1.1 Introduction.

In the nineteenth century, as a result of continuous improvements made to power looms, the necessity for close attention was so reduced that eventually one weaver was able to supervise up to four or six looms. The weaver's work mainly consisted of replenishing the shuttle with weft and repairing warp and weft breaks. Each of these tasks involved a stoppage of the loom. However, if good quality yarns were used, the frequency of warp and weft breaks was comparatively low. Thus, it may be said that the output of the loom depended chiefly upon the frequency of stoppages due to the exhaustion of the weft, a frequency which, of course, depended upon the carrying capacity of the shuttle. This capacity was limited by considerations of shuttle size and weight. When these limits were reached, the number of stoppages due to weft exhaustion still remained considerable. It is, therefore, not at all surprising to find that from an early period in the history of power looms, attempts were made to obviate such and thereby increase both the productivity of the loom and the number of looms allocated to each weaver. These attempts were made along three distinct lines, namely (i) the automatic removal of an exhausted shuttle and the substitution of a loaded one, (ii) the provision of a continuous supply of weft from a stationary weft package by using grippers, etc. instead of shuttles, and (iii) the automatic ejection of a spent spool or cop holder from the shuttle and the substitution of a full one. Of these, the last mentioned was the first to gain a wide and lasting commercial success and the developments in this area form the subject of this study. It should be pointed out that this paper provides an account of the developments based on British patents, reports and comments in British trade journals and deals essentially with a U.K. perspective.

1.2 The definition of the automatic loom.

Generally speaking any power loom is automatic in that one operation follows after another without any involvement on the part of the operative. Throughout this study, however, the word automatic implies a further stage of automation in which the exceptional
circumstances as opposed to the normal are responded to automatically. The exceptional situations to be considered are the shuttle reaching the box, warp breakage, breakage or absence of weft and the exhaustion of weft supply in the shuttle. Although the development of normal operations are of some interest, it is the reactions to exceptional situations which form the subject of this study. Of these, the last (the weft replenishment requirement) is the major concern.

Automatic weft replenishment differs from the automatic response to warp and weft breaks and failure to reach the box in that it enables the loom to continue to operate without stopping or requiring immediate direct attention from the operator. It still requires indirect and less immediate intervention to keep the magazine filled with new pirns, but with a magazine of sufficient capacity (in relation to count of yarn) the work becomes routine, can be scheduled, and uses unskilled labour.

1.3 The developments leading to automatic weaving.

Until the middle of the eighteenth century, the textile industry was basically a domestic industry. Weaving was performed in the homes of the workers alongside farming. Towards the end of the century, however, the application of water, and then steam, as a motive power together with technical advance in spinning and weaving machinery led to the establishment of factories.

The work of the hand weaver mainly consisted of throwing the shuttle from one side of the shed and catching it at the other side using the other hand. Alternatively, and especially in the weaving of fabrics which were too wide for the arms of one man to stretch across the loom, two weavers were required on one loom. It is believed that handloom weavers could only insert about twenty picks a minute using this technology [1]. This method continued until 1733 when John Kay of Bury invented the 'fly shuttle' [2-4]. An associated improvement was made by Robert Kay, John Kay's son, who in 1760 invented the drop box, a device by which the weaver could bring into use any one of three different shuttles, each containing a different colored weft [3].

John Kay's invention of the 'fly shuttle' increased weaving productivity substantially and was perhaps the most important in the chain of inventions which ultimately revolutionized the weaving industry. It had a great impact on spinning, too, in that it destroyed the equilibrium which existed, up to that time, between the production and consumption of yarn. It created a greater demand for spun yarn, which in turn highlighted the relative inadequacy of the spinning machinery of the day and probably gave an impetus to technological developments in that area.
Kay's invention, in 1733, overcame the difficulty which had stood in the way of mechanically co-ordinated looms for a century*. Previous attempts had been made to produce mechanically co-ordinated looms as far back as the sixteenth century, and their failure had been associated with their inability to pass the weft through the shed satisfactorily. These machines often relied on levers to pass the shuttle through the shed [5].

Mechanically co-ordinated looms seem to have originated from the 'Dutch engine', which was invented in the sixteenth century and was capable of producing a number of narrow fabrics at a time [6]. A similar loom was patented by John Kay and Joseph Stell in 1745 which, like the 'Dutch engine', relied on the application of "any power" to run the loom [7]. These were very important improvements, so far as the weaving of narrow fabrics was concerned, in that the operations of opening the shed, throwing the shuttle, beating the weft and taking up the cloth as it was being woven, were all carried out by the loom. However, the development of a mechanically co-ordinated loom capable of weaving wide fabrics was a more complex problem, for in this context the methods used in ribbon looms were inadequate due to the fact that, while picking could be accomplished easily and safely in a narrow loom, it proved to be a major obstacle in wide looms.

The first mechanically co-ordinated loom capable of weaving wide fabrics seems to have been the work of a French navy officer, M. de Gennes, in 1678 [8]. The picking arrangement of the loom was rather interesting in that an endeavor had been made to copy mechanically the existing manual arrangements on hand looms. This involved passing the shuttle by means of a lever half-way through the shed where it was received by a corresponding lever on the opposite side of the loom, a principle which is in current use for weaving wire mesh. This was also the principle used in another attempt to construct a mechanically co-ordinated loom by Vaucanson in 1745 [9].

Another attempt was made by Robert and Thomas Barber in 1774 [10]. Most authorities seem to agree that the patent specification reveals a picking mechanism which was identical to the cone overpick, universally adopted in later years [5, 8, 10].

Mechanical co-ordination is clearly prerequisite for power operated looms. However, in this context, the inventions described above appear to have gained little or no commercial success. By contrast a series of inventions made by Dr. Edmund Cartwright, although in themselves of limited success, appear to have laid the foundations for power operated machinery. Dr. Cartwright took out his first patent for a power loom on

*At this stage, these were looms in which the movement of all the parts was co-ordinated mechanically but nothing more than human power was used to drive them.
the 4th of April, 1785 [11]. In this loom, the warp was placed vertically and the shuttles were thrown across the loom by "springs, the oscillation of a pendulum or the stroke of a hammer." It relied on the power of two powerful men to work the loom and was thus commercially no great achievement [12]. However, a year later he took out another patent which possessed a number of novel features [13]. One of these was a warp stop motion based on the use of droppers, a principle still in use in present day looms, although its action was probably less reliable then than nowadays, as may be gathered from the patent specifications. Like most current warp stop motions, Cartwright's used the momentum of the sley to apply the considerable force needed to disconnect the drive. Based on the same principle, an elementary weft stop motion was also provided. It is of interest that a mill at Doncaster was erected by Dr. Cartwright and filled with these looms but was not successful [14].

These developments led to the design of another loom by Dr. Cartwright in 1787 [15], which is universally accepted as the first important attempt at laying the foundations upon which the power loom was ultimately perfected by subsequent inventors. Again, the loom in itself was of limited success and the patent specification reveals the likely cause. This probably is associated with Dr. Cartwright's attempt to dispense with the separate operations of warping, sizing and beaming by providing a creel of bobbins from which the warp threads could be drawn and sized during their passage to the healds. Nonetheless, the loom possessed a number of novel features amongst which were a device for stopping the loom when the shuttle failed to enter the box and a temple. In addition, the loom appears to have included positive take-up and let off motions as well as warp and weft stop motions. Subsequent inventors, among whom William Horrocks and Thomas Johnson stand out prominently, made steady progress [8] in the development of the power loom until, in 1822, Richard Roberts [8] practically completed it by settling on what virtually became the non-automatic power loom of the day. The loom contained a number of improvements. These included improved wheels and levers to produce the requisite movement of the heddles where two or more shafts were employed, an apparatus for taking up the cloth, an improved let off mechanism and finally an arrangement for employing several shuttles, each containing a different kind or colour of weft.

Subsequently the development of a rotary temple by a number of inventors, namely Thomas Johnson and James Kay in 1805 [16], Ira Draper in America in 1815 [1], Joseph Daniel in 1824 [17], Andrew Parkinson in 1836 [18], William Kenworthy and James Bullough in 1841 [19], and John Railton in 1842 [20], made it possible for the weaver to operate more looms. Although Cartwright had endeavored to accomplish
self-acting temples in 1787, nonetheless, it continued to be normal practice for some time to control the selvedges of the cloth by a rod fitted with pins at each end which had to be repositioned after a few picks had been inserted.

Another development in this era was detection of broken weft using the weft fork. It appears that the first attempt to produce a weft stop motion in the form of a weft fork was due to John Ramsbottom and Richard Holt in 1834 [21]. This was one of the components of a vertical power loom in which two pieces of cloth were woven at the same time. The weft fork mounted on the stationary frame could penetrate a grid carried on the sley unless prevented by the presence of weft lying across and between them. However, it is also claimed that the same principle was used by Gilroy in 1831 [22]. This invention was improved upon by William Kenworthy and James Bullough and patented in 1841, and by James Bullough in 1842 [23].

At this juncture, a major element of the weaver's work consisted of stopping the loom before the weft supply became exhausted, replenishing the weft supply and restarting the loom. This work, and the strict supervision it entailed, made it possible for a weaver to attain a reasonable efficiency on no more than a very limited number of looms. Even during the early years of this century, a maximum of three to four looms to a weaver was common. The development of means for replenishing the supply of weft yarn by a mechanical device was, therefore, a major breakthrough. The most important developments in this area related to cop and bobbin changing looms which eventually gained great commercial and practical success, as will be noted later.

Cop changing, however, evolved first from shuttle changing, a procedure which extends back to 1834, a century after Kay had produced the fly shuttle. In that year, John Patterson Reid and Thomas Johnson patented a mechanism designed to change shuttles automatically when the weft broke or ran out in a vertical loom [24]. Shuttle replenishment was to be done by an instantaneous movement without stopping the loom, and with no action on the part of the operative.

Six years later, in 1840, a very similar shuttle changing mechanism was patented by Charles Parker [25]. In both these mechanisms each shuttle box comprised a drawer with two or more compartments and a shuttle was placed in each compartment. When the shuttle in one compartment ran out of weft, the other compartment was moved into the picking position and weft was supplied from the alternative shuttle. The weaver then had to replace the expended shuttle while the loom continued running.

Another line of development related to shuttleless looms. In 1844, John Smith patented a "needle loom" (rapier loom) which inserted double
picks only [26]. Two years later, W. Unsworth patented a loom which used two sets of weft carriers possibly related to selvedge formation. The fabric selvedges may have been incapable of withstanding the finishing processes, as was the case with regard to fabric produced on later types of shuttleless looms. This may also account for the time lag between the developments by Smith and Unsworth and the next shuttleless loom, which was patented in 1877 by G.H. Smith [5].

The origin of automatic bobbin changing looms extends back to 1857, when Patrick McFarlane patented what appears to have been the first cop changing mechanism. This incorporated means for automatically supplying mule spun cops which were carried in containers since their shape otherwise made them difficult to handle automatically. The arrangement was very similar to that of shuttle changing in that the weaver had to thread the cop through the eye of the container before placing it in the magazine. Later, however, the introduction of bobbins and pirns in conjunction with self threading shuttles made it possible to supply the bobbins to the self threading shuttle without a container and without any need for manual threading of the weft.

The introduction of bobbin changing looms led to a prospective increase in the number of looms which could be attended to by each weaver but to achieve this attention had to be given to the repair of broken warp and weft threads. In automatic weaving, it was imperative to adopt warp stop motions if the number of looms per weaver was to increase. The importance of warp stop motions obviously had been identified in the very early stage of the development of automatic looms in that there were over forty patents for stopping the loom upon breakage of warp threads in and before 1897. An effective weft fork was also required for similar reasons.

Devices for shuttle positioning and shuttle checking along with weft feelers and weft cutters were also of great importance. These, however, started to appear when the more basic of automatic looms were all developed.

The early automatic looms were only capable of weaving simple plain cloths for bleaching, dyeing or printing. Eventually, however, they became capable of weaving almost all types and classes of fabrics normally produced on non-automatic looms.
1.4 Weft preparation.

So far, the main features of the development of automatic looms have been introduced as if their development took place in isolation from that of the rest of the industry's technology. In fact, there were interactions between this development and that of other processes. Of these, the one which has most bearing on the development of automatic looms is that of weft preparation.

When cop changing looms were first developed, directly spun mule yarn was commonly used for the weft. However, in the absence of self-threading shuttles, and because of their awkward shape which made their mechanical handling difficult, mule cops had to be supplied to the shuttles of automatic looms in containers. After the introduction of self threading shuttles, attempts were made to supply skewered cops (without a container) to automatic looms but without much success. In consequence the mule cops had to be rewound onto bobbins for use in automatic looms. Alternatively, ring yarns directly spun onto bobbins could be used in automatic looms. Of these, the former was thought to be more appropriate, in that it offered the prospect of clearing the weft of faults during the winding process, which might be expected to reduce the frequency of weft breaks thereby increasing the benefits to be gained from using automatic looms.

It is not part of the present study to survey the development of winding machinery or of the types of pirns or bobbins used for weft supply. It is worth noting, however, that at some time between 1860 and the end of the century, machines for winding parallel sided pirns similar to those in current use had become available. Whether these were developed in response to the needs of automatic looms or were a completely separate development, they certainly made the development of automatic weaving much easier.

It is worth noting at this point that the terms cops, bobbins and pirns are used interchangeably in the patent specifications without specifying the true nature of the weft package. Therefore, in the following patent survey, no attempt has been made to specify the actual type of weft package used, and the emphasis is placed on whether or not the weft was supplied to the shuttle in a container.
2 Developments during the period between 1857 and 1900.

2.1 Introduction.

So far, automatic weaving has been discussed in general terms in the context of the history of power loom weaving. However, in order to be able to assess the capabilities of automatic looms at different periods, it is necessary to look in much closer detail at the developments as revealed by the more formally arranged patent literature after 1855*. It ought to be pointed out, however, that throughout a patent survey, there may be a tendency to conclude that each time an inventor applied for a patent it was somewhat better than previous patents and that it was the subject of a commercial application. It was, of course, quite possible that the patentee was not aware of the earlier patents, or that the new patent was a second (or even third) best method because the best method was already patented. Alternatively, the patentee may have patented the best method but still proceeded to patent alternative methods to obstruct competitors. It is also possible that an inventor was simply patenting a small refinement to, in effect, extend the life of the previous patents. For these reasons contemporary accounts and comments in the trade press have been referred to in an attempt to determine those ideas which were applied successfully and used commercially (although the degree of success cannot usually be ascertained). It must also be realized that reference to patent abridgements does not always permit an appreciation of the detailed working of each inventor's device, although the underlying principles can usually be determined.

The second half of the nineteenth century witnessed the development of the first reliable and successful single shuttle automatic bobbin changing loom and the principles adopted for weft replenishment were to become the main basis for future developments. By the turn of the century, the weft replenishing mechanism for changing one kind or colour of weft was technically quite suitable for the production of the largest proportion of the cotton industry's output, consisting as it did of low to medium quality cotton fabrics, mainly used for dyeing, bleaching and printing.

However, the same weft replenishing mechanism was unsuitable for the woollen and worsted industries at that time. This arose from the fact that firstly, the weft replenishing mechanism, for a remarkably long time, relied on the weft fork to initiate the change and this was

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*The survey of patents relating to the evolution of the automatic loom has been carried out mostly by reference to British patent abridgements.
unacceptable in woollen and worsted fabrics. No proper weft feeler mechanisms were then available. In consequence, partially missing picks were associated with weft replenishing mechanisms. Secondly, woollen and worsted fabrics often made use of more than one kind or colour of weft and automatic weft replenishment was not available in this context. These two deficiencies were remedied only after a fairly long period of development, as will be seen in due course.

2.2 Developments prior to the introduction of the Northrop loom.

On 13th April, 1857, Patrick McFarlane patented what appears to have been the first cop changing mechanism [28]. The mechanism employed cases or containers carrying cops stored in a magazine. The means of pushing the container into the shuttle was a lever ('depressor') which was actuated by a cam and was held in the raised position by a catch. When the weft in the shuttle failed or became exhausted, the weft fork lever released the depressor which descended and forced the last or lowest cop case into the shuttle and the used or defective cop with its case into a basket below the magazine. At the next rotation of the crank shaft, the parts were restored to their normal positions. The system offered a number of different arrangements. In one arrangement, the cop case was supplied to the shuttle from a chamber immediately above the shuttle box. In another interesting arrangement, two shuttle boxes were moved up and down as required in a vertical frame large enough to contain three boxes. The shuttle in the top box could be supplied with weft while the bottom shuttle box was in use. This principle was later, in the post 1930 period, employed in a pick-and-pick automatic loom developed by the 'Crompton and Knowles Loom Works' of the United States.

It is of interest that McFarlane's automatic loom also included a warp stop motion which, through audible or visible signal, indicated to the weaver that the loom was stopped [29].

The work by McFarlane showed evidence of remarkable ingenuity and foresight on the part of the inventor. The specification not only referred to several methods of placing cops in a shuttle but also indicated the necessity of employing a warp stop motion in order to get the greatest benefit from the automatic mechanism for supplying the weft.

However, to initiate the change, a weft fork was employed. This practice in general led to partially missing picks [8]. This arose from the fact that the change was only initiated when the weft had completely run out, and this was a feature which highlighted a deficiency of automatic weft replenishment which continued for the next fifty years. In
consequence, automatic looms were only suitable for weaving cloths in which such faults did not matter. Thus, while they were not suitable for the woollen and worsted sections of the industry, they proved more acceptable in the weaving of plain grey cotton fabrics used for dyeing, bleaching or printing.

According to the issue of the 'Textile Journal' for 8th September, 1902, the loom appears to have had some continuing success, for it was stated that:

"The most successful English loom at work at the present time is the one made by Hattersley Ltd., the invention that was patented in 1857 by Patrick McFarlane." [30]

It seems rather strange that forty-five years after the invention was first patented, there was suddenly, for the first time, an article in favor of McFarlane's automatic cop changing loom and the firm which had undertaken to build it. This was strange, not only because of the time lag, but also because the more highly developed Northrop patents had by then appeared.

However, the sudden interest in McFarlane's invention is perhaps justified when the extent of competition between the Hattersley (and other English made looms) and it's main American rival, the Northrop* loom, is realized. An article in the issue of the 'Daily Dispatch' for 27th November, 1902, called "The Battle for the British Market" referred to the competition between different loom makers and commented:

"Lancashire will be the battle-ground for the automatic looms for many years to come." [29]

In the event, however, Lancashire did not show any great interest in automatic looms.

Returning to the origin of automatic looms, the next recorded patent was due to Thomas Ingram of Bradford in 1860 [31]. Although the specification referred to fresh bobbins being supplied to the shuttle, in fact cops carried in cases and already threaded were supplied to a skeleton shuttle; thus a self threading device was not necessary. The first automatic loom which changed bobbins rather than cops enclosed in cases

*The inventor, J.H. Northrop, had been an employee of Hattersleys.
and employed a self threading shuttle was the Northrop, as will be noted later.

Ingram's invention related to means for supplying a fresh cop to the shuttle when the weft was broken or used up. A number of cases containing cops were placed in a hopper ready to be pushed into the shuttle through an opening in front of the shuttle by means of a transferrer. The exhausted cop was ejected through an opening in the back of the shuttle. Upon weft breakage, the weft fork, instead of stopping the loom, raised an arm on the sley which at beat-up actuated the release of the transferrer. The transferrer then pushed the new cop into the shuttle as it was pulled back by a spring. In this manner, Ingram had used the sley to initiate the change but had failed to use its positive action for actually inserting the cop into the shuttle.

By contrast, however, the next cop changing loom which was patented by John Leeming in 1861, did rely on the sley movement for pushing the cop into the shuttle [32]. This appears to have been the first time that the weft replenishing mechanism was sley operated. It marks an important line of development and, of the later inventions, the more successful utilized the sley movement in order to improve the precision of timing the action to the sley position, thus ensuring correct alignment of weft package and shuttle.

It was claimed in the specification that the mechanism was capable of supplying cop cases with different colors of weft to the shuttle. The mechanism appears to have changed the cop after a prescribed number of picks, because the change was initiated through a jacquard mechanism. Presumably, the jacquard mechanism was also responsible for controlling the weft colors so that the frequency of changing would be correlated with the frequency of use of the various colors.

However, the fact that the change was initiated after the predetermined number of picks made the mechanism less desirable, in that the mechanism had to be so programmed that the change was effected before the weft supply ran out. This could, in general, lead to a great deal of wastage and/or rewinding of partly used pirns. On the other hand, the fact that the weft fork was no longer responsible for initiating the change was an improvement. However, a succession of patents for similar jacquard controlled weft replenishing mechanisms in the years to come seems to suggest that these were not reliable in their early forms.

Following this mechanism, as revealed by the absence of patent applications for automatic cop or bobbin changing looms until 1891, it is evident that the developments in this area had been halted. During the same period, on the other hand, many different types of shuttle changing looms were patented. Later, these began to compete with bobbin changing looms, particularly in the weaving of finer and more delicate
yarns which might have been damaged by a pirn changer. Developments in this area continued in parallel to developments in bobbin changing looms during the twentieth century. Some of the more important developments in shuttle changing mechanisms will be referred to in due course.

2.3 The development of the Northrop loom.

On 23rd June, 1891, A.G. Brooks, on behalf of J.H. Northrop, patented a mechanism developed in the United States for automatically changing bobbins [33]. Three years later, the mechanism was developed further into the famous Northrop loom.

This appears to have been the first attempt to change bobbins rather than cops enclosed in containers. It follows, therefore, that the threading of the bobbins had to be achieved, without operative intervention, automatically. For this purpose, the shuttle was so constructed that the yarn was introduced automatically into a curled delivery eye.

The mechanism consisted of means for automatically removing the bobbin from the shuttle and substituting a new one in its place whenever the weft broke or ran out. The fact that the change of weft package was initiated under either of those conditions reflects the use of a weft fork to monitor the need for change. This was also a feature of some of the earlier machines discussed above and, as well as presenting the prospect of broken picks in the fabric, it also implies that there would be part bobbins to be rewound and returned to the magazine. This situation was rather similar to that in present day automatic cone winding where certain forms of yarn breakage result in the supply package being discarded and a new one introduced.

It is interesting to note that the sley on the beat up provided the hammer movement, as in Leeming's mechanism, as well as operating a lever for pushing the shuttle into the proper position in the box, thereby improving the precision of the shuttle alignment in the length, as well as the width direction. This was one of the most important features of the mechanism, in view of the fact that it was imperative to get the shuttle properly positioned before the weft replenishing took place, in order to prevent possible damage to parts of the loom and to carry out the task effectively.

An interesting alternative arrangement incorporated the ability to carry cops instead of bobbins by mounting them on thin blades with bobbin-like heads to enable them to be engaged in the shuttle. This
probably was to overcome the reluctance of firms to change their methods of working to accommodate the needs of the new loom.

A further development of the technology available to Northrop related to a weft feeler patented by G.O. Draper on 2nd October, 1894 [34]. This appears to have been the first attempt to build a weft feeler that operated on the weft in the shuttle rather than that lying in the shed. Automatic looms utilizing such a device would be capable of producing the finer and better quality fabrics in which partially missing picks were not permissible.

The feeler mechanism was very simple and consisted of a detector which was pivoted on the sley and which at each beat up entered the shuttle, coming into contact with the weft on the bobbin or cop to measure the thickness of the bobbin. When the weft ran off to an extent necessitating a change of package, the tail of the detector immediately put the changing mechanism into action. Another version of the same type of weft feeler mechanism was patented in 1900 [35]. However, the fact that the mechanism measured the diameter of the weft package possibly made it unreliable, in that the presence of slight variations in the shuttle position and vibrations in the bracket holding the feeler probably made it rather impractical to obtain an accurate measurement of the amount of weft on the package. Furthermore, the mechanism was perhaps liable to damage the yarn, particularly if it was not accurately set. This could explain why, for many years, automatic weft replenishing mechanisms continued to rely on the weft fork for initiating the change.

A Northrop loom patented on 27th November, 1894, perpetuated the use of the weft fork to initiate weft replenishment [36]. This loom seems to have been an improved version of the 1891 loom invented by J.H. Northrop and patented by A.G. Brooks. The bobbins in the 1894 version, however, were carried in an intermittently rotating drum and the shuttle was provided with spring clips inside and a groove into which the weft was drawn by an automatic action. The picking mechanism was of the underpick type which was not normally used for non-automatic looms at that time [37].

On the 1894 Northrop loom, the principal features of the fork and grid weft fork arrangements invented by Ramsbottom and Holt in 1834 were used. However, instead of being adapted to stop the loom, the motion was used to detect the failure of weft and at the same time to initiate weft replenishment. Furthermore, it was stated that if the shuttle failed to thread up, or if the weft was cut pick after pick, the repeated action of the weft fork would cause the loom to stop [38].

In 1896, two years after the introduction of the Northrop loom, W.F. Draper and J.H. Northrop patented what appears to have been the first temple cutter for use in automatic looms [39]. Previously, no weft
cutting mechanism was available. In consequence, the ends of the spent or the new weft could have been woven into the fabric. Although this fault could be rectified in the mending process, nonetheless this was not desirable because of the extra cost. To prevent "lashing in" (i.e. weft tails being woven into the fabric), a cutting blade was employed to be activated twice, once to cut the tail of the used package and a second time to sever the end of the fresh bobbin. The blade was actuated through a weft feeler mechanism of the type which measured the thickness of the weft following weft replenishment. According to the 'Textile Manufacturer', however, it had been found that the tail of the expended weft package did not lie in the path of the thread cutter [40]. In consequence, the mechanism could only sever the end of the new weft package effectively. For this reason, an extra cutting device was subsequently employed [41].

In due course the news about the development of the Northrop loom reached Britain. After the publication of the first patent of 1891, the 'Textile Recorder', in 1893, gave a detailed account of the mechanism and, starting in 1895, gave particular attention to the question of automatic looms in general, and the Northrop loom in particular. In its issue for 15th April, 1895, the Northrop loom was called a "wonderful loom" [42] and in its issue for 15th May, 1895, it referred to the adoption of the Northrop loom in the United States "to the extent of 300" and stated that "orders were in hand for 5,000 more." The article continued by noting that the speed at which the loom was working was 190 picks per minute (the width was not specified) and that the weavers worked as many as sixteen looms [43]. This was a particularly important achievement as compared with the normal state of practice in Britain.

By June, 1895, the Northrop loom had arrived in Britain and was undergoing inspection. The 'Textile Recorder' in its issue for 15th June, 1895, gave particular attention to the weft changing mechanism, referring to the fact that the substitution of a light object such as a bobbin could be achieved more effectively and with a greater degree of certainty than was the case for the change of a shuttle or a cop [44]. This comment was probably designed to slight Hattersley and British loom manufacturers generally, as they were devoting themselves particularly to the development of shuttle changing looms.

Evidently, by June, 1895, when the loom was brought to Britain, initiation of the change was performed by a weft feeler mechanism, probably of the Draper type as that was the only weft feeler mechanism available by then. Confirmation of this was given by the Textile Recorder as follows:
"In addition to the mechanism for changing the pirn, a motion has been added by which, when the pirn or cop is reduced to a small size, being practically cop bottom, the change is made. This is effected by the use of a feeler, which descends on to the cop every time the shuttle enters the box at the opposite end of the loom to the changing mechanism." [44]

It is apparent, however, that the weft feeler mechanism had not proved to be particularly successful, as the Northrop loom and other automatic looms, continued to rely on the weft fork to initiate the change, for many years until the weft feeler mechanism was perfected. Nonetheless, the main feature of the Northrop loom lay in its weft replenishing mechanism and, as the 'Textile Recorder' put it:

"Whatever may be thought of this mechanism, one thing is certain that no doubt can be entertained as to its practical success. The mechanism does the work and has brought within the range of employment an operation long sought for, of this there need to be no question." [44]

Nevertheless, the article went on to note that the loom added to the cost of production and that some trouble would be experienced with the weavers. The statement regarding the cost is, however, vague. If by "cost", capital costs were implied, then this was certainly true, as the looms were more complex than those normally used. Furthermore, they had to be imported from America. However, this did not necessarily mean that average total costs increased. On the contrary, it was quite possible that the unit labour cost decreased as a result of an increase in the number of looms each weaver was to tend. The extent to which these savings might have offset the capital cost, was the determining factor in indicating the rationality of adoption of such looms. It is not known on what grounds labour problems were anticipated in view of the fact that automatic looms were not introduced in British firms until seven years later, in 1902.

In 1896, the Northrop loom was reported to have been working on both light weight and heavy weight grey cotton fabrics in the United States. The looms were running at 183 picks per minute and each weaver was tending 20 looms. In conjunction with this development, the weavers earned on average 20 to 25 per cent more than the weavers working on non automatic looms [45].
However, it is evident that the Northrop loom was only capable of producing fabrics with a single solid colour of weft. It was therefore, suitable for weaving only a limited range of fabrics. As can be gathered from an article published in the issue of the 'Textile Recorder' for 15th April, 1902, the Northrop loom had, by then, been employed in the production of plain cotton fabrics only:

"It must be allowed that the Northrop idea is competent, more than any other improvements of recent years to effect such economy in the weaving of plain fabrics." [46]

Commenting further on the issue, the article continued:

"The Northrop loom has so far reduced the amount of time which the weaver has to give to each loom of cotton fabrics, that he is capable of running twenty looms, where on the ordinary system four to six is the maximum.

To change from one bobbin to another in the shuttle without removing it from the shuttle box, and the loom running at full speed, making 190-200 shots per minute, to say the least, is a mechanical triumph."

The article went on to emphasis that the whole of the advantage of the Northrop loom lay in its capability to change the weft package while the loom was running and that, if the loom had to be arrested for even a short time whilst the change took place, the invention was no longer so significant. Whilst it is true that the invention would have no longer been so remarkable mechanically and whilst it is also true that the loss in productive time would have resulted in a lower loom efficiency, nevertheless, the fact remains that more looms could still be allocated to each weaver. This would still have been a remarkable improvement.

It is worth noting that a number of later inventions did endeavor to slow down or even stop the loom while the change took place [29]. This was possibly to enable looms to be run at normal non-automatic loom speeds of over 200 picks per minute, a condition which British manufacturers considered to be desirable, as can be gathered from an article in the issue of the 'Textile Recorder' for 15th August, 1902, when
a less than optimistic view was expressed. Specifically, it was anticipated that the adoption of automatic looms and, in particular, the Northrop loom would meet resistance and difficulty mainly due to two factors, yarn quality in relation to loom speed and repairs. On the question of yarn quality and loom speed, it was stated that:

"It is admitted that the quality of yarn used is better and the speed of the loom less in the United States than here. Now, it is precisely here that the superiority of the British spinner and manufacturer is apparent. Out of a lower grade of cotton, he is able to produce a yarn which alike for warp or weft is capable of being made into cloth at a speed largely in excess of that prevalent in America. The point at once arises, whether all things taken into consideration, it pays better to use better yarn and lower speeds, or cheaper yarn and higher speeds." [47]

The last sentence, above, makes it clear that the writer of the article had overlooked the fact that the most important advantage of the automatic loom lay in its capacity to reduce unit labour costs through allocation of more looms per weaver. It was only proper to judge the loom by determining the extent to which the savings in labour costs would have reduced the average total costs.

On the question of repairs, the article commented:

"The question of repairs is one of great importance, and, so far, no one seems to have given this point proper consideration. It is obvious that the more elaborate the mechanism, the greater the possible chance of breakage, and the larger the repair bill, the greater the cost of production."

This clearly shows "the timidity and scepticism of manufacturers" as the 'Textile Manufacturer' put it [48], for there was no particular evidence to support the statement. On the contrary, it is evident that in the United States, where the loom had been working for some time, it had been found that the repairs were less on automatic looms than on non automatic looms [49]. Whilst, it is true that this probably arose from the fact that automatic looms were not as old, nonetheless there was no
evidence to suggest that the repair costs on automatic looms would have been higher, all things being equal.

It therefore appears that in the British industry automatic looms did not receive a universally enthusiastic reception although editorially, the 'Textile Recorder' commented that the introduction of the new system was inevitable [50]. By contrast, in the United States, automatic looms were already being introduced at an increasingly rapid rate. By 15th May, 1902, it was reported that 80,000 automatic looms were working in the United States [51], whereas in Britain automatic looms were still undergoing tests and only two firms were reported to have introduced them. These were Messrs. Ashton Brothers of Hyde and Guthrie and Co. Limited of Portsmouth, near Todmorden. The former had installed 500 Northrop looms whilst the latter had installed a number of Hattersley shuttle changing looms.

It was stated that they would be watched with much interest. In the event these firms became involved in several disputes with the trade unions over wages and the number of looms each weaver was to tend. However, it was unlikely that in the absence of such disputes, other firms would have taken steps to introduce automatic looms on a similar scale as in America. This arose from the fact that the general trading conditions were excellent despite a decline in the British share of world trade. Moreover the weavers' wages were quite low and as such it is probable that the reductions in the unit labour costs did not lead to a lower average total cost. General confirmation of this was given in the contemporary textile journals. Editorially, the 'Textile Manufacturer' in its issue for 15th July, 1901, commented that:

"This (Northrop) automatic loom was developed in America for the reason that America had need of it. Throughout America, the scarcity of weavers retarded the development of the weaving industry. In England there were enough weavers to keep down wages and allow manufacturers their pick of hands... English Manufacturers had their pick of well trained weavers, at low rates, and could not see the advantage of unnecessarily trying new machinery and going through the trouble and expense of training otherwise expert weavers in the use of the new loom." [52]

A year later the 'Textile Manufacturer' stated [53]:

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"A Keighley mechanic emigrated to America. He had conceived the idea of an automatic loom, but with good weavers out of work in England, there was no prospect of the invention being a success. In America things were different. Capitalists were desirous of becoming manufacturers, and although their money would buy looms, it would not buy weavers. The high tariff duties gave manufacturers an opportunity of reaping a golden harvest, but that harvest could only be gathered by making cloth, and the cloth could not be produced without weavers. Northrop, then found that these changed conditions would make an opening for his invention. His loom was taken up by some large makers and everybody knows how it has succeeded on the other side of the Atlantic."

It therefore seems that the conditions in the two countries were quite different. The adoption of the automatic loom in the United States owed much to the scarcity of weavers. In Britain, however, the manufacturers found that profits could still be made on non automatic looms in spite of the superiority in some respects, of the automatic looms [54]. It was anticipated that in the longer term, Britain was going to be faced with severe competition from the United States and Japan, a fact which was often brought to the attention of British manufacturers [55]. It is of interest to note however, that this prospect far from encouraging the adoption of automatic looms may to some extent have had the opposite effect in that some British manufacturers took steps as early as 1901, to diversify their range of products beyond the reach of automatic looms. Indeed it was stated in the 'Textile Manufacturer' that it was in the finer sections that the future of the industry would lie [56].

In conclusion, it must be recognised that initially the Northrop loom was capable of replenishing only one kind of weft and that it also led to missing and partially missing picks. Therefore, the loom was not suitable for weaving the finer cotton fabrics, worsted or woolen fabrics. The fact that the loom was initially used for weaving grey cotton fabrics seem to confirm this. Nevertheless, it is evident from the comments above that the Northrop loom was a land mark in the development of weaving machinery and that it revolutionised the American textile industry. It caused interest and controversy among commentators in Britain but the manufacturers were found to be largely indifferent either because they did not need it, could not afford it, were aware of its limitations, or feared labour problems. What cannot be denied,
however, is that it fired the imagination of inventors on both sides of the Atlantic as the continuation of this patent survey makes clear.

As will be noted later, the Northrop loom was developed further and ultimately represented one of the most important and versatile automatic looms available.

2.4 Early attempts to develop a multi-colour automatic loom.

It will be recalled that the origin of multi colour automatic looms extends back to 1861 when John Leeming patented an automatic loom which changed the cops (carried in containers) after a pre-determined number of picks. Although the loom possessed a number of interesting features, it had not apparently gained any commercial success.

Two more attempts were patented on 1st March, 1898, in the name of E. Hollingworth relating to the supply of different kinds or colors of weft to the shuttle. It is worth noting that at least some, and probably most of a series of British patent applications by E. Hollingworth of the Dobcross Power Loom Works originated in the associated company of Crompton and Knowles in the United States. Thus they did not reflect the interest in Britain so much as the intense competition between Crompton and Knowles and the Northrop/Draper combination to increase their respective shares of a rapidly expanding market in the United States.

The first of Hollingworth's mechanisms consisted of a drum shaped magazine which carried a number of weft bobbins arranged in groups having different colored wefts corresponding with those in the shuttles [57]. The magazine was arranged over the single shuttle box of a multiple box loom and was oscillated in accordance with the pattern mechanism so as to keep opposite to the transferrer a bobbin corresponding with that in the shuttle in use.

One of the weak points of the mechanism seems to have been due to the fact that the magazine was constantly oscillating in accordance with the box change pattern mechanism. Another complication is revealed by studying the patent. The magazine and weft fork were on the right hand side of the loom with a number of shuttle boxes on the left hand side of the loom, and since the broken weft was detected towards front centre, it was too late to effect a change during that loom cycle. Therefore the weft fork not only had to initiate the change, which must include a 2 cycle delay until the shuttle (already empty) is again at the right hand side, but it also had to cancel the take up and the pattern selection indication so that it was the same shuttle that came to the right hand box two picks later. Thus, it was as if the loom had stopped for 2 cycles except that no disruption to the running occurred. This highlights a problem common
to all multi box automatic looms. That is the need to preserve or remember which shuttle requires the new pirn*. Finally, the mechanism relied on the weft fork to initiate the change.

The second mechanism related to a two colour automatic loom. However, instead of relying on the weft fork to actuate the replenishing mechanism, the change was effected after a certain number of picks [58], as in Leeming's mechanism. Whilst this practice eliminated partially missing picks, nonetheless it is possible that it could lead to a great deal of wastage because the amount of weft on a bobbin would vary and it would be necessary to programme the change for the shortest likely length in a bobbin. This made the mechanism unattractive. The weft fork was retained for its normal purpose of stopping the loom when the weft broke.

Between 1899 and 1902, a series of mechanisms was patented in the names of Baker and Kip for automatically supplying up to four different kinds or colors of weft cops (enclosed in cases) to the shuttle. These patents were notable for the widespread use of electromagnetic devices for detecting weft exhaustion as well as for controlling the weft replenishing mechanism. The same type of electromagnetic devices were said to have been applied to shuttle changers [59]. The reliance upon a series of electrical contacts, for example between the bobbin and a feeler inside the shuttle and between a contact on the shuttle and one on the race, suggests that the mechanism would be unreliable. The fact that a great deal of development and perhaps second thoughts were involved in this series of patents suggests that practical difficulties may have been encountered. This was perhaps the reason for the development of a prototype loom which was to undergo a trial in Bradford in 1902 [60]. The outcome of the trial is not known but it would appear that a shuttle changing loom developed on the same principles had proved more successful [61].

This pattern of development was typical of a number of applications of electrical indicators which had been used with temporary success on looms. Like the electromagnetic jacquards of 1856-61 which were certainly demonstrated as working, none seemed to have enjoyed lasting success. This was probably due to the fact that they depended upon an electrical contact being maintained reliably over long periods of

*Alternatively, it was possible to eliminate the need for a memory by the provision of weft feeler mechanism at the drop box side of the loom which felt the weft in the shuttles immediately before they were picked to the replenishing (single box) side of the loom and which were capable of actuating the transfer mechanism by the time the shuttle arrived at the single box side of the loom. However, it will be seen in due course, that, the technical problems in the way of memory mechanism were removed long before it became possible to eliminate the need for them in the manner just described.
time, a requirement that under mill conditions would be indeed difficult to meet because of corrosion and oxidation of contacts. In later years, the use of electromagnetic holding relays and, more recently, solid state switches, eliminated this problem.

A rather different mechanism capable of accommodating up to four different colors or kinds of weft was patented at the turn of the century, by J. Gabler [62]. The bobbin magazine comprised a number of vertically sliding compartments moved in accordance with the box change pattern mechanism so that, for each position of the box, the corresponding compartment of the magazine was depressed so as to bring the lowest bobbin in the particular compartment of the magazine opposite the transfer hammer of the bobbin changing mechanism. The change was effected sideways. It is possible that the continuous movement of the bobbin compartments might have led to excessive wear of the mechanism, a disadvantage which would make the invention unattractive.

None of these early attempts seem to have been commercially successful. However, accepting that these looms were more attractive for woollen and worsted sections of the weaving industry and for the weaving of other high quality fabrics, then it is probable that the failure of these mechanisms might have been as much due to such faults as partially missing picks as to the inherent failings of the arrangements for supplying more than one kind of weft. As will be noted later, although in a series of patents by Crompton and Knowles around 1909-10 the principles of multi colour automatic looms were developed to an advanced stage, nonetheless they did not become a commercial possibility until proper weft feelers became available. In consequence, the operation of automatically changing the weft continued to be confined mainly to plain cotton goods. Although George Hattersley and Son of Keighley, in 1902, developed an automatic shuttle changing loom for woollen goods which was capable of weaving warp figures, it was nonetheless unable to change different colors or kinds of weft [63].

Subsequent developments led to the introduction of reliable multi colour automatic looms in the early 1920's, as will be seen in due course.
3 Developments leading to the introduction of multi colour automatic looms and further development of single colour automatic looms between 1900 and 1920.

3.1 Introduction.

The period between 1900 and 1920 was notable in that the principles upon which multi colour automatic looms were subsequently developed were introduced. This entailed the development of memory mechanisms and also reliable weft feelers, the latter being of general relevance to the advance of automatic weaving. Other developments related to automatic loom attachments and large capacity magazines. These matters are considered below.

3.2 Developments relating to various single colour automatic looms.

Between 1900 and 1920 a number of different arrangements were patented for automatically replenishing bobbins or cops. Some of these looms were developed commercially and were demonstrated as working. Others were perhaps never built. They are of interest, however, in that they help to show the wide range of looms that were potentially available to the weaving industry in general and to the cotton manufacturers in particular. The fact remains, however, that the most successful single shuttle automatic loom was still the Northrop.

One of the very early attempts to apply a weft replenishing mechanism to Jacquard looms was due to W.P. Thompson in 1903 [64]. The mechanism was initiated by the weft fork. There was of course, no particular difficulty in the application of a weft replenishing mechanism to Jacquard looms per se. Accepting, however, that in Jacquard weaving many fabrics made use of more than one kind or colour of weft and that such faults as partially missing picks were not permissible, it is unlikely that a single colour automatic jacquard loom such as Thompson's loom would have been successful.

It is of interest, however, that three months before this mechanism was patented the 'Textile Recorder' and the 'Textile Manufacturer', both reported that the "Walker automatic loom", a jacquard shuttle changing loom capable of supplying different colors of weft (in even picks) which had already been produced, was apparently working satisfactorily [65]. The loom was mentioned to have been developed for the worsted section of the industry. For this purpose, it was stated that an "indicating finger" (presumably a weft feeler of mechanical type) was used to initiate the replenishing mechanism.
The following year, a French inventor, A. Briot, patented a mechanism for automatically supplying cops provided on a tongue or skewer to the shuttle [66]. The mechanism incorporated a stationary magazine into which cops were placed. A cop feeding device withdrew one cop at a time from the magazine and brought it within the reach of the sley. Upon initiation of the change by the weft fork, the cop feeding device was brought into a horizontal operative position and during the forward movement of the sley, the feeder pushed the full cop into the shuttle in place of the spent cop. To enable this to be done, the shuttle box was constructed with an open front and back, and the cop was said to be held in the shuttle by means of "grippers". The way in which the cop was placed in the shuttle, however, made the mechanism unreliable, in that the cop feeding device could be damaged if the shuttle was not properly positioned. For this reason, in an improved version patented on 15th February, 1907, the cop feeding device was provided with a feeler which projected beyond the feeder to rise to its upright position and subsequently stopped the loom [67]. The mechanism would have been made more reliable, had a shuttle positioning device been included. Although the mechanism had been produced and was commercially available, the 'Textile Manufacturer' was dubious of the practical success of the loom, due to the complexity of the mechanism [68].

In 1906, another alternative arrangement for automatically replenishing the weft was patented by T.R. Shillito. In this, spools were carried by the links of an endless chain which was guided by a frame and driven by a toothed roller [69]. The spools fell one by one into a specially formed portion of the frame underneath the shuttle ready for removal to the shuttle. When the change was initiated, the transferrer took up the full spool and pressed it into the shuttle via an opening in the bottom of the shuttle pushing out the used spool from the opening above where it was thrown into a basket below. After each transferring operation the chain moved and brought the next full spool into position. A loom using this arrangement was apparently being manufactured by Messrs. Sachsische Webstuhl Fabrik, Chemnitz, Saxony but according to the 'Textile Manufacturer', if the spools were not of the same thickness at top and bottom, "they came to lie obliquely" and a sure insertion by the transferrer was not secured [70]. This could have been caused by the fact that the transferrer gripped only the middle of the spool while pressing it into the shuttle. This seems to have been one of the earliest attempts to develop a spool changing loom, but apparently without much success. By contrast, a few years prior to the invention of the above mechanism, a French inventor, Oscar Cossert had developed a spool changing mechanism which according to the 'Textile Manufacturer' was running successfully and was stated to be preferable to existing shuttle
changing looms [71]. This is of interest in that British-made shuttle changing looms such as the Blackburn automatic loom produced by Messrs. William Dickinson and Sons Ltd., Phoenix Iron Works, Blackburn for some time had been used on the Continent, with much success [72].

Between 1905 and 1907, a number of mechanisms were patented by W.R. Stitt of Belfast for changing bobbins. It was also claimed that the mechanism could easily be adapted to change shuttles automatically instead of bobbins. This feature was probably aimed at overcoming the reluctance of potential users to change their working methods in the spinning or the preparatory section to accommodate the needs of bobbin changing looms.

The 1905 mechanism was rather simple and much resembled Briot's mechanism of 1904. However, unlike Briot's mechanism which incorporated a shuttle constructed with an open front and back, as can be gathered from the diagrams given in the issue of the 'Textile Manufacturer' for the 15th May, 1905, Stitt's mechanism used a normal shuttle, but incorporated a shuttle box which, at the moment of transfer, tilted and came into contact with the magazine, to allow the sideways transfer of the bobbin, as the sley was about to move forward [73]. It is possible that this mechanism had not proved successful in practice since an endeavor was made by Stitt to develop an alternative method of transferring the weft package to the shuttle. In a mechanism patented in 1907, the shuttle box was no longer required to tilt each time a change was to take place [74]. Apparently the loom was available commercially and was available at a comparatively low price [75]. It is not known whether the loom proved successful on a commercial basis.

Mechanisms of the type patented by Stitt in 1905 nonetheless busied inventors in Britain and on the Continent. J.W. Cook patented a very similar mechanism in 1907 [76], and G. Zell, in 1909, and J. Gabler, in 1910 patented mechanisms almost identical in principle to the 1905 mechanism developed by Stitt [77-78]. None of these appear to have been produced commercially.

By contrast, another method of replenishing the weft patented by J. Harling and R. Harling in 1910, was on the market within two years [79]. The loom had been developed by Messrs. Harling and Todd, Burnley, who also produced the Jackson automatic loom conversion attachment as will be noted in due course [80]. This mechanism was of the type which upon initiation of the change by the weft fork was brought to a stop to effect the change. The loom was provided with a vertical hopper in which was arranged a double row of bobbins. The sley did not provide the motion for the transferrer to push the new bobbin into the shuttle. Instead, the power for effecting the change of bobbins was
obtained from a loose pulley on the driving shaft of the loom. Although with mechanisms which contained this format, the timing of the change did not present any problems in that, for effecting the change, the loom was stopped and the sley became stationary, another complication arose in that the loom had to be stopped with the sley in the correct postion to ensure the alignment of weft and shuttle. It is of interest, however, that in 1912, both the 'Textile Recorder' and the 'Textile Manufacturer' reported that the loom was working satisfactorily [81]. Furthermore, the 'Textile Manufacturer' added that a large number of these looms had been made and placed on the market. What the outcome was, unfortunately is not known, as is the case with a similar mechanism developed in 1916 [84].

An interesting mechanism, patented in 1911 by J.S. Ainley, related to what appears to have been the first attempt at developing a loom winder [82]. Weft winding was effected on the loom by picking the substantially exhausted or spent shuttle into an auxiliary shuttle box. This box was moved into an inoperative position, the weft end from the spent shuttle was united to the thread from a supply spool and then the peg or spindle of the spent shuttle was rotated by means of a gear in order to wind a fresh supply of weft onto the shuttle peg. Whilst the winding operation was taking place, another shuttle was brought into operation by the movement of the drop boxes. Thus, the loom did not have to stop and no loss in efficiency occurred. While there is no evidence to suggest that the loom was used extensively, this was indeed a very interesting mechanism, in that it combined winding and weft replenishment operations, a principle similar to the Unifil loom winder which was introduced many years later.

Another interesting mechanism was patented by Siemens Schuckertwerke on 13th February, 1913 [83]. In this, an electrically driven loom, the speed of the driving motor was automatically reduced for bobbin changing and was raised again after the bobbin changing had been completed. This feature might have modified the strength of the pick. It might also have resulted in shading effects due to variations in speed, but since the loom was only claimed to be suitable for weaving grey cotton fabrics, this would not present a significant problem.

In conclusion, it can perhaps be stated that although a number of different arrangements for automatically supplying one kind or colour of weft were developed, some of which were made and marketed, nonetheless, the Northrop loom seems to have been the most suitable and successful loom of this kind during this period probably because of both the finance and working experience resulting from the large and receptive American market. Other looms developed during this period do not appear to have had any lasting success.
3.3 Developments relating to multi colour automatic looms.

It will be recalled that between 1861 and 1902, a number of attempts were made to supply different kinds or colors of weft to the shuttle, but without much apparent success. However, during the period between 1900 and 1920, the principles upon which multi colour automatic looms were built in the 1920's and 1930's, were established. The most important development in this area was the introduction of a mechanical memory mechanism. The developments during this period were due almost exclusively to Crompton and Knowles. Only a few of the relevant mechanisms were patented during this period by others, particularly Ruti.

Following his original patents of 1898, between 1905 and 1913, E. Hollingworth recorded another series of patents relating to means for bringing bobbins with weft corresponding to that in the active shuttle into position, to be acted upon by the transferrer as the drop boxes moved up and down in accordance with the pattern mechanism. However, the fact that a great deal of alteration and perhaps second thoughts were put into these mechanisms over the eight year period between 1905 and 1913, seems to suggest that they were perhaps not reliable in their early forms [85-88].

These mechanisms were unable both to detect the need for a change and complete the transfer in the limited time for which the sley was in its most forward position. Thus, it was necessary that the detection should be made on one pick and the transfer executed two picks later, always provided that a box change had not taken place in the meantime. If a box change did take place, then the transfer mechanism had to be capable of memorizing the need for a change in that particular shuttle until the shuttle was again brought into use. However, instead of memorizing the need for a transfer, the weaving mechanism was put out of action for two cycles as described earlier. Another unsatisfactory feature was the absence of a proper weft feeler mechanism.

In 1909, Hollingworth patented more than twenty improvements to weft replenishing mechanisms which, with the exception of a few, were all minor improvements on the previous mechanisms developed by Crompton, and Knowles. Although a mechanism patented on 27th July, 1909, related to a single shuttle automatic loom supplying only one kind or colour of weft, it is of interest in that its principles were used in an important mechanism for multi colour automatic looms patented by Hollingworth, as will be seen in due course. The single shuttle mechanism incorporated a magazine with several compartments which
were separately closed from below by flaps [88]. Instead of controlling the magazine through the box change pattern, a separate pattern mechanism was employed which could be arranged to cause a bobbin to be transferred first from one compartment and then from another compartment. Alternatively it could be arranged to cause first all the bobbins in one compartment to be transferred and then the bobbins from another compartment and so on. This arrangement eliminated the need for the oscillation of the magazine, since it was only through opening the flaps that the bobbins were released from different compartments.

This method was used in a mechanism patented by Hollingworth on 21st August, 1909, which was indeed a very major and significant improvement [90]. In a loom provided with a four compartment magazine for carrying bobbins of different colors corresponding to those in the shuttles at the other side of the loom, a mechanical weft feeler of the type which measured the thickness of the weft on the bobbin was used in conjunction with the single shuttle box at the magazine side of the loom. When the weft feeler indicated "substantial" exhaustion of the weft, a bar on the particular magazine compartment was raised above a lever normally held beneath it by the fingers on one of two sliding rods. The shuttle was then picked to the opposite side of the loom. When the box containing the empty shuttle was next brought level with the race board through the box change pattern mechanism, the raised bar was released, and carried the lever beneath it which, through a cam, actuated the replenishing mechanism. Subsequently, upon arrival of the empty shuttle at the single shuttle box, a bobbin was transferred from the compartment into the exhausted shuttle. If more than one shuttle needed replenishment in succession, the bars corresponding to particular magazine compartments were raised and, when any of the boxes carrying a depleted shuttle next came level with the race board, the corresponding bar was released and the change was effected when the empty shuttle arrived at the single shuttle box. In this manner, the need for a change in relation to the exhausted shuttles was memorized mechanically almost in the same manner as in the 4 x 1 and 2 x 1 box looms produced by both Dobcross and Crompton and Knowles in the 1930's and 1940's. The only difference was in the number of sliding bars, which on the later developments had been reduced to 1 from 2. The implication of using a memory was that the weft package had to have a reserve bunch of weft to at least cover the two pick cycle which was required for the replenishing mechanism to be activated.

The feeler mechanism used in association with this mechanism does not appear to have been effective since it measured the diameter of the weft package, and in the presence of vibrations in the sley and in the bracket holding the feeler, it probably was impracticable to obtain an
accurate measurement of the amount of weft on the package. Although, in a further development patented on the same day by Hollingworth, the weft feeler was made independent of the sley, nonetheless it probably still gave a rather crude indication of weft exhaustion especially in the presence of hairy or compressible yarn. The employment of the weft fork to initiate the change and set the memory mechanism into operation would have, of course, been impracticable in that it would have led to two missing picks. Thus although the principles of a memory mechanism were available in 1909, in the absence of a reliable weft feeler mechanism, they were not regarded to be of any immediate commercial value.

In the same year, 1909, Hollingworth patented three different types of magazine. The first was in the form of an endless chain which carried different kinds or colors of weft in groups and was of large capacity [91]. The second was a rotary magazine provided with several divisions or groups, each division containing bobbins with weft of different colors corresponding to the weft on the bobbins in the different shuttles [92]. The third was a modified multi compartment vertical magazine [93]. A number of other similar magazines were patented in the period between 1910 and 1913, although none appear to have been exploited commercially [94].

On 5th October, 1910, Hollingworth patented an improved version of the mechanical memory patented on 21st August, 1909 [95]. The only difference between the two mechanisms was that while the latter had two sliding rods for controlling four compartments of the magazine, the former involved a single rod which carried as many fingers as was necessitated by the number of compartments in the magazine. This modified mechanism is identical to that used in 4 x 1 box and 2 x 1 box automatic looms developed by Crompton and Knowles and marketed in the interwar years. However, at this juncture, there was still no reliable and accurate weft feeler available which is a factor that tended to limit the success of multi colour automatic looms for some time. What is important, however, is that the obstacle of providing a mechanism to store the need for a change in a particular shuttle had been overcome and as soon as reliable weft feelers started to be introduced, multi colour automatic looms became a real commercial possibility.

The year 1911, witnessed the development of another important loom by British Northrop. This was a modified version of the Northrop loom especially developed for weft mixing and producing simple woollen and worsted fabrics [96-97]. The loom used two shuttles which made two or a multiple of two picks. This minimized the shading effects resulting from slight variations in colour or count of one supply from the preceding or following supply of weft. The two drop boxes were
positively controlled and operated by means of a simple half-toothed gear wheel or "segment" wheel which brought firstly the top box into position for two picks and, secondly, the bottom box for the same number of picks. The original mechanism included a mechanical weft feeler comprising two fingers arranged two shuttle box spaces apart so that they could respectively penetrate the inactive boxes on alternate picks (feeling could not take place whilst the boxes were changing) thus feeling the weft in the shuttle which was next to become active. By 1915, however, it is evident that this weft feeler had been replaced with an electrical weft feeler, probably of the type which relied on two prongs. Both the 'Textile Recorder' and the 'Textile Manufacturer' referred to this fact without specifying the particular features of the mechanism [98]. It was stated in the 'Textile Recorder' that the feeler mechanism was electrically operated from a low voltage supply obtained from a 12 volt dynamo of a capacity large enough to feed 150 looms.

The 'Textile Manufacturer' pointed out that the adoption of these looms could reduce weaving costs by as much as 30 percent. It continued by stating that:

"A trial installation was put down three years ago for the production of a serge fabric woven with a worsted warp and a woollen weft. The results were quite satisfactory ... At the moment, there are about 500 Northrop looms of the heavy type at work in Yorkshire, and the excellence of the fabric produced, coupled with the low cost of manufacturing, argues well for the future of the loom." [98]

In the event, this loom proved successful for weft mixing in double picks and in the 1920's a loom for weft mixing in single picks was also developed. This loom was an important development in that woollen and worsted sections of the industry could make a somewhat limited use of automatic looms, this being facilitated by the availability of a weft feeler.

The next mechanism for changing different colors or kinds of weft was patented on 5th February, 1916, by Maschinenfabrik Ruti Vorm. C. Honneger [99]. This mechanism comprised two or more coaxial circular bobbin magazines separated by partitions which were controlled so that one of the magazines was oscillated on indication of weft failure, to bring the required bobbin beneath the transferrer. A weft feeler (probably of the U type*) was located at the single box side of the loom.

*The operation of the forked weft feeler mechanism is explained subsequently.
After the feeler detected the substantial exhaustion of the weft, the shuttle was picked to the other side of the loom. It was stated in the patent specification that, if the operative shuttle box was changed after indication of the need for weft replenishment, the change of bobbin was interrupted until the proper shuttle box became operative. Thus, some form of a memory mechanism had been employed to store the need for a change in a particular shuttle. It is important to note that this type of mechanism proved quite successful commercially in the 1920's. By then, however, the improved version of the U shaped feeler mechanism had been employed to initiate the change.

Between 1919 and 1922, three more attempts were made to develop a multi colour automatic loom [100-102]. These shared one common feature, namely that the need for a change was initiated via electrical contacts in the various compartments at the multiple box side of the loom. It is not clear how these detected the absence of weft but it was claimed that as an electrical circuit was closed, the transferrer was actuated and a bobbin was transferred into the spent shuttle which had, in the meantime, arrived in the single shuttle box at the other side of the loom. Because the weft feelers were located at the multiple box side of the loom, and gave the indication of the need for weft replenishment immediately before picking to the single box side of the loom took place, the need for a memory was eliminated.

In conclusion, it should be noted that although the principles of automatic replenishment of different kinds or colors of weft started to be introduced from 1909 onwards, commercial application of these principles was delayed until reliable weft feelers became available. The first multi colour automatic loom to gain any commercial success was that developed by Crompton and Knowles and marketed in the early 1920's.

3.4 Developments relating to weft feeler mechanisms.

The origin of weft feeler mechanisms extends back to 1894, when draper patented what appears to have been the first attempt to build a weft feeler that operated on the weft in the shuttle rather than that lying in the shed.

The early weft feeleres were designed to measure the thickness of the weft package and act as a diameter gauge. The feeler was operated when the sley was brought to the beat up position. If there was an insufficient diameter of weft available, the feeler would fall freely causing weft replenishment to be initiated. In theory, the feeler could be set so that the change mechanism was not actuated until the weft package
in the shuttle had been reduced to a pre-determined diameter. In practice, however, its action was indecisive. This arose from the fact that the position of the shuttle, after it was brought to rest in the shuttle box, tended to vary slightly, with the result that the position which the bobbin occupied could also vary. Furthermore, as mentioned previously, in the presence of vibrations in the bracket holding the feeler, it was impracticable to obtain an accurate measurement of the amount of weft on the package. In addition, if the weft feeler was not pivoted on the sley and was instead mounted on a fixed support, the vibration in the sley made the measurement still less accurate. In consequence, either a high percentage of waste was made or the feeler acted too late. Bennett, in his book 'An Introduction to Automatic Weaving' referred to this problem and stated that:

"... it was scarcely possible to set the feeler to act when the weft in the shuttle had been reduced to a pre determined amount ... The original type of feeler was one which often resulted in a high percentage of weft waste being made, whilst frequent adjustment or renewal of contact parts was necessary." [103]

The renewal of contact parts referred to above was stated to have been necessitated by the effects of "false contacts" (i.e. contacts made with the shuttle or the bobbin as distinct from the yarn). Another disadvantage of this type of weft feeler mechanism was that it could damage the weft if it were not set properly. Weft feeler mechanisms of this type, nonetheless, busied inventors on both sides of the Atlantic for a remarkably long time. Endeavours were made to make the feeler more sensitive, but for reasons already referred to, these attempts did not prove to be successful. Subsequently, however, the principles of the side sweep and other feeler mechanisms were successfully developed.

One of the earlier attempts due to J. Gabler and patented on 13th January, 1903 [104], was most interesting. It employed the principle which a number of years later, was perfected by Ruti. The weft feeler mechanism consisted of a horizontal shaped feeler controlled by a spring which projected into the shuttle box at one side of the loom and came into contact with the weft in the shuttle after its entry into the box. The mechanism does not appear to have been developed commercially. Had it been produced and tried under mill conditions, it is possible that reliable weft feelers would have become available much sooner.

In the same year, another attempt was made by the Northrop Loom Co. to produce a weft feeler which was mounted on a fixed support rather than the sley. The feeler entered the box as the sley beat up and
attempted to measure the thickness of the yarn [105]. As in previous designs of this type, the weft feeler must have given only a crude indication of the exhaustion of the weft, especially for hairy or compressable yarns.

A comparable arrangement was patented in 1904 by W.R. Stitt and A.J. Davidson [106]. This device was one of the components of a bobbin changing loom. It is interesting to note that the loom was commercially available in 1905 [107]. Although the loom was said to cost less than other automatic looms due to the simplicity of the mechanism, nonetheless it does not appear to have had any lasting success.

Similar weft feeler arrangements based on the principles of measuring the thickness of yarn were also patented by H. Sefton in 1906 [108], E. Hollingworth in 1909, 1915 and 1919 [109] and British Northrop in 1917, 1919, 1921 and 1924 [110]. None of these weft feeler mechanisms seems to have been a commercial success. In consequence, automatic looms continued to rely on the weft fork for initiating the change for a remarkably long time. For example, in a single shuttle automatic bobbin changing loom invented by P.J. Terry in 1926, although a weft feeler mechanism of the type which relied on the thickness of the yarn was employed to initiate the change, the weft fork mechanism also initiated the change upon breakage or absence of weft [111]. This tends to confirm the unreliability of the early weft feeler mechanisms especially in view of the fact that it was stated in the 'Textile Manufacturer' that the loom could be worked without the feeler mechanism [112]. The lack of novel features in the design of the feeler at such a late date was surprising and may perhaps account for the failure of the mechanism to claim any commercial success, although the loom was being manufactured and marketed by John Pilling and Sons, Primet Foundry in Colne, one of the most important centres of cotton manufacturing in the U.K. [113].

The question of weft feelers was indeed an important issue. An automatic woollen and worsted loom could not have gained any success in the absence of a proper and reliable weft feeler. Whilst a weft feeler for the worsted industry had to be very accurate and reliable, for the woollen industry, a proper weft feeler would have to cope with hairy and bulky wefts [114], features for which the above mentioned weft feelers were inappropriate.

Between 1909 and 1913 [115], Hollingworth patented a number of electromagnetic weft feeler arrangements. They do not appear to have been exploited notwithstanding that by then Hollingworth had patented the first version of the mechanical memory which appears to have been used on multi colour automatic looms introduced by Crompton and Knowles in the early 1920's [116].
A most significant development in this area was the introduction of a two prong electrical weft feeler, in 1912, on an automatic loom produced and marketed by Messrs. Robert Hall and Sons Ltd., Bury*. The patents for this mechanism have not been found.

A weft feeler mechanism patented by Maschinenfabrik Ruti Vorm. C. Honegger on 14th April, 1914, related to a completely different mechanism; a type still in current use [116]. This weft feeler mechanism was based on the previous principle of pressing the feeler head on the bobbin but the feeler, instead of measuring the surface position of the bobbin, consisted of a shaped fork similar to that used by Gabler back in 1903, which, upon sufficient exhaustion of the weft, moved downwards and actuated the replenishing mechanism. This method of detection of weft exhaustion was more reliable, in that it tested, not merely the distance of the yarn surface from a fixed point, but the actual diameter of the bobbin, thus making the measurement independent of slight variations in bobbin and shuttle position.

Another significant development in this area related to the introduction of the principles of a side sweep weft feeler mechanism by A.H. Owen in 1915 [118]. The weft feeler was pivoted to a spring controlled arm. If there was sufficient weft on the bobbin, the tip of the weft feeler was prevented from moving about its pivot. The effect was enhanced by the slight penetration of the bobbin. When the weft was substantially exhausted, the tip of the weft feeler, upon contacting the hard surface of the bobbin, slipped along it. When the feeler was displaced to a predetermined extent, the bobbin changing mechanism did not measure the thickness of the weft on the yarn; rather, the side slipping weft feeler mechanism depended on there being a difference between the frictional properties of yarn and bobbin, exactly in the same manner as the side slipping weft feeler mechanisms in current use.

In 1916, two weft feeler mechanisms were patented by E.M.V. Kirschner [119-120]. These comprised two points mounted in a casing. The points formed the extremities of two rods which could slide in the casing. The weft bobbins had longitudinal slots normally covered by the weft but uncovered when the weft was substantially exhausted. The points pressed against the weft at beat up, and if one of the points entered the recess, weft replenishment was actuated.

Whilst it can be seen that this is a departure from past practice, it does not appear to be reliable. This arises from the fact that the mechanism relied on one of the points entering a slot in the bobbin. Unless both the point and the slot were aligned properly the feeler tip would have pressed against the body of the bobbin and allowed the loom

*This mechanism is described subsequently.
to continue working. The appropriate condition was indeed difficult to meet in the presence of slight variations in the bobbin position. Moreover, it could not have been used effectively unless provisions were made for correct bobbin orientation. In both versions of this feeler, special bobbins had to be used. This feature in itself may not have appealed to manufacturers. A similar mechanism patented in 1923 also proved unsuccessful [127].

In 1917, H. Wade patented a modified side slipping weft feeler mechanism [121]. The feeler mechanism comprised a feeler and a slide parallel to each other. The feeler was mounted to turn on a fixed pivot against the action of a spring. The feeler was normally held in a locked position by the connections with the slide. As the sley advanced, it pressed against the slide. If the weft was exhausted, however, the feeler slipped along the denuded surface of the bobbin. When the feeler turned to a predetermined extent, weft replenishment was actuated. In principle, therefore, the mechanism was not greatly different from present day side slipping feelers. It appears to have been applied to the Nordray automatic loom developed in the United States in the 1920's.

Perhaps the most lasting of the developments in this area was due to British Northrop who on 11th June, 1918, patented another side slipping weft feeler mechanism [122]. This mechanism comprised a tip member adapted to swing slightly within limits determined by the corners and the wall of the feeler arm, and was provided with blunt teeth. In a modified version of the same mechanism patented on 26th November, 1919 [123], the feeler tip was no longer adapted to swing feely, and in a further modification, patented on 27th June, 1920 [124], the feeler tip was made slightly smaller and only the end portion was roughened. The reduced contact area with the weft and the blunting of the point of contact with the weft made the mechanism more attractive in that the possibility of damage to the weft was reduced. By the middle of the 1920's all models of the Northrop loom were stated to have been fitted with the side sweep weft feeler mechanism developed by the company. This mechanism was later, in 1926, developed into the famous "midget" weft feeler mechanism as will be seen in due course.

Another interesting weft feeler mechanism was patented on 29th October, 1918 by S.S. Jackson [125]. This was a "differential" weft feeler mechanism in which two slides were mounted. At the other end the slides carried a large contact member. The contact member could pivot at the joint of the slide nearest to the tip of the bobbin. In this manner, as the weft on the bobbin was used up, the slide nearest to the bobbin tip was displaced relative to the other slide, and the contact member in effect measured the angle between the 'chase' and the denuded body of the bobbin. This made the mechanism more reliable than the early weft
feelers which attempted to measure the thickness of the yarn in that it was not sensitive to the slight variations in the position of the bobbin relative to the feeler and was better than the previous differential type in that it did not require a special slotted bobbin. When the contact member was turned up to a certain angle, the slide nearest to the bobbin tip failed to support a controller at its other end, and the change was initiated. However, the mechanism does not appear to have been exploited commercially. By contrast, a spring-loaded side-sweep feeler mechanism developed five years later by Jackson [128] appears to have been employed in a shuttle changing loom developed by Jackson known as the Vicker-Stafford which proved to be most successful in the late 1920's and the 1930's [129].

The next weft feeler mechanism patented by Ruti in 1919, was a modified version of the 1914 weft feeler which incorporated a U shaped feeling member [126]. In this arrangement, the forked weft feeler was carried by a lever loosely mounted on a shaft on the sley at the magazine side of the loom. The relative movement of the sley to the frame through a spring connection caused the feeler to "grip" the bobbin. The position to which the feeler travelled, on exhaustion of the weft, caused the end of a lever to be put into the path of a hook which engaged it, causing the hammer actuating lever to be put into the path of the projection of the sley. This was a simple but ingenious mechanism and was probably an attempt at detection and instant change. Furthermore, the fact that an attempt had been made to apply an established principle in a slightly different form seems to suggest that the earlier version may not have been so successful although the employment of a forked shaped weft feeler in itself, was an important development.

In summary, it is evident that from 1914-15, the principle upon which reliable weft feeleres were subsequently constructed, started to be introduced. Most endeavors during the period between 1920 and 1930, were directed towards developing reliable mechanical feelers, although other types of feeler mechanisms became popular in the 1930's and 1940's.

The importance of reliable weft feelers has already been stressed as regards multi colour automatic weaving in particular. Had such weft feeler mechanisms been introduced earlier, it is probable that at least in the United States, the muti colour automatic looms developed by Crompton and Knowles might have gained commercial acceptance at an earlier date. It was in 1918, more than ten years after the first development of a memory mechanism, that Crompton and Knowles developed and applied a side sweep weft feeler mechanism to their multi colour automatic loom [130]. Crompton and Knowles multi colour
looms equipped in this way experienced considerable success during the 1920's.

3.5 Developments relating to automatic loom conversion attachments.

From an early date, there was much interest in devising attachments for converting existing non automatic looms to automatic weft replenishment.

On 16th May, 1902, B. Crossley patented what appears to have been the first automatic loom conversion attachment [131]. In this mechanism, cops enclosed in cases were introduced from a magazine into a curved channel, where, upon the failure of weft, they were forced through a slot in the bottom of the shuttle box into a skeleton shuttle. When all but one of the cases had been discharged from the magazine, the loom was stopped automatically. The cop changing mechanism was actuated by the weft fork. As in purpose built automatics in which cop changing was actuated in this way, partially missing picks were a feature. Apparently, the mechanism was commercially available within two years of its introduction as can be gathered from an article in the issue of the 'Textile Recorder' for 15th March, 1904:

"The loom is by no means in its experimental stage, as several have been running for some considerable time in a mill where we had the opportunity of inspecting it ... It was weaving at a high speed of 210 picks per minute, with a 40 inch reed space, with 14's weft, producing flannellette cloth.

We have, however, on more than one occasion seen the loom running with weft very considerably finer than this and of ordinary quality, no special quality of cotton being needed.

The very simplicity of the attachment will be its chief recommendation incorporated with the facts that no extra power is required to make the change, and there is practically nothing to get out of order." [132]

The article went on to add that the company owning the patents was so satisfied with the results obtained that they had decided to install a
number of looms themselves for producing medium to course grey cotton fabrics.

This was indeed a potentially important development in view of the fact that the initial cost of this machinery was much lower than that of automatic looms. In spite of this, however, they did not achieve any substantial commercial success.

In the same year, another automatic weft replenishing attachment was patented by C. Hamig [133]. The mechanism consisted of a curved magazine and relied on the weft fork to actuate the mechanism. Unlike Crossley's attachment, bobbins without a container were supplied to a self threading shuttle. The interesting feature of the loom lay in its ability to prevent the mechanism from being brought into operation if the shuttle failed to enter the box properly, through a lever which lifted the weft fork. This, however, would have led to two or multiples of two missing picks in the fabric in that the weft replenishing mechanism was only put into action if the shuttle was properly positioned when it arrived at the single box, at the replenishing side following a two pick cycle.

It is worthy to note that these add-on devices were linked to the existing weft fork, emphasizing the lack of a reliable weft feeler for incorporating in the conversion.

Another automatic loom conversion attachment was patented in 1903, by J. Duckworth, J. Eddleston and C. Whalley [134]. The mechanism consisted of a large L shaped hopper for accommodating cops carried in containers as in Crossley's mechanism. Unlike Hamig's mechanism, however, if the shuttle was not boxed properly, the weft fork, instead of delaying the change, stopped the loom, and no missing picks were formed in the fabric. In a later development of the mechanism patented on 25th May, 1904, a motion was provided to prevent the cop from being pressed out of the magazine until the shuttle was in a proper position to receive it. Furthermore, the loom was made to stop upon repeated action of the weft fork as in the Northrop mechanism.

These patents, however, do not seem to have had any commercial success and no record of their use has been found. By contrast, a modified version of the Crossley automatic loom conversion attachment patented in 1903, by G. Haworth seems to have been successful [135], in spite of the fact that the mechanism was said to have been particularly suited to underpick looms. Most non automatic looms at that time, were of the overpick class.

As compared with Crossley's invention, the device was improved in that instead of pushing the cop into the shuttle from beneath, the cop was pushed into the shuttle from the top of the shuttle box. This eliminated the need for an oscillatory arm to remove the expended cop.
This mechanism had been developed commercially by the Burnley Automatic Loom Ltd. and was commonly known as the "Burnley" automatic loom. According to the 'Textile Recorder' the looms fitted with this attachment were capable of weaving at high speeds. Furthermore, the mechanism was said to be so simple that it could be applied to ordinary looms in two or three hours [136].

In 1904, another series of patents by M. Sporri related to the conversion of non automatic looms. In the first mechanism, the full weft bobbins were pushed out of a magazine into the shuttle in the box below the magazine at the beat-up by a sley-operated hammer upon indication of weft failure by the weft fork. The mechanism was simple and it was claimed that it could be applied to overpick looms [137]. In another arrangement, the shuttle box, the picker and the swell were said to be arranged such that the shuttle could be driven by either an underpick or an overpick motion [138]. In a further modification, the bobbin changing mechanism was stated to be brought into operation by either a weft fork or by a weft feeler mechanism of the diameter gauge type, according to whether the loom was employed for weaving "plain or fancy" goods respectively [139].

A further bobbin changing attachment was due to A.J. Jackson between 1905 and 1906 [140]. The mechanism was capable of supplying cops without a case from a vertical magazine to a self-threading shuttle. The cops were skewered on a tongue or skewer having a specially formed base which could then be fitted into the shuttle. In its use of skewered cops, the mechanism was similar to the first Northrop mechanism of 1891, which was capable of carrying cops instead of bobbins by mounting them on thin blades with bobbin like heads to enable them to be engaged in the shuttle. A loom fitted with this attachment was produced and marketed by Messrs. Harling and Todd of Burnley within three years of the invention being patented [141].

It must be pointed out that the force actuating the hammer was derived from the driving shaft of the loom and not the sley. This was a backward step in that problems could have arisen in timing the change. It is surprising to find that the 'Textile Manufacturer' called this an important feature when it stated:

"An important feature of this loom is that the force actuating the slide for operating the hammer of the ejector is derived from the most powerful point of the loom - the driving shaft itself thus obviating any direct jar upon the sley. The changing is accomplished by a cam on the driving shaft of the loom at the period when the sley rests upon the
forward and return centre, at the extreme forward point of its beat and thus great accuracy is obtained in the process of inserting a new cop; moreover, very little jar to the weaving parts of the loom is effected, this leading to easy and better working." [142]

Apparently, the loom was running satisfactorily, as both the 'Textile Recorder' and the 'Textile Manufacturer' reported so after inspecting the loom at work. The loom was mentioned to have been running at 180 picks per minute (the width was not specified) manufacturing the ordinary plain cloth associated with the Burnley district [141, 142].

The most important feature of the mechanism was that it could be fitted to both overpick and underpick looms. This made it appealing, particularly in view of the fact that a large number of non automatic looms running in Lancashire at that time, were reported to have been newly installed and according to the 'Textile Manufacturer', could be in operation producing good cloth for well over twenty years more [142]. In the event, automatic loom attachments, in general, did not enjoy any great commercial success. By 1933, there were only 3,541 automatic loom attachments in place in the British cotton industry as compared with 13,995 fully automatic looms and around 600,000 non automatic looms [143].

The next bobbin changing attachment, patented on 15th September, 1909, was due to Carl Klein of Gotenborg, Sweden [144]. The mechanism was said to be reliable in action and also readily applicable to both overpick and underpick looms [145]. In addition, the mechanism contained a shuttle positioning device which was only brought into action when the change was to be made. It consisted essentially of a finger which came into contact with the shuttle and pushed it into proper position for receiving the incoming bobbin. Immediately, the change was effected, the finger moved back to its normal position so that picking could proceed [146].

It is evident that Messrs. William Dickinson and Sons Limited, Phoenix Ironworks, Blackburn, had taken up development and manufacture of the mechanism [147]. Having inspected a loom fitted with this attachment in operation, the 'Textile Manufacturer' reported that they had been impressed with its "simplicity of action and the ease" with which it was controlled. Furthermore, it was stated that the company had received orders for a number of these attachments already [148].

It is of interest that within two years, a loom of lightweight construction fitted with this attachment had been developed. The loom
had been named "The Phoenix Automatic Weft Replenishing Loom" and possessed a number of interesting features. These included an arrangement for holding the loose threads extending from the weft packages, a weft cutting device attached to the temple, a warp stop motion and an automatic let off motion of the type used on the Northrop loom [149]. The loom was obviously working satisfactorily as the 'Textile Recorder' reported:

"We recently inspected this loom in operation, and at an average normal speed of 170 picks per minute, the loom was giving good weaving results." [150]

Another series of patents, in the period between 1910 and 1912, relating to a bobbin changing attachment was due to W.W. Pilkington, J. Whittaker, R. Bradshaw and J. Briggs [151]. These patents eventually, by December, 1912, led to the development of an automatic loom by Messrs. Butterworth and Dickinson Ltd., Burnley, which appeared to change bobbins rather than cops. The loom, named "The Whittaker Loom", consisted of an ordinary loom fitted with the replenishing mechanism [152]. It was claimed that the mechanism could be readily applied to existing looms. Other features of the loom were a shuttle positioning device, means for holding the weft ends on the magazine, a cutting device and means for stopping the loom upon repeated action of the weft fork [152]. The mechanism, although simple, according to the 'Textile Recorder' was working satisfactorily, as may be seen below:

"We recently inspected a battery of sixteen loom at work and were impressed with the excellent way in which the weft replenishing mechanism performed its functions." [152]

For a number of years, developments in this area halted until in the period between 1917 and 1918, a number of mechanisms were patented by H. Wade. These mechanisms had been developed in the United States by the Hopedale Manufacturing Co. and formed the Nordray automatic loom attachment marketed by the company in 1921 [153]. This was incorporated in a loom which resembled the Northrop, particularly in the magazine and general construction [154, 155]. The attachment employed a side slipping weft feeler mechanism, a number of which had been developed by 1920. Evidently the loom was working satisfactorily, and the fact that it was similar to the Northrop loom was probably due to the fact that the builders were former officers of the Northrop Loom Co. [156].
It must be pointed out that although a number of these early automatic loom attachments enjoyed some initial success, none seems to have had any lasting success. Developments relating to weft replenishing attachments were, nonetheless, continued in the following years and one of the most successful automatic loom attachments capable of changing bobbins, was patented by the Whittaker Loom Co. and H.E. Wittaker on 27th November, 1923 [157]. The mechanism made use of a small V shaped magazine. By way of further development, instead of two inclined planes arranged in reverse direction, the magazine was based on several such planes arranged in a sinuous or zig-zag manner. The bobbins were retained by a spring flap provided with a stop which could act as a fulcrum for the flap. The transferrer was L shaped and comprised a hammer extending at right angles to an arm mounted on the transferrer shaft. The mechanism also made use of a side sweep feeler mechanism patented by Horrockses Crewdson and Co., J. Lewtas and E.H. Blackhurst [158]. Evidently, in just over a year, a loom fitted with this attachment was being manufactured and marketed by the Whittaker Loom Co., Preston [159]. The loom was named "The Whittaker Loom" after its inventor H.E. Whittaker. It will be recalled that back in 1912, Messrs. Butterworth and Dickinson of Burnley also produced a loom called "The Whittaker Loom." The patents for this loom, were due to W.W. Pilkington, J. Whittaker, R. Bradshaw and J. Briggs. Whatever the relationship between J. Whittaker and H.E. Whittaker (if any), it should be noted that the looms were completely different and were being produced by different loom makers. The name does not imply similarity in the principles used in the two mechanisms.

Two years after the patents were taken out for this mechanism, the 'Textile Manufacturer' reported that it had been applied to an ordinary 45 inch reedspace plain loom made by George Keighley of Burnley, and that eight of them were continuously running at the Whittaker Loom Co., Yard Works, Preston, at speeds varying from 192 to 200 picks per minute [159-161], which was almost the same as obtained on non automatic looms. This illustrates the commitment that the British inventors had to the development of a reliable automatic weft replenishing attachment which could be fitted to existing non automatic looms. Indeed as the 'Textile Manufacturer' put it:

"The owner of ordinary looms has to decide whether he can afford to junk his present equipment and install new and much more costly automatic looms ... The opinion has been consistently held by some, that a weft replenishing mechanism to be successful in gaining the
favor of Lancashire manufacturers would have to be capable of being applied to existing looms." [162]

In the event, although automatic loom attachments did not make any headway in Lancashire in general, this attachment was nonetheless one of the most favored in the 1930's, in particular.

It is interesting to note, that an almost identical loom was being produced in 1923 by the French company Ateliers Des Vosges [163]. However, the magazine was not only of a large capacity designed to carry 40 bobbins, but was also removable.

Further attempts were made during the period between the 1920's and 1940's to develop other alternative automatic weft replenishing attachments, amongst which the Fischer automatic loom attachments proved most successful.

3.6 Early development of large capacity magazines and developments relating to secondary and other devices.

Another trend during the period between 1904 and 1912 related to the provision of large capacity magazines in order to reduce the frequency with which battery filling had to occur. The aim was probably to concentrate the weaver's effort on supervision and repair of broken threads since, at that time, battery filling was mostly performed by weavers, particularly so in Britain and other European countries.

The very first attempts were due to British Northrop and were patented between 1904 and 1909 [164-166]. The first two attempts related to large capacity rotary magazines in which the bobbins were carried in several separate stacks. The patent of 1909, by contrast, related to a spare bobbin magazine of large capacity, [166] used in conjunction with a horizontal hopper. The magazine comprised an endless belt provided with retainers for gripping the middle of bobbins, successively removed from the hopper by an arm. The magazine guided the bobbins to the transferring position. Although interesting in design, these mechanisms do not seem to have been exploited commercially. Between 1909 and 1911, a number of large capacity magazines of both the vertical and rotary types were patented, some making use of two magazines for carrying bobbins. None were developed commercially [167-172].

The only successful mechanism of this type was patented in 1911, by A.G. Koechlin [173]. The bobbin magazine was rather similar to the Fischer bobbin loader (box loader) which became popular many years later. The bobbins were contained in a box which had a sloping bottom. The bobbins passed out of the box through an open guide channel to a
position under the transferrer. The box was said to be capable of oscillating periodically to assist the separation of the bobbins. This was almost identical to a mechanism developed by Messrs. Robert Hass and Sons Ltd., Bury in 1912, in which the bobbins passed out of the box singly down grooved guides which supported them at the top and base until they passed under the transfer hammer [174]. The loom to which this arrangement was attached, had other interesting features. Most important was an electrical weft feeler. The feeler entered through the side of the shuttle at every alternate pick and contacted two prongs or terminals. When they contacted with a metal sheath surrounding the bobbin, a circuit was completed, a magnet was energized, a lever was raised by the magnet and the weft replenishing mechanism was put into action [174]. It is not known who the inventor of the loom was or how successful the weft feeler was, although the principle seems to be similar to electrical weft feelers in use in present day looms. It is possible, however, that the company had obtained the rights to produce the loom from the original inventor or inventors who may have been non British, since no patents for these mechanisms have been found.

Apparently, the loom seems to have been working satisfactorily as the 'Textile Manufacturer' reported:

"We recently had the pleasure of seeing one of these looms at work. At the time, it was weaving a warp of ordinary 36's twist and inserting 170 picks per inch of 42's weft in a five leaf satin weave. The makers state that at the present time, a mill in actual work has only three weavers for 100 looms." [175]

This was the only loom of this kind that was demonstrated as working during this period but it seems not to have met with any lasting commercial success.

Amongst the secondary devices associated with automatic weft replenishment, shuttle positioning and weft cutting motions were probably the most important. Although the Northrop loom of 1894 incorporated means for cutting the weft tails and used the sley to position the shuttle properly in the box, a great deal of further development took place in these areas.

British Northrop took out patents on spring loaded shuttle positioning arrangements in 1905 [176]. However, the fact that later, in 1911 a shuttle feeler mechanism was developed by Northrop [179] to prevent the actuation of the weft replenishing mechanism in the case of shuttles being improperly positioned, seems to suggest that the mechanism of 1905 was not reliable in action. This seems to be also true
of similar shuttle positioning devices patented by Hollingworth in 1905 [177], and J. Gabler and R. Kunz in 1906 [178].

The other line of development during this period related to weft cutting devices. In patents by Crompton and Knowles and Northrop, these consisted of stationary and movable blades fixed on the temple, operated by connections from the sley [180-183]. However, they do not appear to have been used at the time on looms manufactured by the patentees. By contrast, a similar weft cutting device patented by H. Wade, in 1918 [184, 185], seems to have been used on the Nordray automatic attachment developed in the United States in 1921. A number of shuttle positioning and weft cutting devices similar to those mentioned above were also included in automatic looms developed during this period but were not patented separately.

A number of other miscellaneous developments also occurred during this period. These related to bobbin and magazine positioning devices, means for securing weft ends in the magazines, means for collecting weft tails, etc. [186-196] Secondary devices performing such functions were also included in many of the looms and attachments patented during this period and like certain of the shuttle positioning and weft cutting devices, these were not patented separately. Further developments were also evident in the period between 1920 and 1940.

4 The introduction of multicolour automatic looms.

It will be recalled that Crompton and Knowles were the first to develop principles for automatically replenishing different kinds or colors of weft in 1909-10, although these principles were not exploited commercially. The application of a reliable side-sweep weft feeler mechanism by Crompton and Knowles to their multicolour automatic loom, in 1918, could explain the subsequent commercial success of the mechanism.

In October, 1921, a four box automatic weft replenishing loom developed by Crompton and Knowles was brought into Britain. Apart from the application of the above mentioned weft feeler mechanism to the loom, the memory and the replenishing mechanisms were virtually the 1910 versions. From the descriptions given in both the 'Textile Recorder' and the 'Textile Manufacturer', it appears that the weft fork was only responsible for stopping the loom upon breakage or absence of weft [197]. The loom made use of four boxes, operated on the drop-box principle, at the opposite end of the loom to the replenishing mechanism. The weft feeler mechanism was located at the magazine side. This meant that replenishment took place two picks after the feeler had signaled
exhaustion of the weft in the running shuttle. If the boxes changed, then the need for weft replenishment in that particular shuttle was stored mechanically. The description of the memory mechanism given in the 'Textile Manufacturer', below, makes it clear that it was in fact the 1910 version and not an earlier one.

"Each of the four separate compartments in the magazine is governed by a rolling gate at the bottom of each race. Each gate is in turn, controlled by an upright finger mounted at the inner end of the magazine. Through a connection to the boxes at the other end of the loom, the upright fingers are always kept in synchronism with the running shuttle. An oscillating or rocking case-iron arm is pivoted on a short horizontal shaft mounted across the full width of the magazine. Thus, as the shuttle boxes move up or down to bring the requisite colour into action, the upright finger controlling the chamber containing the same colour of weft takes charge of the gate to permit a change of pirn if exhaustion is indicated by the feeler, and at the same time the gates of the other chambers in the magazine are closed to prevent the egress of a pirn of the wrong colour." [198]

A number of American firms showed a genuine interest in the loom and by November, 1922, it was reported that over 20,000 looms of the type referred to above, were in regular use in the United States, although in Britain, the loom was virtually unknown [198]. Furthermore, at least in America, the loom was said to be a proven success for weaving cotton, silk, woollen and worsted materials.

The next important development in this area was due to British Northrop and D.M. Hollins who on 16th July, 1923, patented an alternative method of automatically replenishing different kinds or colors of weft [199]. The mechanism related to a multi shuttle loom fitted with an electromagnetic feeler and memory mechanism. The box motion was at the left hand side of the loom and the magazine was at the right hand side. A side weft fork was used and this also was at the right hand side. The vertical magazine was open at the front and back but at the ends had four pairs of slots which held different colors or kinds of weft in four separate vertical columns. The pirns were held in the compartments by a pivoted lever which was moved on its pivot to release one pirn when required.
The shuttle boxes worked on the drop-box principle, and the pattern chain operated on the "one-card-one-box" principle in which only four kinds of card were necessary, one for each box. The box-motion was also provided with a hand control through which any box could be brought to the active position, probably for pickfinding purposes. When a pattern card provided an indication, a particular shuttle was brought to the race level and an "indicating-lever" rocked on its pivot against spring action. A contact on this lever then made one of a series of contacts. If the weft feeler indicated weft exhaustion, a circuit was closed and a solenoid controlling the weft supply for that particular box, was energized. The spring-controlled core of this solenoid was drawn down and released the corresponding indicating lever which was moved away from the original contact to another contact. The original circuit was thus broken and a fresh circuit was closed through wires and an electromagnet controlling the transferring mechanism. If the drop boxes did not change, the circuit described remained closed and a pirn was transferred into that shuttle from the corresponding compartment of the magazine as soon as it arrived at the single box side of the loom. However, if the boxes changed, the circuit was broken but was re-established when that shuttle box was next brought to the race level, and a transfer was subsequently effected. This method of storing the need for a change was an important development. The 'Textile Manufacturer' described it thus:

"After the need for a fresh weft pirn has been indicated or registered by the feeler, it is immaterial whether the nearly empty shuttle remains active, or is rendered inactive for some considerable time by the control of the pattern cards. Changes of the other colors of weft may also occur without affecting the registration which has previously been made." [200]

Furthermore, it was stated that:

"The certainty with which the correct selection of the colour is made is really surprising."

The success in the United States, of the Crompton and Knowles 4 x 1 box automatic loom fitted with a mechanical memory was probably the main motive for British Northrop producing a loom on similar lines but choosing electromechanical rather than pure mechanical means for storing the need for replenishment. However, the memory mechanism
itself apparently was not due to the company, as can be gathered from the 'Textile Manufacturer':

"The Northrop Loom Company approached a firm of electrical engineers and explained their requirements. The firm concerned produced an exceedingly well made and simple contrivance, which really consists of four small automatic switches with lever connections to the magazine containing the reserve supply of pirns." [200]

The loom seems to have been working satisfactorily for, when the loom was exhibited in 1925, the 'Textile Recorder' reported no change, modification or improvements on the original mechanism [201]. The box change motion was to be modified in later years but the memory mechanism continues to be used on present day looms. The availability of this device enabled the Northrop loom, by 1923, to be used in producing a wide range of fabrics both grey and colored.

In 1925, British Northrop introduced an automatic terry-towel loom. The loom was fitted with a standard type of rotary battery and automatic pirn changing mechanism, the side-sweep weft feeler mechanism and a weft cutting mechanism in addition to other standard features such as warp stop motion, side weft forks, positive warp let-off mechanism for the ground beam, etc. Besides making this loom to weave with a single shuttle, British Northrop had also produced a terry loom fitted with a two box motion. This enabled colors to be used in the headings as desired. The mechanism was first patented on 5th September, 1924, in the name of British Northrop and D.M. Hollins [202], and comprised a two compartment pirn magazine based on the multi-compartment magazine used originally in the Northrop 4 x 1 box multi-colour automatic loom. The electromagnetic weft feeler and memory mechanism were also the same as those used on the 4-box automatic loom but using only two instead of four magnets, circuits and solenoids. Other features of the loom were also identical. It is thought that this was the first attempt at producing an automatic terry-towel loom capable of changing two colors or kinds of weft. The 'Textile Manufacturer' predicted "with certainty" that:

"The application of the Northrop automatic loom to terry weaving seems destined to be a great success." [203]

In the early 1920's, the Swiss firm of Ateliers de Construction Ruti, also developed a 4 x 1 box automatic loom which appears to have
been an improved version of its original mechanism patented back in 1916. It is evident that by 1924, the loom had been fitted with the shaped weft feeler mechanism developed by Ruti and patented in 1919 [204].

The 'Textile Recorder' in its issue for 15th January, 1924, reported that the loom had been produced commercially and that the speed of the loom was at least as high as any non-automatic drop box loom. Apparently the loom was working satisfactorily, for the 'Textile Recorder' went on to add that:

"The actual production (efficiency) obtained at a mill using 250 of these automatic drop box looms was 85 per cent and upwards." [204]

By 1925, a two shuttle automatic loom for weaving silk and rayon fabrics had also been developed by Ruti. The loom possessed a number of new features. The pirn hopper was divided into two parts each containing 14 pirns. The hopper was moved forward or backward, in accordance with the box change pattern, to present the pirn corresponding in colour to the active shuttle under the transferrer. The pirn changing was initiated by the U shaped feeler mechanism which operated from below [205].

According to the 'Textile Recorder', by 1925, 1,200 looms of this new model were already working in Continental mills. Furthermore, it was stated that:

"These new silk automatic looms have been tried with success in this country, and are now being used by well known English firms. They have given the best results in the following combinations: with wool or cotton warp and silk or rayon weft; with silk or rayon warp and wool or cotton weft; with silk or rayon on warp and weft (when good qualities and high counts are used)." [205]

It is not known where and in what numbers the loom was adopted. It is clear, however, that in spite of its initial success, it is possible that the loom had not proved completely successful in practice in that, in the later years of the 1930's, a number of shuttle changing automatic looms were developed by Ruti and other loom makers for the weaving of rayon and silk.

It is evident, therefore, that by 1925, three different loom makers, Crompton and Knowles, Northrop, and Ruti had developed various types of automatic multi colour pirn changing looms. This provided a wide
section of the industry with the opportunity of benefitting from the adoption of automatic looms. During the next decade, improvements were made on the looms mentioned above. For example, in 1930, the firm of Ruti patented a thread holder for use in conjunction with the pirn magazine of its looms [206], and in 1937, the multi compartment stationary pirn magazine used in the multi colour automatic loom developed in the 1920’s was provided with cell closing flaps to prevent the pirns from falling into the discharging end [207]. This led to the introduction of a modified 4 x 1 box loom [208].

In the early 1930’s, British Northrop introduced an improved version of its four colour automatic woollen and worsted loom. The replenishment battery had four grooves in which the full pirns were carried. The synchronized operation of the boxes and the weft replenishment was controlled through the electrical memory mechanism described in the original patent of 1923. The loom was also modified to carry larger weft packages. In addition, the employment of a positive rotary and reversible dobby for up to 24 shafts (the Leeming) which was directly geared with the worm take up motion and the box motion, made pickfinding a less time consuming task [209]. Another feature of the loom was a positive warp let off motion.

Between 1936 and 1937, A. Saurer patented three notable mechanisms. Although the first two patents related to a mechanism for changing colors of weft, they nonetheless formed the foundation upon which a multi colour automatic loom was subsequently developed. For this reason, these two patents, which described the general features of the 100W Saurer loom introduced in Britain in October, 1937, will be reviewed first [210]. The principle features of the 100W model were a drum shaped pirn magazine comprising two discs fixed to a shaft, which was locked in both directions against turning, whilst the change was taking place [211], a mechanical weft feeler of the side-sweep type, and means for preventing the change, if the shuttle was not properly positioned in the box [212]. The magazine was capable of carrying 23 pirns and the loom was said to have been particularly suitable for weaving cotton fabrics at a surprisingly high speed of 234 picks per minute with a 26 inch reed space. Indeed, in connection with the 1949 Textile Recorder International Textile Machinery Exhibition, the loom was referred to as "The fastest loom in the exhibition" [213].

Another model of the loom, the Saurer 200W, incorporated the same type of mechanism but was made heavier in structure for producing heavy fabrics up to 20 ozs/sq yard, twice the weight of the fabrics for which the 100W model was intended [214].

These two models formed the basis for all other models of Saurer looms. For example, the 4 x 1 box, 4 colour pirn changing automatic
loom patented by A. Saurer on 18th March, 1937 [215], could be constructed by fitting the appropriate mechanisms to both 100W and 200W models. Unlike most 4 colour pirn changers which used the four vertical slides system, the circular battery was retained. In consequence, the four colors of pirns were placed in cyclic order in the magazine and a selector mechanism acted to rotate the battery one, two or three pirns as necessary so that the correct colour was presented for change.

It is worth noting that by 1947, a two shuttle automatic loom with single colour magazine for weft missing in double picks had also been developed. In addition, shuttle changing looms similar in principle to the pirn changing looms were also available. All these could be accomplished by fitting the required parts to the 100W or 200W model. These two models, when fitted with the appropriate parts, provided a range of looms capable of weaving silk, rayon, cotton, linen, wool, and hemp [216]. Although there were looms already available for producing the fabrics mentioned, perhaps the greatest advantage of the Saurer looms lay in the facility to change over very quickly to manufacture other types of fabrics. This was a radical break with the conventional practice. Certainly no other loom manufacturer had set out to accomplish this. Furthermore, these looms were capable of running at very high speeds [217].

One year after Saurer patented the 4 x 1 box automatic loom, in 1938 Crompton and Knowles patented a different mechanism for supplying two kinds or colors of weft in an automatic loom [218]. This was applied to a 2 x 1 box loom which had a swinging pirn magazine which was normally stationary, but at indication of weft failure, rocked about its pivot to present the proper compartment over the shuttle box, for direct transfer of a pirn. The mechanism also comprised shuttle positioning and weft cutting devices. In addition, it included a vacuum operated weft control [219]. This mechanism was claimed to have prevented slack from developing between the stored pirns and the weft end holder at the outer end of the loom, as well as helping to remove the cut ends on the ingoing and outgoing pirns so that no weft tails would be inadvertently drawn into the cloth. The loom was exhibited in Britain in 1949 and, by then, it also comprised a centre weft fork motion and a safety device which prevented the transfer when the magazine was not in correct position [220]. This loom was commonly known as the S6 model and was said to be particularly suitable for weaving quality fabrics in silk, rayon and other synthetic fibres. Depending on the type of yarns used and the fabric construction, the speed of the loom ranged from 172 to 182 picks per minute. It is also of interest that later design changes made it possible to convert the S6 loom into a 1 x 1 box loom, utilising a single shuttle and transferring pirns alternately from the front and rear.
cells of the swinging magazine [221]. Thus there was no need to modify
the magazine of the original S6. Prior to this development, Crompton
and Knowles were exclusively engaged in the development and
production of multi colour automatic looms.

It must be pointed out that the multi colour automatic looms
described above, were 2 x 1 box and 4 x 1 box looms. Therefore, the
maximum number of colors used was 2 and 4 respectively.
Furthermore, the number of successive picks inserted from any colors
could only have been an even number since, in common with all the
systems reported after 1861, there was only one shuttle box at the
magazine side of the loom. To permit the use of more colors and odd
numbers of picks from each colors, necessitated several shuttle boxes on
each side of the loom. Such looms were known as "pick and pick" or
"pick at will" looms. Automatic weft replenishment for these looms was
developed between 1935 and 1942. They were few in number and
complex in design as will be seen in due course.

4.2 Introduction of pick and pick automatic looms

Pick and pick automatic looms involved much more complicated
mechanism than the 4 x 1 box or 2 x 1 box automatic looms. This arose
from the fact that the looms had to be so designed that they could pick
from either side of the loom in any sequence depending on the weft
pattern required. Furthermore, it was necessary to position the shuttle
box containing the shuttle next in use level with the race board at one side
on the loom and an empty box level with the race board at the the other
side of the loom. In these circumstances, the implementation of
automatic weft replenishment was a substantially more difficult and
complicated task than on a loom in which picking took place alternately
from each side. The problem was, nonetheless, of particular importance
for weaving certain jacquard cotton and rayon fabrics as well as fancy
woolen and worsted fabrics, although admittedly such fabrics constituted
only a very small percentage of the total U.K. fabric output. Such fabrics
were currently produced on non automatic pick and pick looms.

The first attempt to produce a pick and pick automatic loom seems
to have been due to Crompton and Knowles and was patented on 5th May,
1925 [222]. The loom incorporated drop boxes and a weft feeler,
referred to as a detector mechanism, at one end, and horizontally spaced
shuttle boxes and a multicolour weft magazine at the opposite end. A
stand carrying the detector mechanism was employed which, through
levers, was connected to the pattern mechanism and was moved up and
down opposite the drop boxes. It was stated that:
"As soon as the pattern chain is advanced, and before the drop boxes have shifted, the stand carrying the detector (located at the drop box side of the loom) is aligned opposite the box which is next to become active."

This is taken to mean that a single feeler moved with the box stack, penetrating the box with which it was alligned at front centre, but that just before the box motion began to move, the feeler was shifted by the box pattern chain so as to align with the box next to be used. It was stated that the detector was responsible for indication of weft exaustion in any one of the four shuttles and that the picking mechanism, the dobby and the box motion became inoperative until the change was initiated. Furthermore, it was claimed that once weft exhaustion had been indicated, a new weft package of the required colour was held in position, above the horizontally spaced shuttle boxes, and that as soon as the depleted shuttle arrived at any one of the horizontal boxes, at the magazine side of the loom, the transfer was effected. In a modified arrangement of the same mechanism patented on 15th September, 1926, a vertical hopper having a number of compartments with an equal number of discharge openings was moved to present one of the discharge openings opposite one of a series of vertically moving shuttle boxes [223]. The transfer was then effected by means of a plunger side-ways.

It is evident, however, that these mechanisms had not proved successful initially, although the principles formed the basis of the famous PAPA 4 x 3 box loom which was probably the most successful automatic pick and pick loom, commercially [224].

The next attempt to develop an automatic pick and pick loom was due to K. Schwabe. The loom had four boxes at each side. Altogether Schwabe patented three mechanisms between 1935 and 1937. When the need for weft replenishment was indicated, the relevant shuttle moved right through the boxes at the magazine side of the loom into a special extension box. The loom stopped for about two seconds while the selected pirn was transferred in the normal way to the shuttle, which was then returned to its box by a moving rack. Weaving then continued from this or any other shuttle [225]. The picker of course, had to be displaced to allow the shuttle to enter the auxiliary shuttle box. In the initial version, the picking spindle was displaced horizontally as soon as the weft feeler mechanism was activated. Two years later, on 14th August, 1937, the mechanism was slightly modified. To allow the shuttle to pass into the auxiliary box at weft replenishment, the picking stick, instead of being moved laterally out of the path of the shuttle, was moved down and returned before the next pick [225-226].

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Indication for a pirn change was given electrically at the left hand side of the loom (the side opposite to the magazine) by the weft feeler mechanism. The weft feeler was in the form of a pivoted metal tongue contained within the shuttle box itself. When the shuttle entered the box at the left hand side of the loom, the feeler was moved against the pirn. When the pirn was empty, the feeler contacted a metal sleeve on the pirn and an electrical circuit was completed which led to the initiation of the change. The pirns were provided with a reserve bunch of weft.

To indicate which of the 4 colors was to be selected for the shuttle when it entered the magazine extension box, each shuttle had a pair of contacts on its walls. The position of these contacts was different on the different shuttles, according to which colour of weft each shuttle contained. There was also a corresponding set of contacts in the box wired to the magazine selector. When a shuttle indicated a change, its particular colour contacts engaged a particular pair of contacts on the box, and this colour indication was transferred to the magazine to select the colour required. The correspondence between the shuttle contacts and the magazine compartment that had been selected was checked again when the shuttle entered the magazine box to change [227]. A co-axial rotary magazine capable of holding different colors or types of weft was used.

The loom was produced by the firm of Schwabe, founded 1880 in Bielsko (formerly in Austria, then in Poland). After the Second World War, however, the firm moved to Dixi in Switzerland and continued the production of pick and pick automatic looms [228]. By then, however, the loom had been fitted with a multi compartment vertical magazine and had five shuttle boxes on each side. This loom was said to have been particularly suitable for heavy woollen cloths. It had a 25 shaft closed shed dobby, the loom speed was between 118 and 122 picks per minute and the reed width was 86 inches. By 1957, the construction of the loom had been greatly improved and the loom was then available in five widths ranging from 73 inches to 96 inches. It is worth noting that the sole manufacturing rights for this model the "Schwabe Jura Loom" had been taken over by British Northrop [229]. In spite of this, it is evident, that the loom did not enjoy any great commercial success, at least in Britain. This, in part, was probably due to the fact that the electrical mechanism for pirn selection was indeed very complicated. It has been stated that, due to this complexity, one electrician was required for every three or four looms [230]. This is not to say that the mechanism was technically unsound. On the contrary, it represented a radical departure from conventional practice in loom making.

By contrast, Crompton and Knowles, in carrying out further development of the pick and pick automatic loom, adopted the idea of
forming a space for spent pirn ejection between boxes of the existing stack. This gave rise to a 4 x 3 box loom in which the top shuttle box was lifted away from the remaining boxes below it to provide a space for the spent pirn to be ejected. The mechanisms of this loom were patented between 1937 and 1942 [231]. The new loom known as the Crompton and Knowles PAPA was a modified version of the standard Crompton and Knowles W3 loom developed in the early 1920's and was said to be readily convertible to an automatic 4 x 1 or 4 x 2 box loom or to a non automatic 4 x 4 box pick and pick loom [232]. The 4 x 3 pick and pick automatic version was capable of weaving up to three colors of weft but as compared with 4 x 4 box pick and pick non automatic looms, the range of patterns that could be woven was limited, not only by the boxes available, but also by the additional requirements for the change motion, described below.

The weft feelers, as on the W3 loom, were arranged in a bank of 4 and moved up and down with the 4 boxes at the left hand side of the loom opposite to the magazine side. Either electro/mechanical or electrical feelers could be used with the appropriate type of pirn. The feelers were only sensitised when a shuttle was to be picked into the top box at the magazine side of the loom. If an indication for change was given, the change took place on the next pick after detection. Pirn changing was effected by a special vertical movement of the top box which separated from the two boxes below it and rose towards the magazine. The hammer then inserted the new pirn and pushed the old one through the bottom of the top box, where it was ejected forwards by a slide through a space equivalent to one and a half shuttle boxes that had been formed between the top and two lower boxes. The ejected spent pirn was collected in a canvas bag. Changing could thus take place irrespective of whether there were any shuttles in the lower boxes or not. The first pick after the change, however, had to go either to or from the middle or bottom box at the magazine side. This pick could not be delivered to or from the top box at this side of the loom. If the top box was required for this pick, a "dead pick" could be indicated. This involved delaying the loom cycle for one pick without stopping the loom to allow the top box to return to its normal position. Any of the boxes could then be used on the second pick after the change.

Since change could only occur when a shuttle entered the top magazine box, the box chain had to be so designed that each shuttle was frequently directed to this box. In addition, each pirn was required to have a bunch long enough to carry the pirn through the intervening parts of the pick repeat after it had been detected for change. The length of the bunch obviously depended on the size of the design repeat. Unusually long bunches could have created difficulties in the winding department.
It is evident that the loom was working satisfactorily. Indeed, it has been stated that the PAPA 4 x 3 box loom was probably the most successful automatic pick and pick loom ever produced [233].

It is also worth noting that in 1949, the range of looms developed by Crompton and Knowles was on exhibition in Britain. The 'Textile Recorder' commented as follows:

"In putting on the market, their 'all purpose' W3 woollen and worsted loom, Crompton and Knowles Loom Works have endeavoured to meet the need for versatility. This loom can operate as a 4 x 1 automatic pirn changing loom for an even number of picks and up to 4 different colors of weft, and can be converted in less than 30 minutes either into a 4 x 4 pick and pick non automatic loom or into a 4 x 3 automatic loom weaving 3 colors of weft, taking one pick from each colour with each of the three shuttles picking once in each turn." [234]

The mechanism was improved further on 2nd July, 1948, by the provision of a pneumatic weft end holder [235]. It consisted of a double acting pump mounted on the loom side and actuated by a connection to the sley to provide the vacuum. The vacuum system held the tails from the pirns stored in the magazine to the weft end holder. The vacuum also sucked the weft through the holder into a receptacle for waste yarn after the pirn was transferred and the yarn cut off at the temple. In addition, a jet of air under the weft, between the holder and the magazine, kept the stored weft from contact with the moving sley parts. The jet also helped retract the weft on the ingoing pirn, after the cutting at the selvedge, and assisted the vacuum control in disposing of the waste end. A second vacuum operated suction tube held the weft to be cut by the scissors thread cutter at the eye of the shuttle.

The loom was modified further as a result of a patent dated 21st May, 1957. This involved the top box on the magazine side of the loom being lifted away from the lower boxes by an auxiliary box shifting mechanism to provide a gap for ejection of the spent pirn [236]. The auxiliary mechanism was said to have operated more quickly than the normal mechanism so that a gap was produced even if the two lower boxes were being lifted at the same time. It was claimed that the auxiliary mechanism could bring the top box back to its normal position, in time for a pick to be delivered from the top box. Thus the dead pick was eliminated.
These developments led to the introduction of a new PAPA loom in 1957. Referring to these improvements, the 'Modern Textile Magazine' commented:

"This versatile loom will weave fabrics ranging from tropical to heavy overcoatings. The speed of a loom 82 inches between swords is 128 to 136 picks per minute." [238]

It is of interest that, in 1946, Courtaulds Limited set up their own weaving unit at Bull Royd Mill, Girlington, Bradford, to cater on a limited scale for the development of woollen and worsted type fabrics in rayon [239]. The weaving shed contained 48 Crompton and Knowles 82 inch wide W3 looms. These looms were reported to have been chosen for the degree of flexibility they gave in a development mill. The looms could be operated as 4 x 1 box automatic pirn changing looms for an even number of picks and up to 4 different colors of weft. Alternatively, they could be converted into 4 x 4 box pick and pick non automatic looms or into the PAPA. They were equipped with 25 shaft dobbies and the looms were running at a speed of 126 picks per minute. The number of looms attended by each weaver was six [240]. The loom was also widely used in Canadian and American mills [241].

In 1958, the 'Textile Recorder' referred to the versatility of the Crompton and Knowles PAPA loom as its most outstanding feature [242].

By this juncture, automatic looms were now much more versatile than hitherto and multi colour weaving in both double and single picks at this stage was a commercial reality. However, although weft mixing in single picks was possible on pick and pick automatic looms, it is important to note that odd pick weft mixers were also being developed completely separately, but almost simultaneously, with the developments referred to above. The developments relating to odd pick weft mixing automatic looms are described below.
5 Introduction of woollen and worsted odd pick weft mixing automatic looms.

It will be recalled that, prior to the 1930's, on Northrop looms, weft mixing could be carried out with a two box weft mixing motion at one end of the sley and the usual single colour weft magazine at the other. The weft was mixed in pairs of picks. Alternatively, weft mixing could be carried out on the Northrop loom, with a two box check motion at one side, in which case, by controlling the pattern chain mechanism, any units of two picks could be obtained [243]. To insert single picks in a continuous sequence from a number of shuttles containing similar wefts was more difficult, but was particularly desirable in weaving high class woollen and worsteds where freedom from streakiness or bars was necessary but not easily attained [244]. This practice had not, so far, been possible on automatic looms although it had been widely used on non automatics.

The first attempt to develop an odd pick weft mixing automatic loom was patented on 18th January, 1934, in the name of E. Potter, an assignee of W.H. Baker [245]. The loom employed three shuttles for weft mixing purposes, and a weft feeler mechanism. It had two shuttle boxes at both sides of the loom. Each of these shuttles was made to insert single picks in a continuous sequence from each of the three shuttles. The weft feeler was of the side sweep type and resembled the Northrop midget feeler motion. It was located at the left hand side of the loom (the side opposite to the magazine). The weft feeler checked the weft exhaustion, the transfer was effected a few picks later when the depleted shuttle arrived at the top cell of the shuttle boxes on the magazine side of the loom, provided that the shuttle in the lower cell had been picked to the other side of the loom. This method of changing the pirns was a complete break with earlier mechanisms patented by Baker between 1899 and 1902. However, it was no more successful.

By contrast, a similar weft mixing loom developed by the Northrop Loom Co. within two years of this invention, seems to have proved successful in common with all other Northrop loom models [246]. The new odd pick weft mixer had two shuttle boxes at each side of the sley and was made to insert single picks in continuous sequence from each of three shuttles. The loom, was in most respects, similar to the Northrop woollen and worsted looms, but different in parts of the replenishment mechanism. The battery was mounted higher than usual by the depth of a shuttle box [247]. This was due to the fact that the prin was changed only when the shuttle containing the exhausted pirn was in the top box, in the raised position, as in Baker's mechanism. Obviously, on the occasion of a transfer, the bottom shuttle box on the same side
must have been empty so that, on transfer of the new pirn, the empty pirn could fall through the empty shuttle box below and into a receptacle.

The weft feeler at the other side was so mounted that it felt the pirn when the shuttle was in the top box as the box lifted. The three shuttles came successively to this position. The weft feeler was of the mechanical midget type. Alternatively, it was stated that the electrical feeler comprising two prongs could be used, provided that the pirns were fitted with brass collars. In either case, the feeler mechanism delayed putting into action the weft changing mechanism until the shuttle requiring replenishment was in the top box, leaving this box clear. The actual change was said to have taken place at the beat up of the third pick following weft feeler indication [248].

The shuttle boxes and also the delay action of the feeler operated on a cycle of four picks to the round. The shuttles followed a three pick cycle and therefore, the whole movement of shuttles and boxes followed a twelve pick cycle. With a fixed cycle, the three shuttles followed each other in various boxes and picking was alternatively from the right and the left.

It is evident that the loom had proved successful in practice. The 'Textile Manufacturer', in its issue for December, 1936, commented that:

"The loom has passed the experimental stage and has been successfully adopted in mills for the production of high class goods. The looms are built in heavy and medium weights to weave goods from 65 inches to 120 inches." [249]

This and other looms developed by Northrop were exhibited by the company in 1938. According to the 'Textile Recorder' the complete range of looms developed by Northrop was capable of weaving woolen and worsted fabrics, cotton fabrics, as well as the more delicate fabrics made of rayon or silk yarns [250]. Certainly by the late 1930's, automatic looms were available to virtually all sections of the industry for producing fabrics normally produced on non-automatic looms. In particular, the woollen and worsted sections of the industry were now in a position to use automatic looms for the production of high quality fabrics woven with a number of different kinds or colours of weft and plain fabrics free of barriness.
Further developments relating to weft feeler mechanisms.

It will be recalled that by the early 1920's, a number of reliable weft feeler mechanisms had been developed and were reported to have been working satisfactorily. Further developments in this area between 1926 and 1930 led to the development of a number of interesting and apparently reliable weft feeler mechanisms based on the side slip principle.

The mechanism patented on 19th June, 1926, by British Northrop was the famous "midget" weft feeler mechanism [251]. It consisted of a floating non pivotally mounted side sweep feeler which was held between ribs in the top and bottom portions of a casing to prevent it from moving vertically. The casing was adjustably mounted on the loom frame. The feeler was normally held forward by means of a very light spring. When the sley beat up, the weft engaged the feeler and forced it back. However, if the weft was substantially exhausted, the feeler slipped along the pirn and pivoted about its toe, inducing the movement of a wire passing through a slot in the casing, which subsequently initiated the change. The pirn was provided with a reserve bunch of weft, since the replenishment was effected on the pick following initiation of change.

Two years later British Northrop patented a rather different type of weft feeler mechanism [252]. Previous feeler motions could be classed as either mechanical or electrical. The feeler mechanism described in this patent endeavoured to secure the advantages of both. Instead of completing an electrical circuit as soon as the metallic sleeve of the pirn was uncovered, this new invention used the mechanical side slip principle, except that, in this modified version, the lateral movement closed a circuit by the contact of two parts inside the feeler case and this, in turn, led to a pirn transfer. According to the 'Textile Manufacturer', this mechanism was preferable to both electrical and mechanical weft feelers, mainly because it was simpler and allowed for fine adjustments [253].

The next mechanism patented by British Northrop, on 12th December, 1929, was an improved version of the mechanical "midget" weft feeler mechanism [254]. Apart from the feeler tip, which was bent and roughened, the mechanism was identical to the earlier mechanism patented in 1926. It relied on the same spring to control both the forward movement, to make contact between the weft and the feeler, and the side slipping movement, which controlled the mechanism indicating the need for weft change. It was stated in the 'Textile Manufacturer' that this side slipping feeler was favoured, probably because of its reliability in practice, proved by the fact that it had been successfully applied to non
automatic Lancashire looms for stopping the loom when the weft was exhausted [255].

The next weft feeler arrangement, patented by W.W. Triggs on the 11th March, 1930, and developed by Crompton and Knowles, was also of the side slipping type [256]. It is of interest in passing that apparently Hollingworth and Hutchinson of Dobcross seemed no longer to be associated with Crompton and Knowles since the developments originating in the latter company began to be patented in the name of W.W. Triggs, or the company itself. This weft feeler mechanism was very similar to the "midget" mechanism. It was enclosed in a casing mounted on the loom frame. As in the midget mechanism, upon exhaustion of the weft, the feeler slipped along the pirn and pivoted about its toe, forcing the movement of a control wire through a slot in the casing. The movement of this wire subsequently initiated the change. The only difference was that the spring which controlled the movement of the feeler was not located within the casing.

Another feeler mechanism, patented by Ruti on 4th April, 1930, also relied on the side slipping principle [257]. As in the Northrop midget feeler mechanism, the feeler was contained within a casing and was controlled by a single spring. It was in the form of a wire with a triangular contacting portion and a circular part which was accommodated within the casing. Upon weft exhaustion, as the feeler came into contact with the denuded body of the pirn, it was displaced and actuated the weft replenishing mechanism.

It is, therefore, evident that, by 1930, side sweep and electrical weft feelers had been well established. As seen previously, the availability of reliable weft feelers overcame the main obstacle which had stood in the way of developing automatic looms for the production of woollen and worsted cloths (and other high quality fabrics). As soon as reliable weft feelers became available, multicolour automatic looms were accepted commercially, and other types of woollen and worsted automatic looms for weft mixing also appeared. Single shuttle automatic looms also benefitted from the introduction of reliable weft feelers. The refinements of the 1920's must have removed any lingering doubts as to whether weft fork initiation should be retained. Other types of weft feeler mechanisms which did not touch the weft and relied on photo electric cells became available in the post Second World War period.
Further developments relating to automatic loom conversion attachments.

It will be recalled that during the period leading up to the early 1920's, a number of attempts had been made to develop reliable automatic loom attachments, but apparently without much success. The only device of this kind believed to have enjoyed some lasting success was the Whittaker loom attachment, which was described above.

In 1931, British Northrop also patented a mechanism relating to means for converting a non-automatic underpick loom to an automatic weft replenishment loom. It comprised a stand or bracket, adapted to be secured to the end frame of the shuttle feeler, and a shuttle positioning device. The stand also carried means to actuate a weft cutter [258]. Indication of weft exhaustion was submitted through an electromagnet when the two prongs of the feeler mechanism came into contact with the denuded metallic sleeve of the pirn. The shuttle box was modified to facilitate transfer and ejection of pirns. Means were also provided on the magazine for controlling the weft ends. In this manner, an endeavour had been made to provide a weft replenishing attachment comprising all essential features necessary to guarantee the success of the operation. The device was probably aimed at overcoming the reluctance of manufacturers to undergo heavy capital investment by changing over to purpose built automatic looms. This was particularly important in view of the fact that by then, the manufacturers did not have the capital readily available. As the 'Textile Recorder' put it:

"Owing to a long spell of bad trade, mainly due to the war, and results of the war, our spinners and manufacturers, in many instances, have not got the capital to bring themselves up to date, and even if they did, they would no doubt hesitate to use it in these times. [259]"

It will be recalled, however, that in spite of financial difficulties, automatic loom attachments had not claimed even a fraction of the commercial success enjoyed by fully automatic looms. By 1933, there were no more than 52,046 automatic loom attachments in place in different countries all over the world [260]. This probably arose from the fact that automatic loom attachments were not as reliable as automatic looms. Referring to the Northrop weft replenishing attachment, the 'Textile Recorder' outlined the problems associated with automatic loom attachments, and suggested that the cause of their failure was due to the following reasons. These were:
"In the first place, the average attachment is not constructed with the accuracy and attention to detail that is found on the corresponding parts of successful fully automatic looms. Again the fitting of the attachment on the loom is often a troublesome and expensive matter, entailing, at times, considerable unforeseen alterations and additions to the loom. And, thirdly, the loom to which the attachments are fitted are not sufficiently well made to work satisfactorily for long periods under automatic weaving conditions. The last of these obstacles in the way of the satisfactory use of automatic attachments is one which cannot be overcome. The trouble can be minimized by selecting for use with attachments only the best looms available, preferably slow running looms of sound material and construction, for the difficulties in the way of the satisfactory working of the attachments are undoubtedly reduced at low speed." [261]

The article went on to add that:

"An attachment which has been developed by the British Norhtrop Loom Co. of Blackburn completely gets over the first of the difficulties given above, and reduces to the minimum the troubles of fitting and the number of parts which have to be added to the loom."

It is evident, however, that the mechanism was not as reliable as the Northrop automatic loom. This arose from the fact that the transferrer was cam operated and not sley operated which gives rise to the usual doubts about accuracy of timing the change. The fact that the difficulties in the way of the satisfactory working of the attachments were said to be reduced at lower speeds seems to confirm this. In addition, the attachment could not be fitted to overpick looms since the rotary magazine interfered with the picking mechanism. This made the mechanism less appealing, in that most non automatic looms running in Britain were still of the overpick class.

It is of interest, however, that in other European countries, too, attempts were being made to develop a weft replenishing attachment as an alternative to fully automatic looms. One such mechanism was patented on 26th February, 1936, by M. Auerbach of The Hague [262]. This was
capable of automatically inserting cops, especially jute cops, into the shuttle. It was very simple and comprised a vertical hopper, a weft feeler and a transferrer. When the change shaft was rotated by the action of the weft feeler mechanism, the transferrer fell from its normal position and came almost in contact with the lowest cop in the magazine. The transferrer was then depressed, first slowly, then quickly to insert the cop into the shuttle "without shock" as the sley moved forward. When the sley moved back, the transferrer was returned to its normal position.

It is evident, however, that the mechanism did not generally prove successful for some time. It was eighteen years after the mechanism had been patented that the textile journals first took an interest in it. By then, however, the mechanism had been significantly improved. The weft magazine employed was either rotary, for finer wefts, or inclined for coarser wefts, and an electromagnetic feeler was employed, instead of the original mechanical weft feeler mechanism [263]. At this time, the mechanism was being produced in Germany, and was regarded with some favour as can be gathered from an article published in the 'Textile Recorder' in the issue for March, 1954.

"As a simple and economic means of converting ordinary looms to automatic operation, the fitting of weft changing attachments has much to commend it and it is, therefore, of interest that the German firm of Auerbach and Co., of Oldenburg, has concentrated production on the manufacture of such units... The Auerbach weft replenishing motion fall broadly into two groups, namely those intended for the coarser yarns such as jute, wool and waste material, and those intended for finer cotton and spun rayon.

The former are cop changing mechanisms which may be fitted either to underpick or to overpick looms without any constructional alterations to the loom, and without any reduction in the running speed."

[264]

In the event, however, this mechanism does not appear to have had any lasting success in Britain. This, in part, may have been due to the fact that by then, the more highly developed Fischer automatic pirn changing attachments had appeared.

On 6th May, 1938, the 'Textile Recorder' referred to the introduction of Fischer attachments for the first time and commented as follows:
"At the present time, Messrs. George Fischer, Schaffhausen, Switzerland, well known for high quality engineering production, have tackled the question from basic principles, and in their Rauschenbach Pirn Changing Device, with special Weft Feelers and Warp Stop Motions have evolved an efficient unit applicable to any single shuttle loom, either loose reed or fast reed; overpick or underpick." [265]

This represented yet another attempt to develop a weft changing device applicable to existing looms. Earlier attempts in this area were reported in the same issue of the 'Textile Recorder' not to have been a satisfactory substitute for fully automatic looms as they did not work as precisely and effectively as the corresponding parts of automatic looms [266]. The fact that in 1938 there were 483,984 ordinary looms, 15,224 automatic looms and only 5,565 looms fitted with automatic attachments in place in the British cotton industry seems to confirm this. As noted previously, since most non automatic looms in place in the United Kingdom were of the over overpick type, magazines had to be contrived which did not interfere with the picking stick. In consequence, vertical or obliquely arranged magazines had been used [267]. The Fischer attachment, by contrast, made use of a semi circular pirn magazine, in which the ends drawn from the pirns were, as in the Northrop automatic loom, secured to the axial spindle of the semi circular magazine via a guide disc. The magazine was automatically advanced by a ratchet mechanism [268].

It was stated by the 'Textile Manufacturer' that the attachment could be fitted to both right and left hand looms and that 40 to 45 inch looms could be run efficiently at speeds of 170/180 picks per minute [269]. It is also interesting to note that by 1938, at least one firm had set out to adopt 155 of these pirn changing attachments. Referring to this development the 'Textile Recorder' commented:

"The looms to which they were fitted were 40 inch reed space underpick looms made by Platt Bros. & Co. Ltd., and H. Livesey, dated 1906/7... The speed of the looms converted was 175 picks per minute against 190 picks for those not converted." [270]

By 1946, it was reported that the Fischer attachment had been fitted to thousands of looms all over the world and that it had met with
tremendous success [271]. The cost of conversion of an ordinary loom to fully automatic working was stated to be only a third, often even a quarter of the cost of a new automatic loom, according to the type and width of the loom. At this time, however, the attachment could be fitted only to single shuttle looms. Later, in the late 1950's, as a result of further improvements, the attachment was made more versatile, as will be seen subsequently.

In the 1949 "Textile Recorder International Textile Machinery Exhibition" the firm of George Fischer Steel and Iron Works Ltd. showed two Lancashire looms, one overpick and one underpick, both converted by the Fischer attachments into automatic looms, weaving cotton and linen fabrics respectively [272]. The system of conversion included a new iron sley, a positive checking arrangement to both boxes, a magazine with a safety device, a shuttle protector mechanism and a weft feeler mechanism. In this manner, an endeavour had been made to provide all the essential mechanisms for carrying out the change effectively and efficiently [273]. In the same exhibition, the firm of Harling and Todd Ltd. also showed one of their non automatic looms fitted with the George Fischer pirn changing unit [274]. This loom attachment was probably the most successful device of this kind to have been produced.

8 Introduction of different models of the Northrop loom for weaving various fabrics.

Different models of the existing single shuttle Northrop loom were developed, between 1920 and the Second World War, for weaving a variety of fabric types. Even by 1925, several models of the Northrop loom were available. The "T" model loom was the standard narrow cloth loom for weaving with from two to six shafts. The battery accommodated 24 pirns equal to about 2 1/2 hours supply on 24's cotton weft [275]. The "H" model loom was specially designed for weaving fustian cloths. It had a stronger frame, sley and back rest than the "T" model, and was fitted with positive tappets for operating up to 12 heald shafts. The "F" model loom was specially designed for weaving sheeting fabrics. It carried the standard features of the Northrop mechanism as on the "T" model [276]. For heavy work, the "F" model loom was specially fitted with a 16 shaft open shed positive dobby [275]. The "K" model loom was specially designed for weaving medium weight cotton, linen, silk, rayon, and wollen and worsted fabrics. It was fitted with either tappets for operating up to 6 heald shafts or with a negative dobby for operating
up to 16 heald shafts. This loom was supplied for cloths from 28 to 70 inches wide [277].

In 1922, the Northrop Damask Loom [278] had been added to the range. The loom was fitted with a jacquard shedding motion. It also included the standard features of the Northrop automatic looms, including the side sweep weft feeler mechanism developed by the company in the early 1920's. It is interesting to note that, by 1924, according to the 'Textile Manufacture', about twenty linen manufacturers had installed Northrop looms. The first to introduce the loom was Hay and Robertson Limited [278].

Another important new addition to the wide range of Northrop looms in the early 1930's was an automatic jute loom. Automatic looms were particularly suitable for jute weaving. This arose from the fact that the cloths were mostly of simple weave, most likely pickfinding was not necessary and the yarn was coarse. Of these, the last was the most important consideration in that, on non automatic looms, the weaver spent a substantial proportion of the available weaving time in replenishing the weft manually when coarse wefts were used. In consequence, the weaver could only attend a very small loom complement in these circumstances. Even by the late 1930's allocations of only one, or possibly two, looms per weaver was common practice in the jute trade [279].

In developing their automatic jute loom, Northrop took account of the fact that jute yarn was strong but lacked elasticity and consequently was not regarded as a good weaving yarn. To avoid strain on the warp, the shed opening was kept as small as possible. A special feature in jute weaving was the use of weft supplied solid cops. These packages could be used in shuttle changing looms but for the Northrop pirn changing automatic loom, it was essential to wind the jute weft onto a wooden pirn. Another feature of the loom was that it was very similar to the standard non automatic type of jute loom then in current use. It was claimed that this made it easy for the operatives to become accustomed to the loom.

The let off motion was of the friction type and it was claimed that arrangements could be made to accomodate beams with flanges up to 36 inches in diameter. The take up motion could accomodate a roll of cloth up to 34 inches in diameter [279]. The weft feeler and the weft replenishing motions were of the usual type used on single shuttle automatic looms. However, the magazine had been modified to hold pirns up to 11 inches long by 1 11/16 inches in diameter.

The range of looms produced by Northrop was shown at the Northrop Demonstration Weaving Shed which was set up in 1935. the range of widths was from 36 inches to 120 inches reed space and there were separate models for cotton, rayon, silk, heavy canvas, flax, jute,
woolen, and worsted. Multiple box looms were included for weaving fabrics from cotton, wool, rayon or silk. There were also two automatic terry towel looms [280]. In 1937, a new linen towel automatic loom was added to the above range [281]. The opening of the new demonstration shed, at the works of British Northrop in Blackburn, completed an extension and re-equipment of the loom making departments. This had been necessitated by the fact that, as a result of an increase in the world wide demand for the company's automatic looms, much work had to be subcontracted.

In 1938, British Northrop exhibited the most recent additions to its already wide range of automatic looms. These were the 4 x 1 box four colour automatic pirn changing loom, the 2 x 2 box 'odd pick' automatic weft mixing loom, a heavy single shuttle pirn changing loom for the production of heavy drill, and a shuttle changing loom for the manufacture of finer and more delicate fabrics [282].

With the coming of the Second World War, the need was for specialised weaving machinery for military fabrics of all kinds. Amongst the most difficult to produce were said to have been narrow webbings varying in width from 4 to 18 inches. The difficulty arose from the fact that these fabrics were very heavy and required a specially built heavy loom. British Northrop was quick to respond to this need and in October, 1939 was reported by the 'Textile Recorder' to have added to their range of fully automatic pirn changing looms, a military webbing loom which had already been installed in different parts of the country giving "excellent" results [283]. The loom was fitted with a weft replenishing mechanism controlled from a mechanical weft feeler motion. Shedding motions varied according to the fabrics which were to be produced, but for complicated weaves the positive rotary dobby was recommended.

It is also of interest that in the late 1930's British Northrop introduced a rapier shuttleless loom capable of inserting single picks of up to seven colors or types. Unlike other Northrop looms, this loom does not appear to have claimed any significant commercial success, although the 'Textile Manufacturer' recommended that this loom was as reliable technically as pirn changing looms developed by the company [284].
The Introduction of shuttle changing automatic looms for weaving rayon and silk yarns.

At the start of this survey, it was stated that attention would be given mainly to pirn changing looms and thus, more than fifty years of development of shuttle changers has been ignored. This was partly to limit the scope of an already substantial study. It was also due to the fact that, not only were shuttle changers an inferior substitute* for fully automatic pirn changers, they also tended to be used mainly in the relatively small silk sector, where the yarn had to be handled gently. However, with the widespread use of rayon after the First War and the consequent expansion of the silk and rayon sector, shuttle changers and their competition with pirn changers in this area of manufacture cannot be ignored.

During the 1930's, a number of loom makers, on both sides of the Atlantic, turned their attention to designing looms capable of weaving rayon and silk fabrics. According to the 'Textile Recorder', it had been found from experience that, for the finer yarns, the automatic pirn changers were not entirely suitable, in that they often led to breakage of the weft yarn. In consequence, an alternative had been found in shuttle changing automatic looms for weaving rayon, silk and other delicate yarns [285].

One of the earliest and most interesting of the new generation of British looms of this kind was that introduced by the firm of George Hattersley and sons Ltd. of Keighley in 1936 [286]. This was a two box shuttle changing loom which included a weft feeler mechanism as well as centre weft forks. The shuttle changing mechanism was operated by four cams on the main cam shaft. The first one prevented the loom from starting if the exhausted shuttle had not been ejected properly or if the new shuttle was not housed in the box properly. The second cam operated the box front which was lifted to permit the ejection of the empty shuttle and the insertion of a new shuttle, and was lowered after change. The third cam operated the shuttle carrier, which conveyed the shuttle from the magazine to the shuttle box, whilst, the fourth cam caused the picking stick to be held during the change. The whole operation occupied a time equivalent to four loom cycles during which time the normal actions were stopped. A shuttle selecting mechanism which was synchronised with the box motion was provided to release the shuttle.

*Shuttle changing looms required a matched set of shuttles, the cost of which was higher than that of the pirns required for automatic pirn changers, the capacity of the magazine was somewhat limited by the size and the weight of the shuttles thus requiring more frequent attention by the weaver or the battery filler if any and the changing operation took longer to be completed.
containing the requisite colour of weft from the magazine. Moving backward and forward along the front of the magazine was a hook which derived its motion from the box motion segment wheels. When a change was required, the hook was moved into line with one or the other of two catches which, when depressed by the hook, released the shuttle containing the requisite colour of weft into a conveyer [287]. In this manner, a mechanical memory mechanism similar to that used by Crompton and Knowles had been employed. The loom was reported by the 'Textile Recorder' to have been running satisfactorily producing a cloth with excellent cover.

In 1937, the firm of Butterworth and Dickinson of Burnley, introduced a two box shuttle changing silk and rayon loom. The shuttle changing operation was almost identical to that used by Hattersley. It was controlled by four cams, by which, respectively, the box front was lifted, the picker was allowed to fall back, the empty shuttle was ejected and the new shuttle was conveyed to the box. The loom also made use of a mechanical memory which was synchronised with the box motion [288].

In Lancashire, in the same year, Messrs. W. B. White and Co. Of Colne introduced a non stop shuttle changing loom for two shuttle rayon weaving [289].

Also in 1937, the firm of Willan and Mills of Blackburn, through their association with the French firm of Ateliers Guillaume Diederichs made and introduced into the U.K., the two box Sante Colombe shuttle changing loom [290]. Within two years, in 1939, a four shuttle model of the loom had also been developed. The loom was fully automatic and capable of any order of even checking. The box motion was synchronised to work with the shuttle changing mechanism. There were four magazines, each for a different colour or kind of weft and each corresponding to a shuttle box at the multiple box side. The magazines were situated on the loom frame, directly in front of the single shuttle box. When the need for weft replenishment was registered through the feeler located at the single box side, the shuttle was sent across the sley to the multiple box side. The change was then effected when the shuttle arrived back again at the single box side. If the boxes changed position at the next pick, after weft exhaustion had been indicated by the feeler, the shuttle change was delayed until the box containing the depleted shuttle was again brought to the level of the race board [291].

It is of interest that, in 1936, British Northrop also developed an automatic shuttle changing loom for the manufacture of the finer qualities of linen fabrics, especially cambrics and high quality damasks. It will also be recalled that, prior to this date, the company had introduced an automatic pirn changing loom for the manufacture of the coarser qualities of linen goods such as towelling and sheetings. This
type of mechanism had not proved completely successful in weaving the more delicate types of yarns and the company resorted to shuttle changing to overcome the problem encountered in the pirn changing operation for such yarns.

The non automatic type of shuttle could be used in this automatic loom, and the magazine could contain nine shuttles. When the shuttle was to be changed, as in the Hattersley mechanism, the loom was automatically stopped, and the control mechanism consisting of cams on the cam shaft was operated. Successively, the shuttle box front was lifted, the exhausted shuttle was ejected, and the new shuttle was carried from the magazine to the shuttle box, the shuttle box was replaced and the loom was restarted. The whole sequence was stated to last four to five seconds [292]. Smooth running and uniform speed were claimed to be reflected in the superior quality of the cloth produced [293]. In this mechanism, the weft could be supplied to the shuttle either on cops or on wooden pirns.

Northrop's shuttle changing loom, although originally aimed at producing finer linen fabrics, was by 1937, reported to have been included in the range of looms suitable for the rayon industry [294]. This development had probably been brought about as a result of competition with other loom makers who had placed on the market shuttle changing looms for the manufacture of rayon and silk fabrics as stated above.

By 1939, in America, Crompton and Knowles had developed a non-stop shuttle changing loom for the weaving of filament rayon. This 2 x 1 box model changed the shuttle without interruption of the normal operation of the loom. There was also a 4 x 1 model in which two cells of the four cell shuttle box contained shuttles that had their weft replenished automatically by the shuttle changing mechanism while the other two cells contained shuttles, the weft for which was replenished by the weaver. This latter loom had been developed for fabrics having the body woven with automatic shuttles and the decorations with the two shuttles that were refilled manually [295]. These looms were said to have proved successful in both America and Britain [296-297].

In the 1940's, Ruti also produced shuttle changing looms in every conceivable variation form the plain silk loom to 11 shuttles pick and pick [298]. One model was a 4 shuttle version of which the shuttle changing was effected with the loom running at normal speed. In order to minimise the wear on the shuttle, when a change was made, the shuttle was shunted at an obtuse angle to a position behind the shuttle box, where it fell down a curved chute into a container. On the pick and pick version the shuttle change was made with the loom stopped. The weft feeler and memory mechanisms were electrical. In conjunction with these rayon
and silk looms, Ruti introduced a flat pirn with a corresponding flat shuttle, which had an advantage over the round pirn in that, for a given size of warp shed, the yarn capacity of the pirn could be increased by 60 to 100 percent [298]. As a result of increasing the yarn capacity of pirns, the frequency with which the expended pirns in the shuttle had to be replaced manually was reduced. In addition, loom efficiency was also increased. Efficiency in the pirn winding department was also increased due to the winding of larger packages.

Referring to the various looms developed by Ruti the 'Textile Recorder' commented:

"The above looms are fine examples of the application of modern engineering techniques to textile machinery." [299]

From this brief account, it is evident that on both sides of the Atlantic, the tendency was to use the shuttle changer rather than the pirn changer for weaving delicate yarns such as silk or rayon. This preference probably arose from the fact that the shuttle changing mechanism did not touch the pirn or yarn and there was thus no possibility of the weft being damaged through contact with the mechanism.

10 Automatic weaving machinery developments in the post Second World War period.

10.1 Introduction.

During the period leading up to the Second World War, automatic looms had been developed to meet a wide range of user requirements. The 'Textile Manufacturer', in its issue for November, 1947, referring to the versatility of modern weaving machinery, commented that:

"Automatic looms can make almost any cloth which can be constructed for commercial sale." [300]

In Britain, however, little modernisation of plant had taken place during the inter war years. The 'Textile Recorder', in its issue for November, 1940, referred to the advantages of using modern weaving machinery, stressing the fact that Britain lagged behind other countries such as the United States [301]. Under war time conditions, however, there was very little Britain could do to improve her weaving machinery.
The war also halted improvements in automatic weft replenishing mechanisms. Both in Britain and America, the textile mechinists had been restricted in their development work, and in some cases, particularly in the United States, had been prohibited from manufacturing textile machinery of new design [302].

In the immediate post war years, the textile industry was destined to find itself with a greatly reduced labour force. It was estimated that the cotton industry, for instance, possessed a labor force amounting to only about 50 per cent of that which it possessed in 1939. It was considered that in order to make the most efficient use of the labour available, there was a need to adopt the most modern equipment in order to increase output per operative, especially so, in view of the considerable increase in the world demand for all types of fabrics which occurred following the end of the war [303]. Furthermore, the industry faced severe competition from other exporting nations during this period and this, too, emphasised the importance of automatic looms. Indeed, as the 'Textile Recorder' put it when referring to the affairs of the British cotton industry in its issue from January 1944:

"To enable Lancashire to meet post war competition, it is essential that its weaving industry should be equipped with the most modern and efficient types of looms available." [304]

With this in mind, the 'Textile Recorder' started promoting automatic looms aggressively. In a series of articles, the range of automatic looms available was referred to and the types of organisation and management necessary for automatic weaving were discussed. It was clear that, for the first time, the automatic loom was being looked upon as the best economic proposition, and attempts were being made to make known its advantages, capabilities and limitations [305].

It is evident, therefore, that it was believed that the automatic loom was about to become widely adopted in Britain in the post war years. The greatly extended use of automatic looms was also advocated in both the second and fifth recommendations of the Board of Trade Working Party Report on the British cotton industry which was published in 1946. It was suggested in the report that 120,000 automatic looms should be installed within five years to give the industry a proportion of 45 per cent automatic looms. However, it was stated that the capacity for the production of the automatic looms (without Government intervention) was quite inadequate to meet the demand of that order of magnitude within a reasonable period of time [306]. It was stated by the 'Textile Recorder' that even if the demand were to be half as great as that
suggested and a period of 10 years were available for it to be met, the loom makers would have the greatest difficulty in providing the automatic looms required [307]. It was also added that the volume of orders already placed far exceeded that which, with existing capacity and the additional capacity that could be foreseen, could be produced in the immediate future and that it was likely to take 5 to 6 years before the total output of automatic looms could equal the total value of looms already on order.

The bulk of the capacity available for the production of automatic looms was located with British Northrop who employed somewhat less than 2,000 operatives and were the largest unit in the loom making industry in the United Kingdom. In terms of operatives employed, the next largest firm was Hattersley who manufactured a very wide range of different types of looms but their automatic looms represented only one amongst many types of products. Moreover, their looms were principally suitable for the production of wollen and worsted fabrics, silk and the finer end of the rayon industry. So far as other British manufacturers were concerned, only a small output of automatic looms was expected from them to meet the requirements of the cotton industry [306].

In January, 1948, British Northrop announced that they had reached a target of 6,000 looms per year. Of this production, about one third was to be exported. Four years later, British Northrop, on the occasion of its fiftieth anniversary of automatic loom manufacturing, announced that the annual output had reached 10,000 automatic looms [308]. Despite this increase in production, the British loom makers were, nonetheless, unable to cope with the demand. In consequence, many of the orders placed in the immediate post war years were later cancelled [306], and British firms started purchasing foreign made automatic looms. For instance, in 1949, the 'Textile Manufacture' announced that some manufacturers in Bradford had purchased Saurer automatic looms [310].

The great demand for automatic looms in Britain and other European countries in the post war period led to the establishment of a number of textile machinery firms in Europe. Their products reflected contemporary commercial developments in automatic loom construction. However, technical developments during this period as compared with the pre-war years were few in number. The range of looms developed in the post war years was often referred to in textile journals and is illustrated below.

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10.2 British made automatic looms.

Starting in 1944, a number of British loom makers set out to improve their existing mechanisms as well as evolving new models. A selection of these developments is described below.

For several decades, the firm of Hattersley and concentrated on developing automatic shuttle changing looms for worsted, silk, rayon and canvas, but had not developed a pirn changing loom. This was remedied in 1944, when the "Hattersley Standard Model" 4 x 4 box non automatic woollen and worsted loom was converted into a 4 x 1 box pirn changing automatic loom [311]. This meant the sacrifice of three out of the four shuttle boxes at the driving end and the introduction of a magazine holding four columns of pirns. In addition, the overpick motion was replaced by a strong underpick motion to deal with long pirns and heavy shuttles [312]. The speed of the loom ranged from 110 to 105 and then 90 picks per minute for reed widths of 84, 90 and 100 inches respectively. The loom was fitted with a mechanical memory mechanism almost identical to that used originally by Crompton and Knowles in their 4 x 1 box multi colour automatic loom. In addition, in 1949, a major improvement was effected by the transfer of the weft feeler and selector arrangements from the multiple box end to the plain box end of the loom [313].

In the immediate post war years, British Northrop introduced the "LF" and "LFW" model looms. The "LF" was designed specially for producing medium weight fabrics in cotton, worsted, rayon or linen. It was built in widths ranging from 20 inches to 75 inches and was provided with a variety of shedding facilities up to a maximum of 16 shafts. The "LFW" was similar to the "LF" model in most respects but was deeper in the frame from back to front to provide sufficient heald space to accommodate 20 shafts. The "LF" and "LFW" were available in single box, two box for weft mixing, two box check and four box check versions.

A modified version of the Northrop two colour check loom was introduced in 1946. On the older type of loom, the magazine containing the two colours of weft was of the oscillatory type. On this modified version, the magazine was of the fixed type after the style of that commonly used for the four colour checks. However, only two solenoids were required for the weft selection instead of four [314]. Another feature of the new loom was the application of a mechanical weft feeler to replace the electric type. This was aimed at cheapening the cost of pirns by dispensing with the 'metal ferule' that otherwise had to be fitted to them. The loom was said to suitable for the weaving of 2 x 2 crepes as well as check designs in multiples of two picks. A similar model of the
loom was also available for flat rayons. It possessed all the refinements described above. This model was also available with a single shuttle and was fitted with the standard circular type magazine instead of a vertical magazine. The recommended speed for checks on a 48 inch loom was 150 picks per minute, whilst, for single shuttle looms of the same width, 165 picks per minute was said to be a suitable speed.

As will be noted later, one of the features of the continental looms developed in the post war years, was the absence of a superstructure. By contrast, British Northrop's range of looms all possessed a superstructure. Furthermore, their looms had been hardly improved since before the outbreak of the war. It was towards the end of the 1950's that two new ranges of fully automatic looms, a special feature of which was the complete absence of a superstructure, were introduced by British Northrop. These were the HST high speed range for producing light and medium weight cotton, rayon and moisture fabrics up to 60 inches wide, at operating speeds between 200 and 250 picks per minute, and the MRT range, suitable for weaving cotton, staple, man-made fibers, worsted and linen fabrics up to 85 inches wide in the speed range of 140 to 200 picks per minute [315]. In both these ranges, loom top framing and the shedding parts, normally above the level of the healds, had been eliminated. 

This led to better lighting, easier and better access for piecing the broken ends, and better appearance.

The HST models were single shuttle looms and were fitted with the standard Northrop single colour rotary battery. The MRT range was available as a single shuttle, a two box weft mixer, or a two or four colour box loom, and was fitted with the standard rotary battery for single shuttle operation and, for two and four colours, with either the two or four colour stationary battery, or the two or four colour rotary battery. The 'Textile Recorder' in its issue for February, 1957, commented:

"These new Northrop looms are notable for their smooth running and freedom from vibration, they are robustly constructed, streamlined in appearance and are built by the latest precision engineering methods."

[315]

In 1950, another British firm, George Keigley Ltd. of Bankhouse Works, Burnley, introduced a new automatic loom known as the "Model K100". It was stated in the 'Textile Recorder' that the loom was identical with the maker's standard non automatic models and that with the exception of the weft replenishing mechanism, resembled non automatic Lancashire type looms [316]. The loom was capable of supplying only
one type or colour of weft and was therefore suitable for the plain varieties of cotton and rayon fabrics. The automatic pirn changing motion incorporated a Z shaped weft battery capable of holding about 24 ordinary 6 inch pirns. The change was initiated from a side sweep weft feeler. The loom also included weft cutting and shuttle positioning devices. The speed of a 45 inch reed space loom was said to be about 180 picks per minute.

In 1951, the 'Textile Recorder' described another British development. This was the "Stansfield" weft replenishing attachment invented by Ernest Baily in conjunction with John Stansfield and Sons Ltd. and developed and manufactured by the firm of Bass Smeaton Ltd. of Wesham near Preston [317]. The motion could be fitted to any ordinary single box Lancashire loom, converting it to a fully automatic machine. The mechanism comprised a circular rotating type of magazine which housed 28 full pirns. The pirn changer was initiated from a sliding weft feeler and pirn change was effected by a sley operated transferrer. It was stated by the 'Textile Recorder' that the pirn change was:

"both instantaneous and positive, being effected with an exceptionally light and smooth action." [317]

One of the most interesting developments during the 1950's was due to the British Cotton Industry Research Association. The patents for their "Shirley Loom" appeared between 1951 and 1956. [318] Basically the loom was an underpick 2 x 1 box fully automatic pirn changing dobby loom fitted with a two slot vertical battery. The box motion was geared to insert alternately two picks of weft from each shuttle. The loom was primarily aimed at the weaving of filament yarns. In 1958, when details of the loom were made public, it was stated by the 'Textile Recorder' that:

"The machine is extremely versatile, and has already woven with complete success a wide variety of commercial cloths ranging from very fine plain weave nylon and a full range of Terylene and rayon fabrics to nylon industrial fabrics and glass cloths; yarns dealt with have included flat and crepe yarns." [319]

The picking mechanism was novel and interesting. The 'Textile Manufacturer' gave a full description of the mechanism as can be seen below:
"A combined bottom shaft and swing rail is employed and the picking cam and its rotating follower run in an oil bath. Made from special hardened materials, the cam and followers are readily adjustable and replaceable. A special picking stick check motion is fitted, connected by a lever directly to the picking stick and which operates a small piston. The piston is free to travel during the normal movement of the picking stick but when the shuttle has left the picker, the stick is very effectively checked by air compression in the cylinder. This prevents sudden shock occurring and ensures that no sudden shock reaches the reed. Special double swells are provided. A longer swell operates the stop rod and a shorter one—which passes through the long one - is used to stop the shuttle towards the end of its movement along the shuttle box. The pressure of the smaller swell is released before picking takes place." [320]

This was a complete break with the conventional practice for picking arrangements.

The magazine was capable of stacking 14 pirns in each of its vertical slides. "Lashing in" of the weft, both on the magazine side after a pirn change and on the double box side during normal running was prevented by suction control operating from a fan built onto the motor. Moreover, at the single box side, a pressure air jet ensured that the weft did not get trapped in the box. The wet feeler was electrical and had two fingers which completed a circuit when a metal collar on the pirn was uncovered sufficiently. A feature of the feeler, however, was the provision of a third finger with a relatively large non metal foot to prevent the metal contacts touching the yarn on the pirn until just before the weft was exhausted.

Commercial manufacture of the loom was to be undertaken by the firm of Wilson and Longbottom Ltd. and redesigning necessary for the manufacture of a production model was completed in 1958. The loom was to be manufactured in effective widths of 48, 54, 60 and 66 inches with speeds ranging from 184 down to 154 picks per minute according to width. Furthermore, 12 or 16 shaft dobby versions and an alternative version with a side tappet motion were stated to be available [319]. Although technically interesting, the loom proved to be a commercial failure.

Another interesting development in the early 1950's was the introduction of the "Ecco X" solid cop automatic loom. The "Ecco" cop
changer was of Italian design but in 1949, the firm of Thomas C. Keay Ltd. of Dundee in Scotland, procured sole manufacturing and selling rights for the mechanism in the United Kingdom, Eire, India and Pakistan. By 1957, 3,000 "Ecco" automatic looms had been installed in the United Kingdom and Eire, over 500 in India and nearly 900 in Pakistan. In addition, a very large number of Italian made "Ecco" looms had been installed in Europe and other parts of the world [321].

The "Ecco cop loader" incorporated an inclined weft magazine and the change was initiated by a weft feeler mechanism. In addition, means had been provided for severing the weft ends [322]. The mechanism was said to be suitable for weaving jute yarns and other yarns which could be presented in the form of centreless cops [323]. It is also worth noting that by 1961, the firm of Hattersley had developed a model HN jute loom fitted with the "Ecco cop loader" [324].

During the same period, a number of developments occurred in the United States and Europe as will be seen in due course.

10.3 Developments in the United States

A number of important developments took place in the United States in the post Second World War period.

In 1948, Crompton and Knowles patented what appears to have been the first photo electric weft feeler. To detect the exhaustion of the weft the pirn had contrasting zones (preferably black and white) each arranged to reflect a beam of light from a lamp onto two photo cells. As the surfaces were exposed by the removal of weft, there would be a change in the amount of light reflected to at least one of the cells, whatever the colour of the weft. Thus, the first cell received decreased illumination from the black zone when a light weft was exhausted while the other received increased illumination when a dark weft was exhausted. The cells were arranged to each operate a relay completing a series circuit for an indicator or control device when they registered a change in illumination from an empty pirn. This invention was described with reference to multi shuttle weft replenishing looms, in which two shuttles were provided with different wefts and were each replenished by reserve pirns of corresponding colour, from a two compartment magazine [325].

In 1953, two notable American looms were described by the 'Textile Recorder'. The first was a new low built addition to the range of looms supplied by Crompton and Knowles. This was a 2 x 1 box weft mixing loom available with a variety of shedding motions. There was a single circular magazine holding 22 pirns [326].
A loom made by the firm of Hunt Loom and Machine Work Inc. of South Carolina is worthy of comment. Commonly known as the "H.R50", it was of the single shuttle pirn changing type designed for the weaving of fabrics up to 66 inches wide. It was said to run faster than most looms and was equipped with dobbby shedding motion [326]. A new version of the loom (the "H.B.3") was described by the 'Textile Recorder', in January, 1954. This had several notable features. First it was claimed to require no lubrication, enabling cloth to be woven with a high standard of cleanliness. This had been achieved by the use of nylon gears and oil impregnated bushes [327]. The second feature of the loom was the absence of the usual starting handle. Starting and stopping was controlled by push button switches located in the centre of the front arch of the loom. This was made possible by the use of electromagnetic clutch and brake in the control circuits of which timing switches were incorporated. The third, and perhaps the most interesting, feature of the loom was the built-in air conditioning and dust removal system. Each loom was equipped with a duct open at the top and running lengthwise under the full length of the drop wires of the electrical warp stop motion. The duct was connected to a main duct, embedded in the floor and connecting all looms, extending to a vacuum unit at the central air conditioning station. It was stated by the 'Textile Recorder' that the new loom had been in operation, undergoing a trial, at the Border Mills for some months and that orders for the immediate delivery of a large number had been placed with the manufacturers [328].

One of the most important developments in the post Second World War period was the production of the "Unifil Loom Winder" by the Universal Winding Co. [329]. According to the 'Textile Recorder', the device was first shown at the Atlantic City textile machinery exhibition in 1950 [330]. The Unifil Loom Winder seems to have been a development of some of the patents of the 1900-1910 era and seems to have been the only successful device of its kind. It was an attachment to the loom which prepared automatic loom pirns in readiness for the operation of the weft change mechanism. After each change, the exhausted pirn passed down a chute to a stripper and was then delivered to a receptacle. A conveyor belt, having permanent magnets which attracted the metal rings on the pirn head, collected the pirns from the receptacle and delivered them to the entrance of the magazine. A finger then aligned the pirns for entry into the chute of the magazine. Cam means were also provided for transferring the lower most pirn to the winding position. At the commencement of winding, a bunch of reserve yarn was wound adjacent to the pirn head, and subsequently, the yarn was guided along the pirn by the traverse guide moved by the reciprocating bar. When the traverse guide reached the pirn tip, it engaged an element, causing a doffing
mechanism to operate. When the loom battery was full, the uppermost pirn held a finger down and the drive to the winding motor was interrupted by electrical/or mechanical means.

The mechanism therefore followed a continuous cycle of operation for automatically transferring weft yarn from creeled cones to woven cloth. In this manner, the need for a weft winding room was completely eliminated while the operation of the winder greatly reduced the handling of yarn and also lessened the chances of mixed weft. Furthermore, substantial economies could be made in the number of weft pirns needed in the mill. The most important advantage of the device, however, lay in its capacity to reduce labor costs, these savings being dependent on yarn count. Indeed as the 'Textile Recorder' recognised in its issue for December, 1957:

"because of the saving in labor, the unit achieves appreciable economies in manufacturing costs ... The actual saving in weaving standard grey cotton with 9's weft is in the neighbourhood of 1.33 (old) pence per yard." [331]

It is worth noting that the mechanism was first available in America in 1950 where, for a number of years, it was undergoing tests, which, according to the 'Textile Manufacturer', had proved completely successful [332].

The "Unifil" arrived in Britain in 1957, and was demonstrated operating in conjunction with the Northrop "S" automatic loom in Manchester. The unit was said to be available for installation in British automatic weaving sheds with delivery in three to four months after ordering [331]. At the demonstration, the unit was reported to be working efficiently on a 44 inch reed space Northrop "S" automatic loom running at 176 picks per minute, weaving a plain wave cotton cloth from 20's cotton warp and 14's cotton weft with 80 ends per inch and 54 pick per inch. The winder was set to wind weft at a rate 22 percent faster than it was consumed in the loom [333].

By 1956, it is evident that, at least two American mills had installed the new loom winder on a large scale. In Britain in 1963, it was announced that the firm of Butterworth and Dickinson who had by then become associated with the firm of Wilson and Longbottom, had modified and fitted their automatic loom, which was of modern design and had no superstructure, with the Unifil loom winder [334]. This loom was known as the "ARC Model" and was said to be particularly suitable for weaving cotton and spun man made fibers [335].

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The Unifil loom winder was important in that it reduced labor costs to a greater extent than other developments in this period, such as the Fischer box loader. Later, with the introduction of the Multifil loom winder, multi colour automatic looms could also be fitted with a similar attachment. The Unifil and the Multifil loom winders were subsequently used quite extensively in Britain and other countries which had introduced automatic looms.

10.4 Developments on the continent of Europe

Since the end of the war, several continental engineers had devoted their attention to the production of textile machinery. A notable example was that of the Italian firm of Officine Galileo of Florence, who were previously exclusively engaged on precision optical instruments, electrical instruments and cameras [336].

Galileo built both automatic and non automatic looms, and the former followed the typical continental style. Thus they were low built and without superstructure, to provide the maximum amount of light during weaving and to permit the weaver ease of access to the warp and weft. The type M1c single shuttle automatic pirn changing loom for weaving plain cotton, rayon or linen fabrics was equipped with an ordinary circular magazine. The loom incorporated a weft feeler and could be fitted with a 16 shaft dobby.

For the weaving of two or four colours or types of weft, two and four box automatic looms (model M1z) were also available. These had the usual vertical magazine. The looms were made in various widths ranging from 185 down to 80 picks per minute according to the width and type of material being woven. In addition Officine Galileo also made a 4 x 1 box automatic loom, Model M1t, for weaving woolen and worsted fabrics. Like the automatic cotton loom, this loom had the usual vertical magazine, having four sections, each colour or type of weft being placed in its own section. The sections each held up to 15 pirns [337]. The firm also produced different types of non automatic looms, cone winding machines and cotton carding machines. The looms produced by Galileo were on exhibition in Britain in 1949, and again in 1958 [338].

Another automatic loom which attracted attention in 1949, was the 'Hrdina Model 44' cotton loom which was made by the Czechoslovak Metal and Engineering Works National Corporation of Prague. It was of the pirn changing type and was very simple in construction [339]. An interesting feature was the high speed at which the loom operated. At the 1949 exhibition, a 48 inch reed space loom was reported to have been operated at almost 200 picks per minute. The loom incorporated a rotary
magazine, weft feeler and cutting motions as well as a shuttle positioning motion.

In 1952 the 'Textile Manufacturer' described a new pirn changing automatic loom incorporating a circular pirn magazine, an electromagnetic weft feeler and hydraulic shuttle checking arrangements, made by the German firm of Gerhard Kestermann, Zahnraede und Maschinenfabric of Bad Oeynhausen [340]. Two versions were produced, both single shuttle, Model WK 700/115 for weaving cloths up to 45 inches wide and Model 700/175 for cloths up to 69 inches. The loom was said to be suitable for a wide range of fabrics, including cotton, line, jute, mixture yarns and man made fibers.

In 1953, the Swiss firm of Ruti introduced a photo electric weft feeler [341]. The device consisted primarily of a light source and a photo electric cell. The light source was situated on one side of the sley behind the drop boxes, while the photo electric cell was housed in front of the boxes. The beam of light intended to shine through an aperture in the shuttle and a further aperture in the pirn, and only the presence of the weft could prevent the light impinging on the cell and stopping the loom [342]. This was a comparable method to the previous attempt by Crompton and Knowles, in that the operation of the device was independent of yarn colour.

Another interesting development in the 1950's was due to A. Saurer. It will be recalled that Saurer looms normally made use of a rotary magazine. In 1955, a new multi compartment vertical magazine was patented by Saurer for use in multi colour automatic looms [343]. This development led to the introduction of a new range of Saurer multi colour automatic looms. These latest models could accommodate four or six colours of weft. The six colour automatic version was based on the four colour model and had a vertical magazine with the same operational features as the one fitted on the four colour loom. All looms were produced in widths up to 107 inches reed space variable in steps of 4 inches, and were said to be suitable for weaving cloths up to 15 oz per square yard [344]. The speeds of the latest models operating under factory conditions were reported to be 165 picks per minute for a six colour loom 55 inches reed space weaving cotton fabrics, 175-180 picks per minute for a four colour 55 inches reed space weaving cotton fabrics and 150-155 picks per minute for a four colour 75 inches reed space weaving worsted fabrics. It is also of interest to note that the four colour automatic loom was said to have been fitted with a photo electric feeler mechanism by 1962 [344]. The looms were convertible to 4 x 4 or 6 x 6 non automatic pick and pick looms.

Looms from the Saurer range were adopted in a Bradford firm of commission weavers. Altogether, there were 204 Saurer looms of three
types in one shed. The first group was 60 4 x 4 pick and pick looms of 86 1/2 inch reed space operating at 118 picks per minute. The second group of looms comprised 80, 82 1/2 inch reed space 4 x 1 box automatics running at varying speeds. The third group of looms comprised 64 single shuttle automatics all fitted with the "Unifil" loom winder [345].

Another line of development in the latter part of the 1950's was the improvement of the 'Fischer' automatic attachment. In 1957, G. Fischer patented a multi colour automatic pirn attachment in which the pirns were arranged in groups round the periphery of a rotary magazine. Each group contained a different colour or kind of weft. The magazine was rotated when replenishment was called for, by a pawl and ratchet mechanism. There was one pawl for each type of weft in a group. The appropriate pawl was moved to engage the ratchet wheel by the energizing of the appropriate solenoid upon the closing of a contact, depending upon the position of the drop boxes. The weft replenishment was initiated by an electrical weft feeler mechanism [346]. The colour selector in the battery, which was entirely mechanical similar to existing memory mechanisms, held the indication of weft exhaustion until the spent pirn returned to the battery end of the loom.

As soon as the mechanism was patented, the firm of Hattersley set out to adopt the new attachment, and a new loom was built incorporating the TMB4 model George Fischer 4 colour battery [347]. The new pirn changing loom was made in a range of nine reed spaces from 45 inches to 69 inches and speeds which varied from about 140 to 170 picks per minute.

According to the 'Textile Manufacturer', by 1961, the new Fischer attachment had also been applied to the 'Hattersley Standard Model loom'. This application referred particularly to the TM2P two colour pick and pick pirn changer which could be used either for single and two colour weft mixing with three to five shuttles, or for weaving two colour pick and pick sequences [348]. This was a modified version of the TMB4 model which had already been used in more than a dozen mills in Yorkshire and Ireland [349].

The George Fischer attachments proved very successful indeed. For example, at the Hanover ITMA Exhibition, in 1963, Fischer pirn changers were reported to have been seen on the stands of no less than twelve different loom makers [350]. In Britain, these attachments were mostly applied to Dobcross and Hattersley looms [351].

Another mechanism, developed by George Fischer, related to means for converting a loom with a multi colour circular shuttle box at one end and a single shuttle box at the other end to an automatic loom fitted with a cop feeler and multi colour pirn magazine. Indications of the need for replenishment were stored on relays, which, if the depleted
shuttle went out of action, would initiate pirm changing when it returned to use. It was stated in the patent specification that any number of shuttles could be used in conjunction with this mechanism [352]. This and other models of the attachment were shown at the 1958 ITMA Exhibition [353]. They seem to have been used extensively in Germany. The firm of Schmeing were producing automatic looms fitted with this attachment [354].

The next development due to George Fischer was the introduction of a box loading arrangement named the "+GF+ automatic pirm loader ALV" in 1959 [355]. This was not a new idea. In the pre 1930 period, quite a number of comparable arrangements for loading the pirn were patented but without any substantial success. This new pirm loader, however, seems to have been the most successful device of its kind. It replaced the conventional circular or vertical battery on the loom with a large container from which pirns were supplied to the transfer, as required. The transfer, itself, was operated on the conventional hammer principle. The problem of securing the trailing end of the weft from the pirn was solved by the introduction of a short bunch on the tip of the pirn during pirn winding. This bunch was slipped off the pirn prior to the change and was held by a suction arrangement until it was cut by the temple cutter. The suction arrangement then removed the cut ends. It was stated in the 'Textile Recorder' in 1959, that leading makers of pirm winders were offering machines capable of producing pirns with the required nose bunch [355].

By preparing the pirns for transfer to the shuttle, the device performed a task formerly carried out by the battery filler and, in this way, reduced the labour costs associated with weaving on automatic looms. It was stated in the 'Textile Manufacturer' that one container could hold up to 144 pirns, and that it was usual to have two pirm containers on one loom to double the weft reserve. When one container was empty, it was removed to the side rails. The new container was then moved into position and was made ready for use by simple lever movement. Moving this lever opened the bottom slide of the container and the pirns were transferred by gravity to the pirm guide [356].

Subsequent developments of the 'Fischer pirm loader' were referred to in the September issue of the 'Textile Recorder' in 1963. By then, a multi colour box loader had been developed. Thus the loader was supplied with pirns in open boxes for single colours or in partition boxes for more than one colour [350].

Another successful automatic loom introduced in the post Second World War period was the Belgian 'Picanol' automatic pirm changing loom. The Picanol looms were the work of three Spanish brothers who, prior to the Second World War, started loom manufacturing in Belgium
and subsequently developed the "Omnium Loom" [357]. This was a 74 inch automatic loom fitted with a rotary pirn magazine. The loom was of the kind in which the empty pirn was ejected sideways from the shuttle. Later, the range was extended to loom widths ranging from 36 inches to 108 inches in steps of 4 inches, capable of running at speeds of 220 picks per minute down to 110 picks per minute. The loom was first put on show in Hanover in 1947.

Between 1946 and 1951, Picanol developed their new lightweight loom, the 'President', which was put on show in 1951. Later, the range of these looms was extended further. Two most important models were the high speed 4 x 1 box 'President 4C' and the high speed duck and canvas loom, 'President CM-CSR'. In the 4C model the magazine was of the vertical type and the pirn change mechanism operated in conjunction with a suction device to control the tails from the pirns in the magazine. Detection was normally by an electric feeler operating in conjunction with metal sleeves on the pirns. The loom was said to be capable of running at 200 picks per minute under factory conditions and was available in width from 36 inches to 122 inches reed space [358]. The CM-CSR model was a single shuttle automatic loom. It was available in 52, 54, 58, 64 and 69 inches reed space and was said to be capable of producing ducks up to about 25 oz per square yard. The 52 inch reed space loom was reported to be weaving at 180 picks per minute under normal mill conditions. It was stated that this model could be supplied with the +GF+/ALV Fischer pirn loader [359].

11 Conclusion.

In conclusion, it should be stated that this survey provides an account of the developments in automatic weaving up to about the mid 1960's based on British Patents and reports and comments in British trade journals. The inclusion of American and other European patents would undoubtedly have revealed many more designs of automatic looms. Further embellishment of the technology took place subsequently. A notable instance is the adoption of electromagnetic warp protection by Crompton and Knowles and subsequently by Northrop [360], and numerous other loom makers. However, by the mid 1960's and, indeed, well before this time, automatic weaving had been shown to be a suitable proposition for the production of all but the most specialised of fabrics.

The first reliable automatic pirn changing loom (The Northrop) was available at the turn of the century. However, it could then only be used in the production of low quality cotton fabrics of the kind usually used for dyeing, bleaching or printing in which partially missing picks
(associated with the use of the weft fork to actuate the replenishment) were of no significance. The first reliable weft feeler mechanisms started to appear from 1914 onwards and, by the early 1920's, the introduction of side sweep weft feeler mechanisms led to the commercial acceptance of multi colour automatic looms capable of weaving different colours in even multiple picks, the principles of which were first developed by Crompton and Knowles between 1909 and 1910. In addition, by then, Northrop had also developed a purpose built even multiple pick weft mixer especially for the weaving of woolen and worsted fabrics. Thus, by the early 1920's, the woolen and worsted section of the industry, as well as the finer sections of the cotton industry, were in a position to make use of automatic looms. However, pick and pick weaving and weft mixing in odd picks were not yet possible on automatic looms. These deficiencies were remedied between 1935 and the early 1940's. Certainly by the end of the Second World War, automatic looms had reached a very high degree of versatility. In consequence, the post war period witnessed, in the main, an embellishment of the technology which was already available. It should be noted that, from the early 1950's, shuttleless looms were becoming an increasingly attractive commercial proposition and from the mid 1960's, the interest in these looms was such that subsequent developments of traditional automatics are of less relevance. The Sulzer loom, for example, became an outstanding success. In 1962, the 5,000th machine was sold, in 1965, the 10,000th, in 1969 the 20,000th and by 1975, over 50,000 Sulzer looms had been installed in more than 60 different countries [361].
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FOURTH ANNUAL CONFERENCE ON TEXTILES AND COMPLEX WEAVES
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The Charles Babbage Research Centre is sponsoring the Fourth Annual Conference on Textiles and Complex Weaves. The conference will accept papers related to little known historic or ethnic woven structures or those involving original concepts and techniques, including those pertaining to the use or modification of equipment. Papers dealing with the application of computers or innovative technology to any aspect of textiles will also be suitable for presentation. Submission should be in one of the four areas:

(a) Ethnic woven structures
(b) Historical Research
(c) Innovative manipulation of weave structures
(d) Application of computers or technology to textiles.

Registration for the conference will take place on the afternoon and evening of Friday, July 11th, and in the morning session on Saturday, July 12th. The invited addresses will be one hour in length; contributed papers will be allocated twenty minutes. These times are intended to include an allowance for discussion and questions. There will be receptions for conference participants on the evenings of July 11th and 12th with a party on July 13th. The meetings will be held at the University of Manitoba on a modern campus located about 15 miles from Winnipeg's International Airport. The talks will be given in the same residence complex reserved for conference participants. Expected residence accommodation cost is $16.00 (Canadian) per night (1 US dollar = 1.40 Canadian dollars).

Contributed Papers

The proceedings of the Conference will be published and will appear as a volume of ARS TEXTRINA. All contributed papers will be refereed; consequently, we would ask you to send a draft of your paper before the conference, if possible. If this is not possible, please submit the final version of your paper by September 1, 1986, in order to give adequate time for refereeing before the appearance of the proceedings.

Abstracts of your papers should be sent (preferably before June 1) to:

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