaves they will produce highly desirable results when wrought in well-chosen materials.

FIG. 58.





G.

THE 8-SHAFT TWILL *(continued)*.

The Nine-Shaft Twill.

The first design given here (fig. 59), is for a satin twill, the weave plan being given in A; straight draft.

Design fig. 60 is one of the many forms used for fancy weaves in either stripes, checks, or colours. Its weave plan, B; straight draft.

Design fig. 61 is a broken form of the twill, giving novel effects. The draft is shown at C. This, to the technical student, is an instructive and suggestive design, as though, in reality, there are only nine threads, yet by the use of the weave plan, D, their skilful distribution gives in the design shown twenty-seven threads to the round or full figure. This figure may be re-arranged by the alteration of the draft. Care, however, requires to be taken to compose the draft in such a manner that, as

Fig. 59.

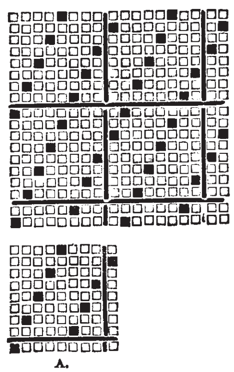


Fig. 60.

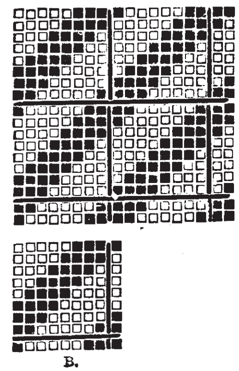
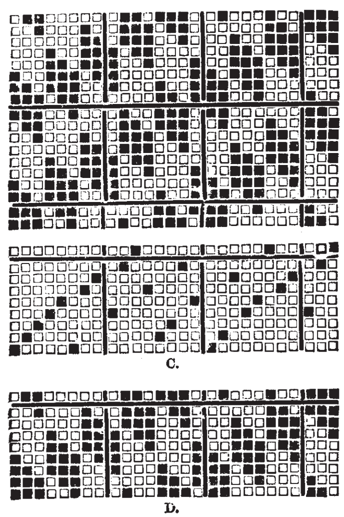


Fig. 61.



The 9-Shaft Twill, etc.

in D, the shafts shall carry an equal number of threads, namely, $9 \times 3 = 27$. This gives three repeats of the nine threads to one figure of the fancy pattern. This required care observed, a perfect joining of the pattern will be made.

From designs such as are here given any number of patterns can be obtained by a slight study of the draft and weave arrangements, the essential point for consideration being to make them neat, chaste, and beautiful, so that when wrought into suitable kinds of fabrics, they may prove of high commercial value.

The Ten-Shaft Twill.

This is the last of this series proposed to be given, as it may be fairly assumed that their fundamental principles will then have been fully treated.

The first design (fig. 62) is a ten-shaft satin, with its weave plan, A; straight draft. If sateens are required to be made on any number of shafts, all that is necessary is to bring the back of the satin cloth to the face; that is, to work one shaft up successively all through the series, and the others down.

In design fig. 63, which is for a fancy fabric, the figure is of the diagonal type, having combined with it a Vandyke border; B is the weave plan; straight draft.

From fig. 63 is derived the next design (fig. 64) with the B weave plan, and the same straight draft. In this way it yields a broken-up effect, very useful in woollen and kindred fabrics, or where type effects of a similar character are required.

In the next design (fig. 65) an extension is made in order to show the joinings of the figures; C is the draft, and D the weave plan. By doubling or tripling this form of draft, a very complicated series of figures could be obtained that would appear as if woven with a Jacquard machine.