

## Innovation in weaving—Vertical bi-phase weaving machine for individual warp thread control

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Prototype of a new weaving machine to replace existing jacquard weaving machine has been developed for increasing the width of the design repeat and doubling productivity. This development also eliminates the constraint of change in warp sett in jacquard weaving machines. Change in warp sett can be made conveniently in this new development. There is only change in the shedding system; one such unit is common to two weaving machines. The weaving machine produces simultaneously two fabrics, one face up and the other face down. The warp yarn does not move unless a change from up to down is required. The warp sheet is in a vertical configuration instead of the usual horizontal plane.

**Keywords:** Electronic jacquard, Electro-magnets, Face-down fabric, Vertical bi-phase weaving machine

### 1 Introduction

Ever since the innovation of looms, the need for improving productivity and fabric design potentiality remain the basic objectives of weaving machinery development. Over the past few years, the weaving machine manufacturers have mainly focused on improving the performance of the machine, increasing the weaving speed and raising production versatility. However, to keep in line with new market requirements these objectives are rapidly changing toward a more utilization of the machine. 'Just in time' and 'quick response' are two concepts which, originating from the making up sector, have gained in importance in all sector of the textile industry. The productivity increase effected has many ways including the progression of certain new techniques, like multi-phase and multi-section weaving.<sup>1</sup> Nonetheless, the weft insertion systems in their current form are no longer able to be improved fundamentally.

The fabric design potential has also been enhanced through continuous modifications in shedding mechanisms, as in the jacquard machines, which over the recent years have undergone significant improvements in many details. However, none of these improvements have really caused any technical breakthrough. As such, the present state of weaving

technology persists with its limitations in productivity and fabric designing capacity.

There have been attempts to revolutionize the creation of fabric designs with the use of CAD system, Subsequent to these efforts and with the development of electronic selection system, the techniques for conversion of these designs into structural designs have been remarkably established. However, in spite of the electronic advances in the above-mentioned areas, the scope for increasing width way repeat size is only moderate. This is due to various constraints in the present shed forming principles. For instance, with the electronic jacquard's expanded hook capacity up to 12,288 hooks, it is possible to create patterns of considerable size at ease. But the drawbacks associated with the jacquard principle related to the huge structure, harness arrangements, fixed warp sett, etc. still persist in these modern machines. Hence, the present day technology does not allow complete flexibility in fabric designing, as for instance, the warp sett cannot be altered and ends per repeat of the design cannot be very large. Therefore, in the present study, a prototype of new weaving machine to replace existing jacquard weaving machine has been developed for increasing the width of design repeat and doubling productivity.

### 2 Design Philosophy

#### 2.1 Challenges

Today's markets require rapid response to changes in fashion and hence it is absolutely necessary to enhance the versatility of looms, in terms of unlimited

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possibilities in warp patterning. The weaving machine's capacity to produce patterns of any size and carrying out a speedy pattern/article change are critical requisites for further fashion demands. Since the above critical requisites cannot be achieved through the existing shedding systems, it is pertinent to evolve a distinct shedding concept conforming to the patterning needs of the future. In this context, the attainment of individual warp thread control is rather significant mainly in following two respects:

- (i) Developing the shed forming principle for complete utilization of electronic advancements. Such utilizations are not only in the selection process but also in the shed forming logic to accomplish the technical necessities, like varying the warp sett.
- (ii) Eliminating certain technical rigidity in the existing patterning process such as the usage of heald frame/harness which effects group control of threads. Such eliminations are important for direct control of threads and getting complete flexibility in fabric designing.

It is noted that the main drawbacks of all the earlier propositions are concerned with their lack of provisions to accommodate vast number of individual thread control elements and to vary the warp density. In this work, the above-mentioned technical aspects are examined. An important fact established is that the development of individual warp thread control system is practicable only with the vertical loom structure.

It is more difficult to obtain higher weaving speeds from modern machines which are already nearing the technical limitations of both yarn and machines. Hence, it is logically analyzed to enhance the productivity as well as to utilize the outstanding features of all the available weft insertion systems.

## 2.2 Development

The prospect of multi-section principle is examined with relevance to the evolution of individual warp thread control system which demands a vertical loom structure. The designing of vertical bi-phase loom attains technical importance in following respects:

- Only the shedding system requires modifications and all the technical achievements of other primary motions, viz. picking and beating, and many of the auxiliary motions can be effectively utilized with trivial changes.
- Certain critical development ascents and ergonomics can be effectively involved.

As such, the basic objective of the research work was to evolve an individual warp thread control system with specific approach to design a vertical bi-phase loom.

## 2.3 Approach

The energy requirement for realizing the warp thread movement is one of the critical factors of shed forming process. It is known that the energy demand of present shedding systems is the cummulation of a number of influencing factors; factors arising from the jacquard and the transmission to the heald and those related to the weaving process. In electronic jacquards of higher electromagnet capacity, there is an additional energy demand for selection process. This demand for electrical energy will become critical in individual warp thread control system as each warp thread will have individual electromagnet for its selection. Therefore, the following two aspects form the basis for evolution of individual warp thread control system:

- (i) Reducing the electrical energy demand of selection process.
- (ii) Reducing the mechanical energy demand of shed forming process. Various stipulations have been made to achieve the above-mentioned aspects and accordingly the evolution process is progressed in developing a suitable selection logic as well as a shed forming system to realize the proposed logic.

## 3 Effective Measures

### 3.1 Measures for Reducing Electrical Energy During Selection Process

The problems which arise out of the usage of individual electromagnets for each and every warp thread are not only concerned with energy requirement but those related with heat dissipation and subsequent possibility of electromagnet 'burning-out' are also some of the major concerns. The factors which are directly related to these concerns are the energizing cycle and duration of individual electromagnets. As such, the three important measures for reducing electrical energy demand of selection process are:

- (i) Minimizing the number of selections per repeat/pattern.
- (ii) Minimizing the continuous selections of individual electromagnets while realizing continuous lifting or lowering of warp threads.
- (iii) Minimizing the selection duration.

It is important to examine first the shed forming techniques of present electronic jacquards<sup>2-4</sup> in the above-mentioned context.

### 3.1.1 Energy Constraint of Electronic Jacquards

The selection sequence of two basic techniques used in electronic jacquards are described below:

*Technique A*—The electromagnet is energized for each 'thread-up' position. The 'thread-down' position is achieved automatically without energizing the electromagnet. In this case, the warp thread automatically forms the bottom shed and for any 'thread-up' position or even to keep the thread already in 'thread-up' position, the electromagnet is energized.

*Technique B*—The 'thread-up' position is achieved automatically without energizing the electromagnet. For each 'thread-down' position, the electromagnet is energized. In this case, the warp thread automatically forms the top shed and for any 'thread-down' position or even to keep the threads already in 'thread-down' positions, the electromagnet is energized.

In terms of containment of mechanical and electrical energy consumptions, Technique A is suitable for weft faced fabric and Technique B is suitable for warp faced fabric. Further, it can be noted that the electromagnets need to be energized as many times as the respective hooks require continuous lifting, like in the cases of Bonas and Van de Wiele machines principle. Similarly, in Grosse, Staubli and Schleicher machines principle, the electromagnets need to be energized as many times as the respective hooks require continuous lowering. Therefore, in weaving distinctly unbalanced designs, a necessity arises to decide to weave with the viewing face on top or underneath.

The above-mentioned aspect of consuming electrical as well as mechanical energy either for each lifting or for each lowering of hook will have a major drawback in individual warp thread control system. For instance, in jacquards, it is possible to weave a fabric containing 13,824 warp threads using a 3,456 hook capacity machine with 4 harness ties. In such case, the numbers of electromagnets required are only 3,456 and hence the energizing of electromagnets for each lifting or lowering of hooks is very much practicable. However, in individual warp thread control system, 13,824 electromagnets are required to weave the same fabric. The tenderization of such a vast number of electromagnets for each lifting or lowering of hook will not only mean sheer waste of

energy but more importantly generation of excessive heat. Hence, in the event of utilizing the present electronic jacquard's shed-forming techniques for individual warp thread control system, an important limit has to be put on the number of usage of electromagnets. This, in turn, will set limits on fabric width and warp density. With the above-mentioned limitations, the basic objective of designing a flexible individual warp thread control system cannot be attained through the present electronic selection systems.

### 3.1.2 Selection Logic for Individual Warp Thread Control

The measures for energy saving and heat control are the two critical requirements in developing individual warp thread control logic. It is pointed out that an effective way to realize these measures is to reduce the selection cycle. As the present jacquard shed-forming techniques are not suitable to effect such reductions in selection cycles, it is proposed to evolve a suitable shedding logic. The stipulations for evolving such new shedding logic can be laid down as follows:

- (i) The new logic should be consistent with the present usage of electromagnets for selection.
- (ii) The new logic should effect means for significant reductions in electrical and mechanical energy consumption specially while realizing continuous lifting or lowering of warp threads.

Based on the above stipulations, the required control logic is established, as indicated in Technique C.

*Technique C*—The electromagnet is energized only when the thread position is to be changed either from 'thread-up' position to 'thread-down' position or vice versa. Here, the warp thread attains true open shed positions and the electromagnet is energized only at absolute need, i.e. only when change of thread position is demanded. Warp thread continues to remain in either of the shed positions till the selection is made for reversing its position. Since the selection principle of Techniques A and B are apparent, the control logic for Technique C is shown in Fig.1(a) and the pattern diagram with corresponding selection diagram are shown in Fig. 1(b). Some of the comparisons of selection diagrams pertaining to the selection Techniques A, B and C are shown in Fig.2.

The total number of selections per repeat for these two logic can be calculated as follows:

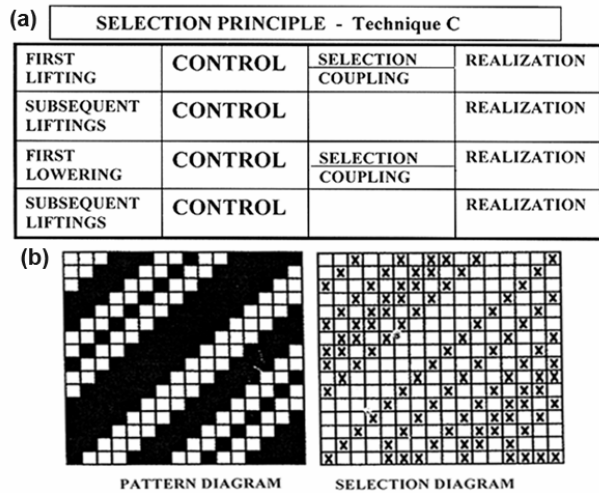


Fig. 1—(a) Control logic of Technique C, and (b) pattern and selection diagram of Technique C

Required selections per repeat/pattern (Technique A) = (No. of 1 end floats) × 1 + (No. of 2 ends floats) × 2 + ... + (No. of n ends floats) × n.

Required selections per repeat/pattern (Technique B) = (No. of 1 pick floats) × 1 + (No. of 2 picks floats) × 2 + ... + (No. of n picks floats) × n..

Required selections per repeat/pattern (Technique C) = (No. of warp floats of any size) × 2.

As such, barring certain basic weaves, the evolved selection logic contributes for significant energy reductions in selection.

**3.1.3 Shedding System for Selection Logic**

The proposed selection logic affects the selection of warp thread carriers only at absolute need, i.e. only when the warp threads are required to be lifted or lowered barring any selections during subsequent lifting or lowering. One of the important pre-requisites for attaining the same is to provide a positive movement to the warp thread carrier. For this purpose, an appropriate electromechanical setup has to be evolved by achieving developments in selection control as well as in realization of warp thread movement. It will not be possible to attain the positive movement of warp thread carrier with the present electronic jacquards unless their selection system is modified suitably.

**3.1.4 Principle of Shedding System<sup>5</sup>**

The selection sequence of conveyor system technique is shown in Fig.3 . The smooth movement of conveyor can be achieved by using ball bearings in conveyor pulleys.

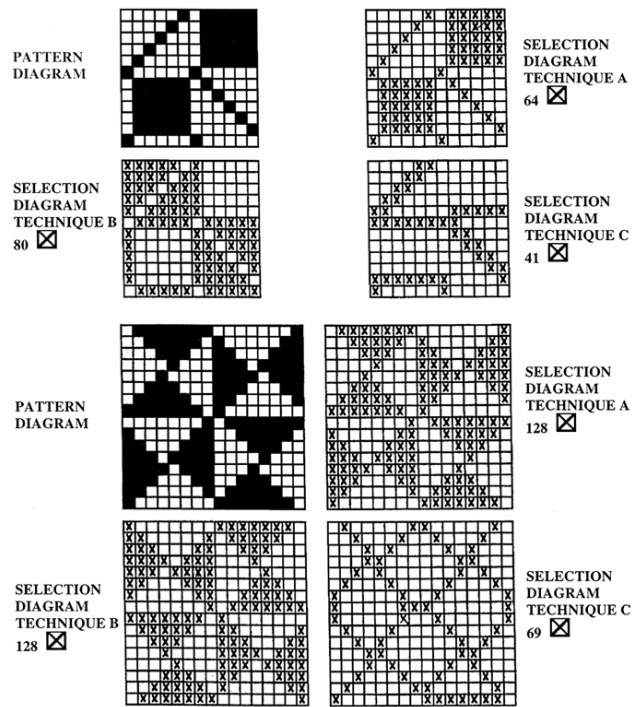


Fig. 2—Selection diagram for Techniques A, B, and C

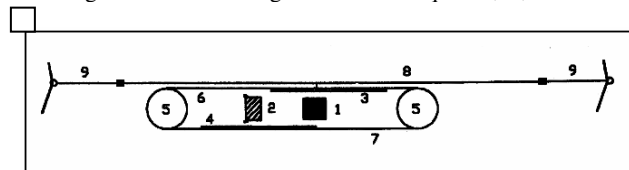


Fig. 3—Schematic diagram of elements of conveyor [1—selector element, 2—pushing element, 3—top latching hook, 4—bottom latching hook, 5—conveyor pulleys, 6—top conveyor belt, 7—bottom conveyor belt, 8—head hook, 9—healds, and 10—warp threads]

In respect to mechanical loading, the conveyor system provides phenomenal advantage as no load is put on the knife while a warp thread remains a number of times successively either in lower shed or in upper shed. In CSS technique, the selector element functions as displacement actuator. However, it posses following two distinct advantages to effect energy reduction:

- (i) The selector element has to displace only a flexible latching element of very less mass.
- (ii) The energizing duration of selector element can be very short. The selector element has to be energized just at the beginning of the forward stroke of knife and require an emerging duration of about 25-30 of crank shaft revolution.

Therefore, a good scope exists for effecting considerable energy reduction in CSS technique. A

simple drawback of this conveyor system is the need for precise arrangement of conveyor elements. However, with today's modern manufacturing facilities any such demands can easily be exercised. Nevertheless, this system fulfills all the technical necessities for performing the proposed selection logic.

**3.2 Measures for Reducing Mechanical Energy Demand of Shed Forming Process**

The CSS technique attains significance as no load is put on the knife while warp thread remains continuously in upper shed or in lower shed. However, the critical means for reducing mechanical energy demand of shed forming mechanism remain with the arrangement of conveyors. This is because the total forces acting on the shed forming mechanism is going to be influenced by the structure of loom and the placement of shedding mechanism in that. The two important concerns in this regard are given below:

- (i) Scope for integrating shed forming mechanism with the loom.
- (ii) Scope for adopting simple mechanism for shedding operation.

**3.2.1 Available Space for Individual Warp Thread Control Elements**

In any individual warp thread control system, the warp control elements have to be provided for each warp thread. In conveyor system also, the conveyor and its associated elements for selection have to be provided for each warp thread.

A section of warp thread is shown in Fig. 4. The 'x' marks show the thread holding positions of each thread. The space between successive 'x' marks is the space available for conveyor elements. One way to

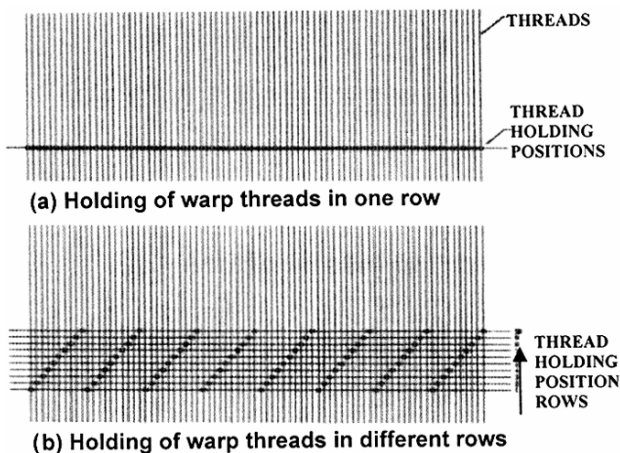


Fig. 4—Threading holding positions

increase this space can be the spreading of thread holding positions into certain number of rows as shown in Fig. 4.

In this regard, there can be a useful progression to stagger the conveyors one behind the other. The horizontal space for the conveyor elements is increased by staggering the conveyors one behind the other instead of keeping them adjacent to each other. Figure 5 shows such arrangements for 1, 2, 3 and 4 staggers.

**3.2.2 Arrangement of Conveyors**

As seen in the forgoing section, the conveyors are to be arranged in rows and columns and further they have to be staggered. The conveyor columns spread in the direction of warp and conveyor rows in the direction of weft. The conveyor staggers need to be in the direction perpendicular to the warp sheet. The staggers can be parallel to the floor and one behind the other called as horizontal staggering. This arrangement provides a new phenomenon as the warp sheet is placed vertically, that is perpendicular to the floor.

**3.2.3 Horizontal Staggering**

The conveyors are staggered parallel to the ground, the overall stagger length is not a crucial factor, though this length is an important parameter in determining the require number of staggers. It provides great scope for ergonomics and for improving working environment. In the planned vertical structure, the warp beam is kept below near the floor level. In that case the warp zone will be uprightly

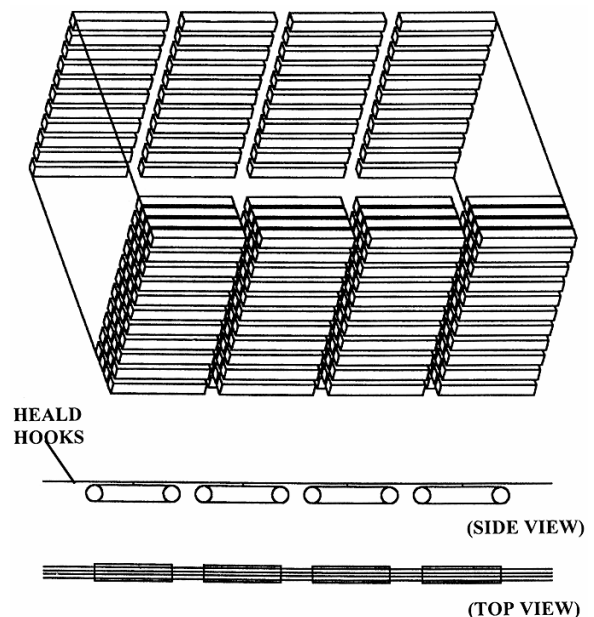


Fig. 5—Arrangement of conveyors

placed in front of the loom which will enable a weaver to attend the warp faults without stretching the body. Further, it will be possible to derive advantages in respect of savings in warp repair time.

The shedding unit can be integrated with the machine and placed at about 1.2 m height from the floor. The arrangement of conveyors parallel to the ground provides scope for applying useful techniques like 'quick article change system'. With the parallel arrangement of conveyors as mentioned above, it is possible to utilize both the ends of the warp thread carriers. Healds can be attached at both the ends of the warp thread carriers and two separate warp sections can be provided for each sections of healds. This composition paves the way for the evolution of a vertical bi-phase loom.

As such, the horizontal staggering order of conveyors not only achieves the practicality of individual warp thread control system but also supports the phenomenal development of a vertical bi-phase loom

## 4 Description of CSS Loom

### 4.1 Elements of CSS Technique System

The basic element of the CSS technique is the conveyor which is an endless tape pulled over two frictionless pulleys. As each warp thread requires one conveyor, it is necessary to use vast number of conveyors. A schematic diagram of the conveyor system for selection technique is shown in Fig. 5.

The selector element and pushing element are placed inside the conveyor. The pushing element is given a reciprocator motion through a simple mechanism. There are two latching hooks attached to the inner sides of the top and bottom conveyor belts. These latching hooks are phased at a distance equivalent to the shed height required at that particular conveyor position. One heald hook is attached to each conveyor with either top or bottom conveyor belt. At the end of each hook, a heald is attached and through the eye of the heald warp thread is drawn. The heald can be detached from the heald hook for facilitating article change.

With an uni-directional displacement given to top and bottom conveyor belts, it is possible to exercise a to and fro movement to the conveyor. The to and fro movement of the conveyor will effect a similar movement to heald hook and heald, which, in turn, will alter the warp thread between its two shed positions. The applied logic is that while the pushing element reciprocates continuously, the selector

element performs the task of latching the latch hook with the pushing element at the specific sequence as per the selection data. Once latched, the pushing element will drag the latching hook till its completion of forward stroke. This dragging of latch hook will effect a forward or backward movement to the conveyor, heald hook, heald and finally to the warp thread depending on which latch hook (either top latch hook or bottom latch hook) is latched with the pushing element. The selection is to be done only when the pushing element is closer to the selector element and hence the backward stroke of the pushing element performs no task.

Since there are two latching hooks in each conveyor phased at a distance equal to the shed height, one of them will always be positioned closer to the selector element ready for latching. Hence, the selection at any interval of design cycle will effect to and fro movement to the heald, thereby altering the shed positions of the warp thread. In this way, the CSS system with its single selector element and pushing element creates true open shed positions.

### 4.2 Selection Cycle of CSS Technique

The schematic diagram of the selection cycle of CSS technique is shown in Fig. 6

Since the warp sheet is kept vertical in CSS technique, the two shed positions can be termed as left shed and right shed positions. At the beginning of the selection cycle, the warp thread is kept in right shed position, i.e. in 'ready to be pushed' position, as shown in parts 1 and 2 of Fig. 6. While the pushing element continuously reciprocates inside the conveyor, the warp thread remains in the right shed as no selection is made. In part 3, the selector element is energized. This enables the top latching hook to latch with pushing element. As the pushing element moves forward, it displaces the conveyor and also the shed position of the warp thread through heald hook and heald. This action is shown in part 4. As shown in part 5, the pushing element reaches its forward end of the stroke and the warp thread attains left shed position. Now the warp thread is in 'ready to be pulled position' and the bottom latching hook is positioned near the selector element.

While the pushing element starts its backward stroke it detaches from the latching hook and continues its motion without altering the status of the conveyor and warp position. This action is shown in part 6. The warp thread remains in the left shed until the selection is made and the pushing element

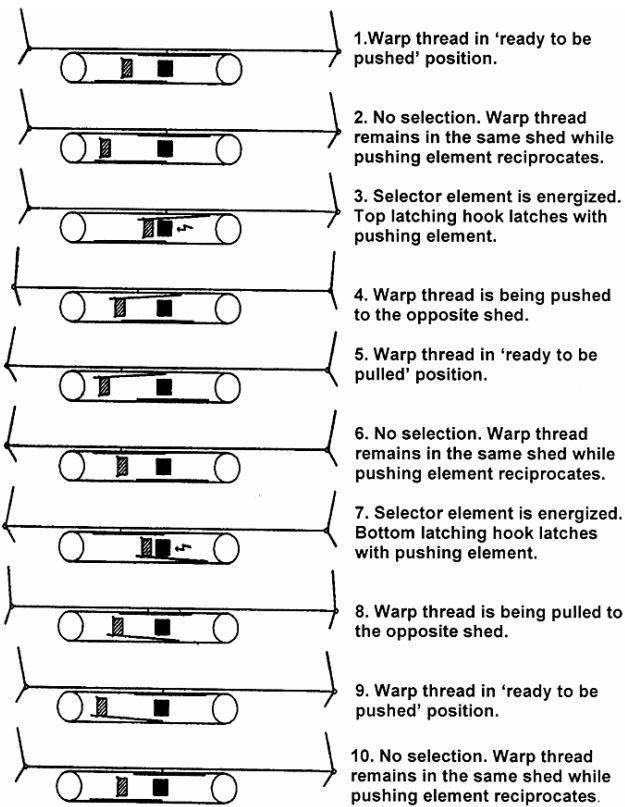


Fig. 6—Selection cycle of CSS technique

reciprocates without performing any task. In part 7, the selector element is energized and the pushing element latches with bottom latching hook. During the forward stroke of pushing element it drags the bottom conveyor belt along with it, causing an opposite movement to top conveyor belt, heald hook and heald as shown in part 8. This movement of heald effects the shed change. In Part 9, the pushing completes its forward dragging of bottom latching hook. The warp threads are in right shed position, i.e 'ready to be pushed' position. The top latching hook is positioned near the selector element and ready for latching with the pushing element when the selector element gets energized. In part 10, the pushing element reciprocates continuously. The warp thread will remain in the same shed till any selection is made.

#### 4.3 CSS Loom Structure

The basic structure of CSS loom is virtually influenced by the horizontal staggering order of conveyors as it reasons out for two phenomenal

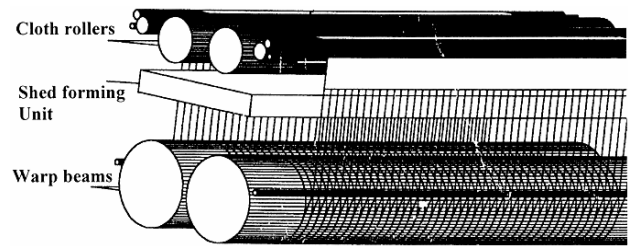


Fig. 7—Schematic diagram CSS loom structure

developments, viz. vertical loom structure and bi-phase utility. In the vertical loom structure, the placing of warp beams near the floor level is a distinct option. Accordingly, the CSS loom structure is proposed and the different views of the proposed loom structure are shown in Fig. 7.

#### 5 Conclusions

A prototype for control of individual warp thread was fabricated and tested. The innovative conveyor system for selection is proved successful in the development of individual warp thread control system. This innovation arranges warp sheet in a vertical configuration, thereby helping the weaver in his operations. The CSS loom design procedure illustrates the possibility of varying the warp sett by merely omitting the nonessential selector elements. The efficiency loss in CSS loom will be approximately double when comparing with that of single phase loom. However, the economy of this loom lies with its increased weft insertion rate per unit floor space and reduced energy consumption during selection process. It shows great promise for further scale up of the innovative weaving machine for commercial trials.

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