YEAR 3 NTC ANNUAL REPORT

Title: **Development of Multiphase Warp-Wave Air-jet Loom**

PI(s): **Mansour Mohamed, Warren Jasper, Abdelfattah Seyam and Mahmoud Salama**

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Relevance to NTC Goals:

The production of weaving machines in the U.S.A. has almost stopped. The dependence of the Textile Industry on imported machinery often means new developments are available first to companies in Europe or Japan. It is the objective of this project to regain a leadership position in the development of weaving machines. The viability of the proposed development has been demonstrated by the operation of a 20-inch wide prototype built by Picanol jointly with McGinley. One of the major advantages of this development is the reduced energy consumption due to the reduction of the amount of compressed air required per pick

Improved productivity at wider width, when realized, would improve the competitive edge of the textile industry. Development of innovative machinery and processes satisfies an important goal for NTC.

Overview:

Over the last two decades, air-jet and rapier looms have taken the lead position in weaving machinery. Speed and versatility have been the main thrust of the new developments. However, until the present, a 2,000 m/min rate of filling insertion[1] remains the upper limit for commercial production, although demonstrations at machinery shows have achieved 2,800 m/min. The main reason for this limitation is the single-phase[2] operation of all commercial weaving technology up to the present.

It is characteristic of the single-phase weaving process that, during insertion of the filling (crosswise) thread, the shed cannot be closed and the reed cannot move to the "beat-up" point (fabric formation point). Conversely, when the shed is closed and changing, the shuttle, the rapier, the projectile or the air-jet is stationary and non-productive. It is a sequential process: first, filling insertion, then beat-up and shed change. This means that a conventional loom cannot produce fabric as fast as its filling insertion system operates. If the filling insertion medium remains stationary half the time, a loom will produce at only one-half the rate it would if the filling insertion was continuous.

The latest looms, such as air-jets, are limited in the same manner. Actually, weft insertion takes place on an air-jet loom in approximately one-half the cycle time, that is, during 180° of crankshaft rotation. Such an air-jet loom which has a filling insertion rate of 1,800 m/min must actually achieve an average filling insertion velocity of 3,600 m/min. This high velocity is achieved at considerable energy cost. Higher speeds would begin to be prohibitively costly due to the fact that as filling (also known as weft) velocity is increased linearly the energy requirement increases exponentially.

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[1] Rate of filling insertion - weaving machine production rate of crosswise thread measured in meters per minute.

[2] Single phase - in which all weaving functions occur sequentially for one pick (crosswise thread) at a time.

The hand-looms of ancient Egypt and the modem air-jet loom weaving up to 15 picks per second operate on exactly the same principle. This inherent sequential characteristic of single-phase weaving seems now to have brought us to a cost/benefit barrier where energy costs become prohibitive.

An illuminating analogy to single-phase weaving is to visualize an automobile averaging 50 miles/hr by traveling at 100 miles/hr for intervals of time and by standing stationary for equal intervals of time.

The search for methods to allow continuous insertion of one thread or simultaneous insertion of multiple crosswise threads has resulted in the developments which we call multiphase or multi-shed looms. Several companies have introduced multiphase weaving machines but none have found commercial acceptance. "Weft-wave" looms have been shown since the ITMA '71 machinery show in Paris. In addition to being mechanically complex, these looms have one common drawback; the fabric quality is not acceptable for most applications. In spite of the fact that twenty years have passed, there is not one machine of this kind in U.S. mills.

Only one company has offered a circular "series-shed" multiphase machine, called the Bentley Orbit loom. Again, although the machine had a theoretical rate of filling insertion of 3,600 m/min, it was limited to very open constructions and to only plain weave fabrics. Few machines were sold worldwide for the production of gauze fabrics.

We therefore have two prior lines of research in multiphase weaving which we can classify as "weft-wave" and "series-shed." Both lines of development have certain advantages and disadvantages in terms of productivity, versatility, quality, capital cost, etc. It can be said that, from a weaving mill standpoint, multiphase weaving versatility and quality has yet to prove that it will be a factor in the textile industry in the future.

Whereas the limit of single-phase productivity is dictated by achievable filling insertion velocity, the warp-wave loom effectively bypasses that limitation while retaining the versatility in fabric-types of conventional equipment. In the warp-wave system sheds are opened, retained and moved in a planar path toward the fabric, with multiple air-jet insertions operating simultaneously. The maximum productivity of this system is no longer determined by insertion velocity but is now dependent upon the speed of shedding and the width of the loom: both can be considerably increased on this system compared to single-phase looms. The main reasons for this increase in speed are:

1. The size of the shed opening can be reduced and the dwell time for the shedding mechanism in the fully open position can be greatly reduced, thus reducing the acceleration required to accomplish shedding.

2. The time available for filling insertion increases by a factor of 3 or 4, effectively eliminating filling insertion velocity as the determinant of productivity.

3. The fact that insertion occurs through a nearly closed tube drastically reduces the energy required. Since the cost of compressed air is a major consideration in air-jet weaving, the McGinley system solves the problem of high consumption of compressed air.

Objectives:

A SO-cm wide prototype machine (shown in **Figure 1)** was jointly developed by Picanol of Belgium and McGinley at a cost of approximately $2 million. This prototype has been used as the subject of this research program, funded by the National Textile Center, Draper Corporation and McGinley Mills, Inc. The objectives of this ongoing research program are to analyze the dynamics of the machine and to study the machine/material interactions with the goal of optimizing the design for a scaled-up prototype (190 cm wide), thus providing a breakthrough in weaving machine development.

Technical Approach:

The McGinley Development

The "Warp-Wave" loom developed by McGinley is quite similar in many functions and in general appearance to currently installed single-phase weaving machines. The difference in the McGinley technical approach lies in an additional function which takes place between a conventional shed-forming mechanism of any type and the point of fabric formation. This new function requires only a few inches (2 to 4) of additional space between those points compared to standard looms.

The basic principle of this new function is a simple one. Each shed formed by any conventional means is retained and moved toward the beat-up point (point of fabric formation) while a crosswise (weft) thread is inserted through it. When the weft insertion is complete, the shed retaining means releases the shed and a new type of beat-up mechanism impresses the weft into the fabric.

As each new shed is formed in the desired weave pattern, it is retained and moved forward. There are, therefore, several openings or sheds existing simultaneously for the purpose of inserting several weft threads simultaneously across the loom.

The mechanism which accomplishes this can best be described in conjunction with a schematic representation included herein as **Figure 2.** This is a side-view diagram of the shed-retaining system. Conventional shed-forming is represented at the far left from which extend two lines representing the two flat sheets of warp threads which constitute the shed as seen from a side view. On the far right is represented the woven fabric, also as seen from a side view.

The components marked A, B, C, and D represent the support for the shed retainers and their source of movement through a closed-loop path. The small circles above B and C represent the open ends of closed tubes extending across the width of the loom. These tubes preserve the previously-formed separation of sheets of warp threads according to the desired pattern. As the tubes B and C move in a direction toward the fabric, weft threads are being inserted in both B and C by air-jet nozzles which are part of each retainer tube. Insertion of the weft in nearly closed tubes reduces the amount of compressed air required for insertion by over 80% of that used on single-phase air-jet looms. At the stage represented in **Figure 2,** the weft thread in tube C has traveled 10% of the loom width and the weft in tube B has traveled 70% of the required distance.

The tubes which retain the sheds are composed of many small segments which are cut angularly so that they appear somewhat diamond-shaped from above. These segments, which are called gates, are individually supported by legs which extend from supports A, B, C & D as shown. These legs permit the partial rotation of each tube segment, or gate, to a second position as shown above A and D. In this position the gates no longer form a closed tube but have each been rotated about 70". They are each now separated by a space equal to the widest dimension of the diamond-shape as viewed from above and the thin edges of each are aligned in the same direction

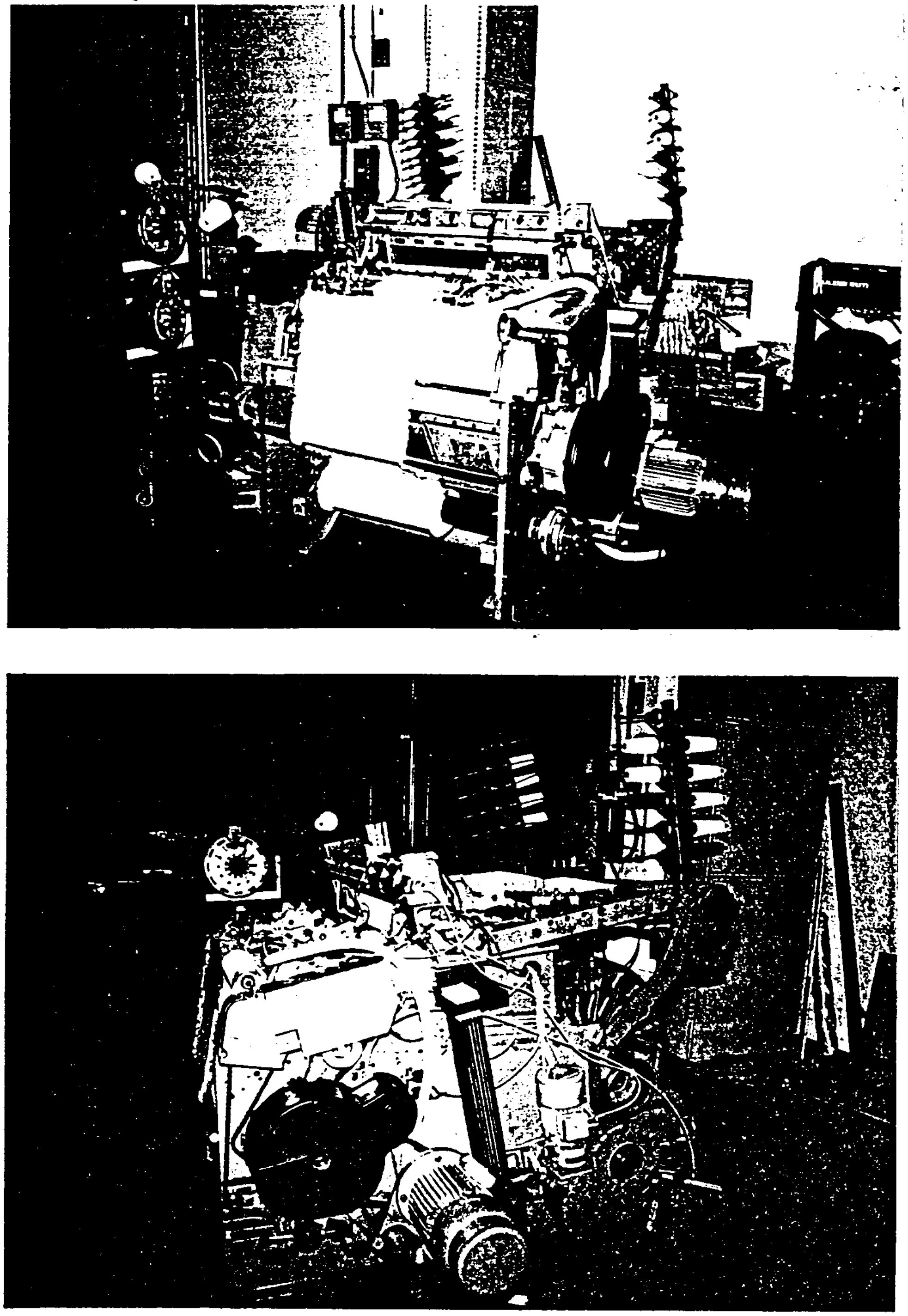

Fig. 1 Prototype

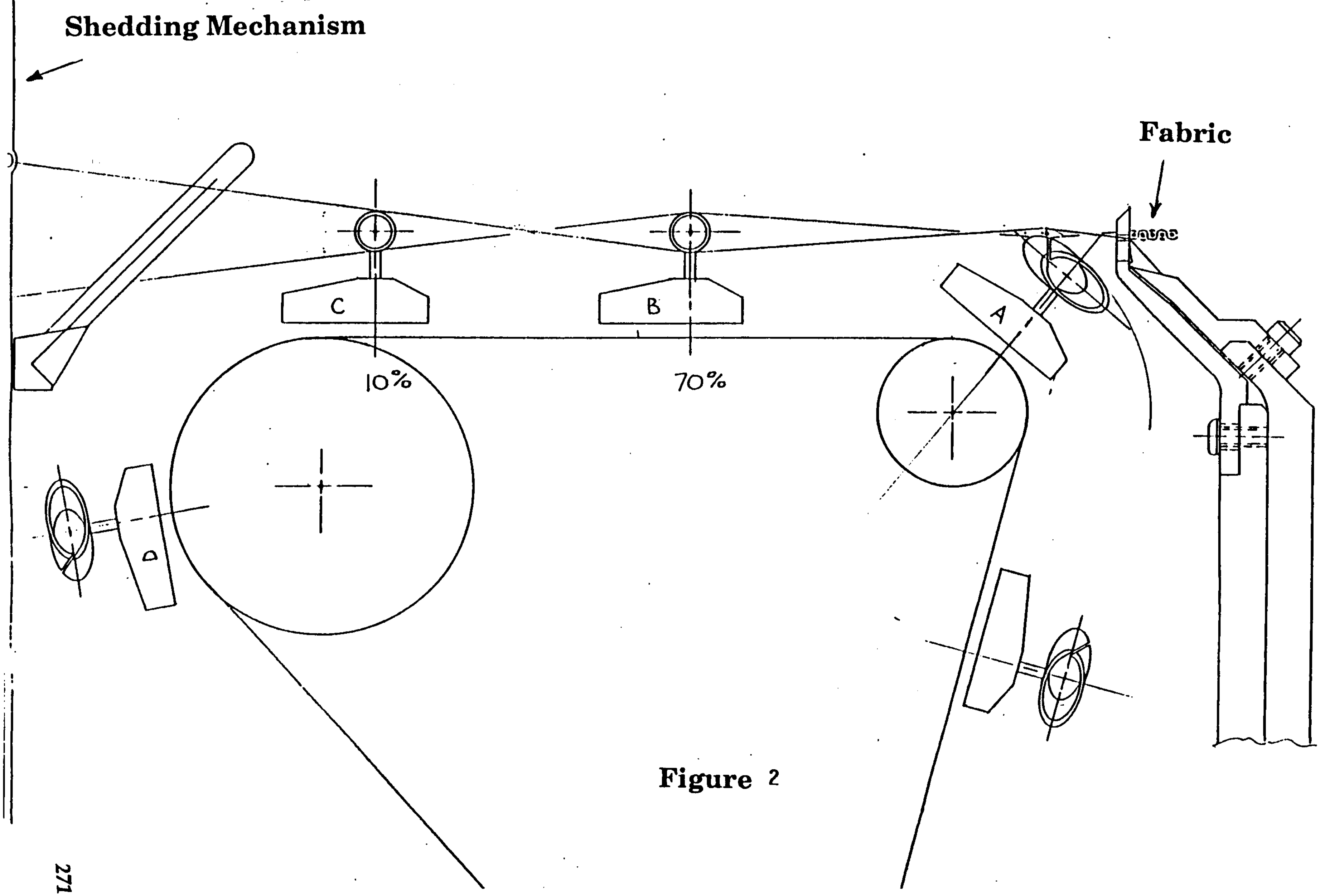

Figure 2

as the warp threads. In this position the gates no longer separate the two sheets of warp threads, that is, retain the shed. The warp threads come together in the spaces between the gates with the weft thread interwoven with them.

As also can be seen above A and D, each gate has a slot cut through the wall for the purpose of allowing the exit of the inserted weft thread from the gates. In the position as shown for gates A, all the slots are aligned across the loom so that the weft thread has an open path to exit from the shed-retaining gates. This movement by the weft is forced by the sheet of warp threads which lie beneath it, as the gates follow a downward curving path. This view at A illustrates a weft thread positioned (woven) between sheets of warp threads, having just been moved out through the aligned slots across the loom as the gates descended.

The beat-up mechanism, shown here in contact with the woven fabric, has just completed the beat-up of the previous weft thread and is in a 60° dwell mode until component A descends sufficiently to permit the start of its backward motion. This patented two-part beat-up system backs away from the fabric, picks up the weft thread just removed from the gates and pushes it forward into the fabric. While doing this, this beat-up system preserves the even lateral spacing of warp threads.

The beat-up mechanism has a full 300” of cycle time in which to accomplish its motion, in contrast to single-phase looms wherein the beat-up mechanism must do its job during the same roughly 150° remaining for the shedding motion after weft insertion takes its 210” out of the fixed available total of 360”. In addition to having approximately twice the time interval for its motion, the distance of that motion is not more than 1/3 the length of that required on conventional looms.

Finally, the returning shed-retainer gates as shown above D are rising to enter, tapered-edge first, through the lower sheet of warp threads forming the shed. Means are provided to assist this entry with the minimum disturbance to the warp. Once within the shed and at the time of full shed opening, the gates turn again to form a closed tube, needing only an interval of 60” of crankshaft rotation. This required interval is the same regardless of the width of the loom. Therefore even the widest “warp-wave” loom permits the full 300” for faster, more energy efficient changing of sheds.

As can be seen in **Figure 2,** all the functions of shedding, weft insertion and beating-up can take place simultaneously, in the most energy efficient manner, without interfering with the other processes.

Figure 3 represents a schematic for further clarification.

The following presents a comparison between the warp-wave loom and the present state of the art in single-phase weaving.

At ITMA ‘9 1 in Hanover, Germany, a Japanese loom builder demonstrated a 190-cm loom operating at 1,500 picks/min. Listed below are some comparison data to point out the essential differences in the two weaving systems.

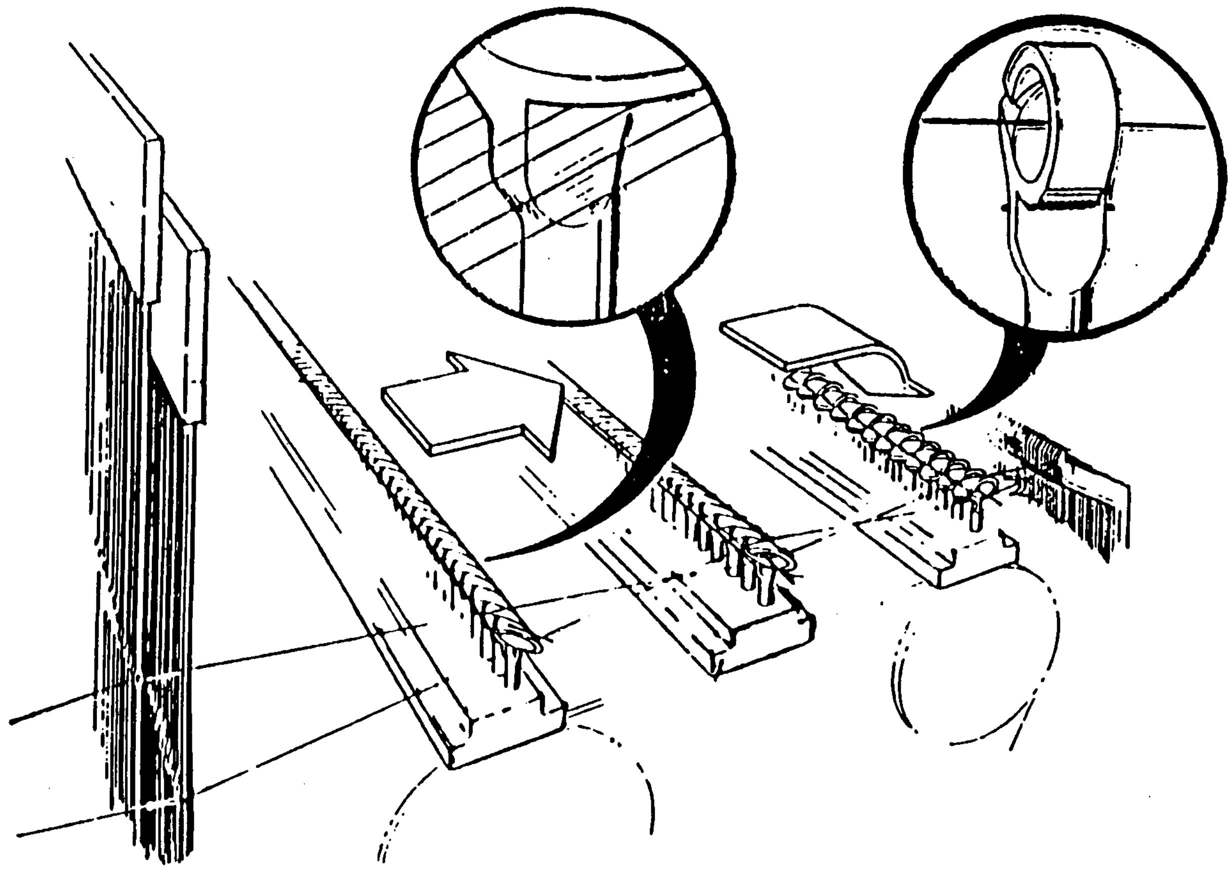

Figure 3

Loom Comparison

	Conventional	Warp Wave	
	190 cm	190 cm	400 cm
Picks per Minute	1,500	1,500	1,500
Insertion Rate in Meters/Min (Productivity)	2,850	2,850	6,000
Crankshaft Degrees Used for Insertion	210	630*	630*
Duration of 360” Pick in Sec.	.04	.04	.04
Time Available for Insertion in Sec.	.0233	.070	.070
Avg. Weft Velocity Req’d in Meters/Sec.	81.4	27.1	57.1
Duration of Clear Shed Req’d in Degrees	210	60	60
Duration of Clear Shed Req’d in Sec.	.0233	.0067	.0067
Available Interval for Change of Shed	.0167	.0333	.0333

* 630° chosen only to simplify comparison, being 3 times the interval available to the single-phase loom. A greater number of crankshaft degrees would slightly increase the travel distance of the shed-retainers, but would further increase the advantage shown here for the Warp-Wave loom. The 630° example used here represents shed-retainer travel of 4.8 inches during insertion. Another 1.6 inches of travel would afford 4 times the insertion time instead of 3 times.

Since the cost of power for compressed air rises exponentially with increases in velocity of air used, it would be very useful to quantify the difference in weaving costs represented by the above figures for weft velocity requirement and for velocity of shaft motion required for shed change.

Accomplishments:

The prototype machine was installed and a new variable speed control for the drive was added. This drive will allow a wide range of operating speed up to 600 ppm.

An automatic data acquisition system has been designed and built with a sampling rate of 6000 hz using an infra red trigger. Preliminary tension measurement was made using the RES teniometer and the signal was recorded by means of a U.V. recorder. This will be used to calibrate the data acquisition system. A tension trace for several cycles is shown in **Figure 4.** The tension trace is lower and different from single phase looms, as was expected. This is an advantage of this new system.

A new design for the air tube/retainer pieces to reduce their size and a new arrangement for the rotation gears has been completed. Estimates for the reconstruction of the retainer boxes (ten) have been obtained and an order to modify them will be made to the machine shop.

Measurement of the amount of air consumption needed for filling insertion is in progress. The addition of a relay nozzle on the air-jet loom simulator to study its impact on insertion for wide looms has been completed.

Plans for upscaling to a 190-cm width have been discussed and are the subject of a proposal submitted earlier to ARPA’s TRP program.

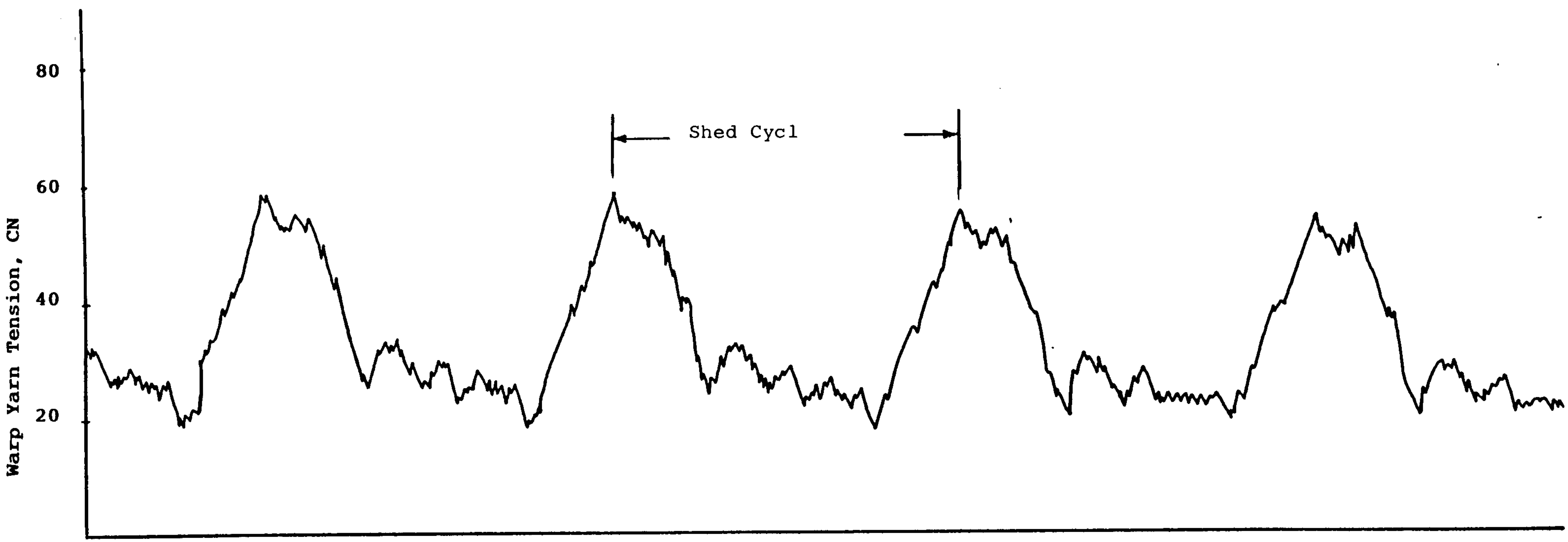

Fig. 4