

Jet Weaving

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&

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General Considerations

- In jet picking, the weft yarn is inserted by means of a fluid known as jet.
- The fluid used in jet-weaving may be air or water.
- The relative velocity between the jet and the weft thread produces a force on the weft which results in its insertion in the shed.
- The air jet weaving machines are supplied with compressed air from a central compressor in the weave room or are equipped with individual built-in compressors.
- The water jet weaving machines are equipped with individual injection pumps to pressurize water supplied from the water main; waste water is discharged into a drain.

General Considerations

- To achieve acceleration of either compressed air or pressurized water together with the leading end of the weft yarn a nozzle is used.



General Considerations

- The mass of insertion medium to be accelerated is very small, relative to the shuttle, rapier or projectile weaving machines, which allows high running speeds.
- Mass of the fluid is about 1.5g.
- Unlike the rapier or projectile insertion systems, there are not many mechanically moving parts to control and insert the weft yarn.
- Technical requirements of the fluid are important: temperature, humidity, impurity content, etc.

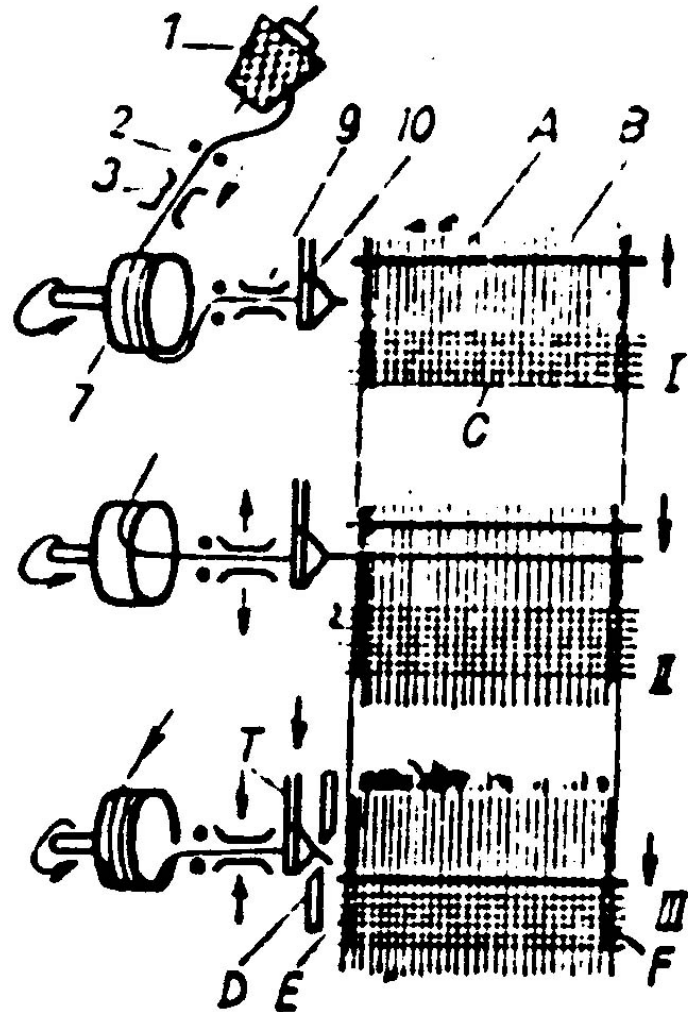
General Considerations

- As the tractive force applied to the weft is not very high, it must be prepared for picking by a metering device.
- In the majority of the jet weaving machines the picking system is fitted only on one side of the machine (single-sided picking) and
- The picking system is fixed firmly to the machine frame so that the beat-up mechanism carries only the reed and/or the air duct.

The weaving process

1 cross wound cone, 2 guide eye and 3 tensioner, 7 metering device (measures the necessary pick length of the weft thread). 9 holders to retain the weft thread after picking, 10 nozzle. The water or air are supplied to through tube T

A — the reed, B — the warp sheet, C — the woven fabric, D — the weft cutter, E and F — the leno weave serving to reinforce the fabric selvages



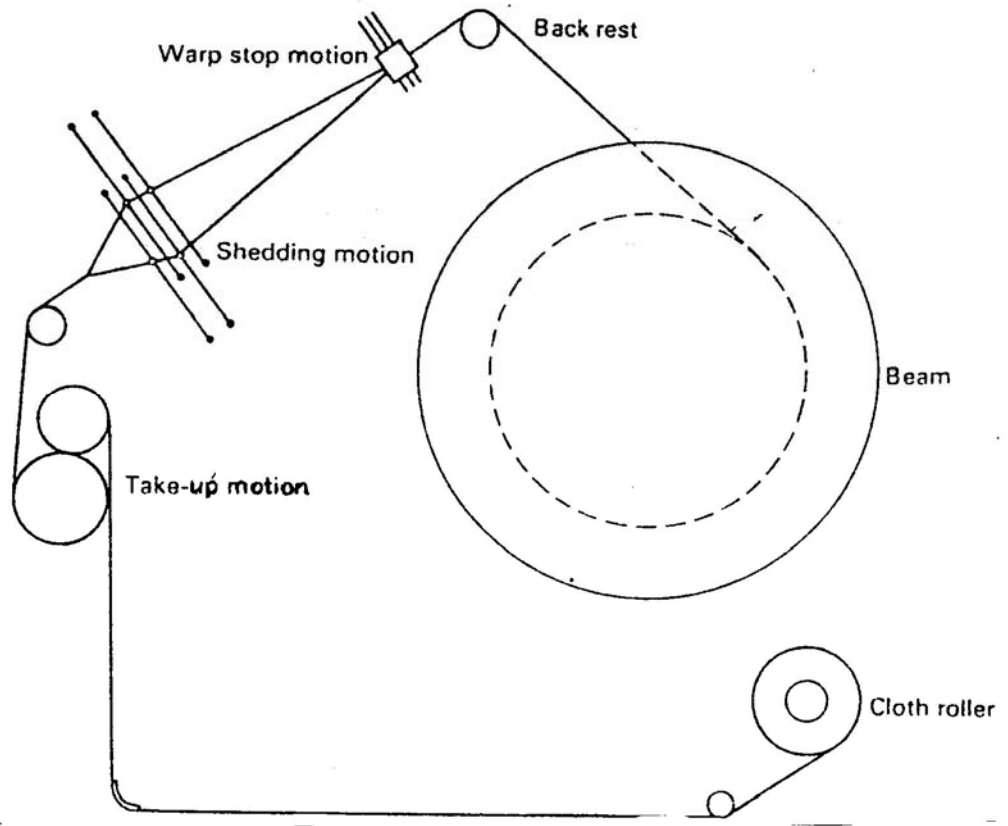
The weaving process

The weft-insertion medium does not require support.

The passage of the warp through the machine can be modified, so that a substantial saving in floor space will be achieved.

The cloth roller is situated under the warp at the back of the loom as illustrated.

This makes servicing of the warp, weft, and cloth from the back alley easier.



The passage of the warp through a jet loom (Elitex air-jet loom)

The tractive force in the weft thread

- If the weft thread was merely surrounded by the air or liquid during the picking and if its velocity was the same as that of the picking medium it would be completely tensionless.
- The weft thread would then curl and snarl on itself across the shed and its insertion would be rather uncertain.
- Therefore, a tractive (drag) force is needed to produce the necessary tension in the weft thread and to maintain that tension for the whole duration of the pick.

The tractive force in the weft thread

- In the jet picking systems this tractive force on the weft thread results from the friction between the air or liquid and the surface of the weft thread.
- This explains why the velocity of the picking medium must be greater than that of the weft thread.
- The level of friction developed in a flowing medium is dependent on
 - the square of the velocity difference,
 - the viscosity of the medium,
 - the roughness and length of the weft thread and,
 - in the water jet insertion systems, the wetting property of the weft yarn.

The tractive force in the weft thread

- Initial velocity of air- 200-300 m/s, initial velocity of water- 40-60 m/s, initial velocity of weft yarn- 20-30 m/s.
- The higher the viscosity the higher the tractive force .
- As the viscosity of the air is very low, high relative velocities must be used in the air jet picking systems.
- Viscosity is largely dependent on the temperature of the medium. For example, the viscosity of water at 0 °C is $0.017 \text{ g cm}^{-1} \text{ s}^{-1}$ while at 100 °C it is as low as $0.0028 \text{ g cm}^{-1} \text{ s}^{-1}$.
- In the jet picking systems the tractive force on the weft thread is the higher the rougher the surface of the weft yarn.
- Considering the low viscosity of the employed picking medium, air-jet picking systems are designed mainly for the spun weft weaving. However, they have become suitable to insert filament yarns with some developments in main nozzle design.

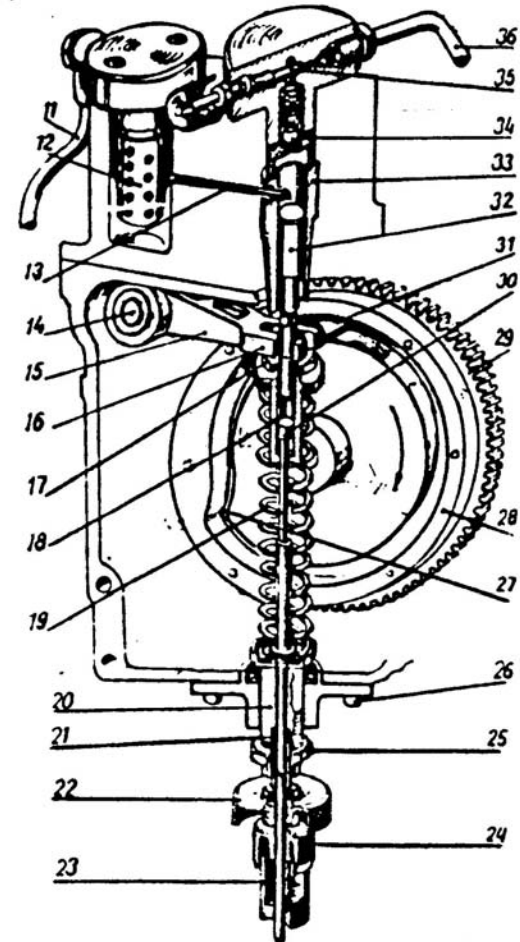
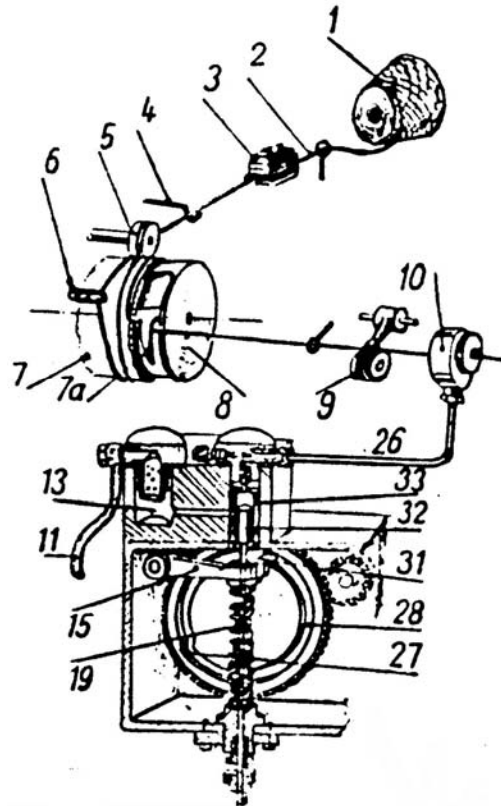
The water jet picking system

- The weft insertion on a water-jet weaving machine is divided into three phases:
 - Acceleration of the water in the pump prior to its injection into the nozzle.
 - Jet outlet from the nozzle.
 - Flow in the free environment in different forms:
 - Compact
 - Split
 - Atomized

The injection pump

The water is incompressible.

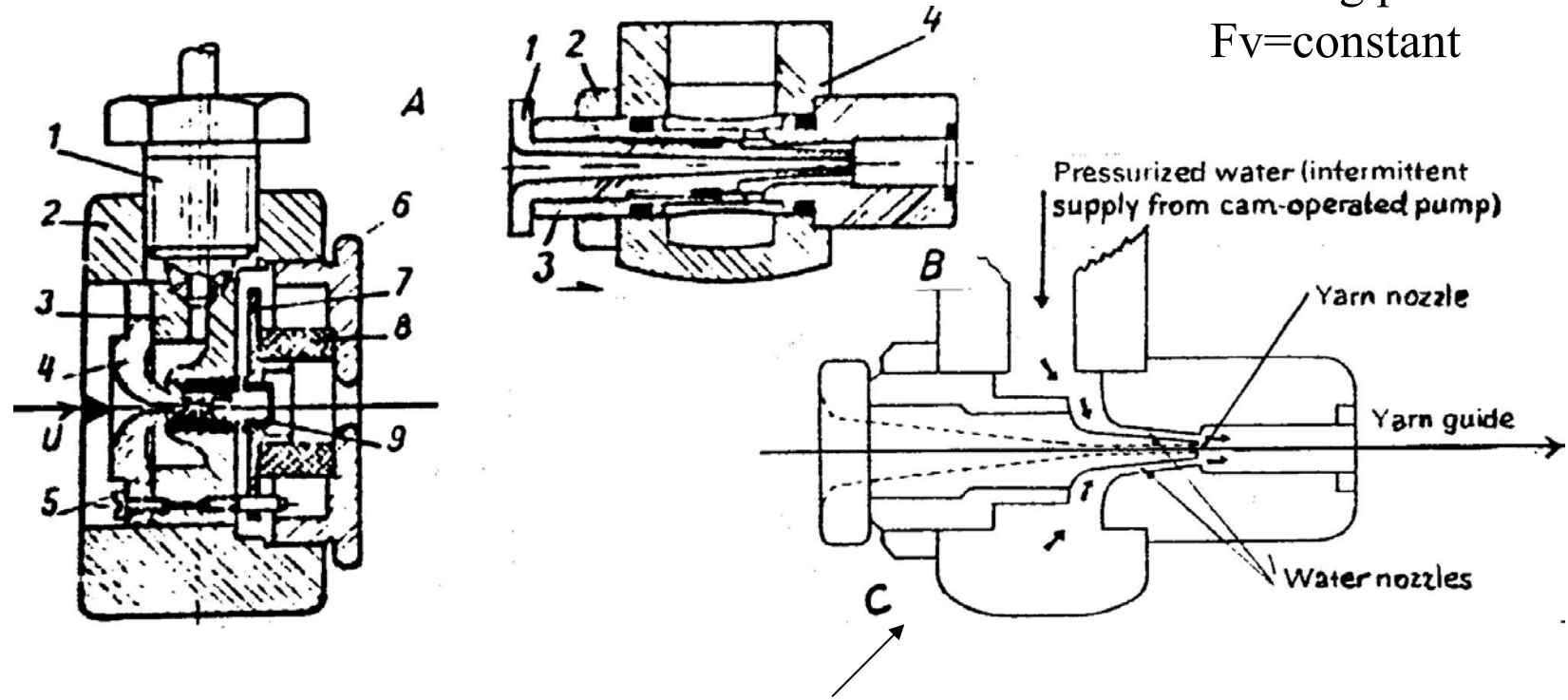
When the water is supplied into a pump cylinder, it is accelerated by a spring loaded piston and the fed through a piping to the main nozzle.



The main nozzle

Open nozzle, no
moving parts.

$F_v = \text{constant}$



The advantage of this type of nozzle is its simplicity. Its disadvantage is a considerably higher consumption of water and water leakage between individual picks.

Bernoulli's equation

$$P + \rho gh + \frac{1}{2} \rho v^2 = \text{const}$$

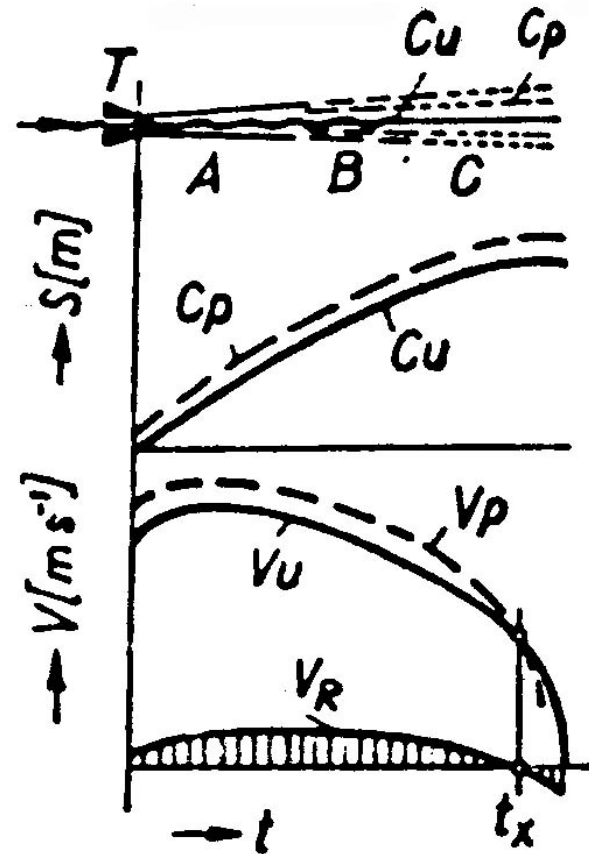
- The pressure in a moving fluid depends on its speed.
- In particular, since an incompressible liquid's flow rate is greater in a constraint region than the rate in a region of a larger cross section, the pressure is low in the constraint region. This produces a vacuum effect to accelerate the weft yarn.
- Similarly, the pressure exerted by the moving air is less than the pressure of stationary air. The stationary weft yarn is pushed towards the moving air.

Flow in the free environment

A — compact, B — split, C — atomized. The most suitable for the weft insertion is the compact portion of the flow and possibly also the split portion.

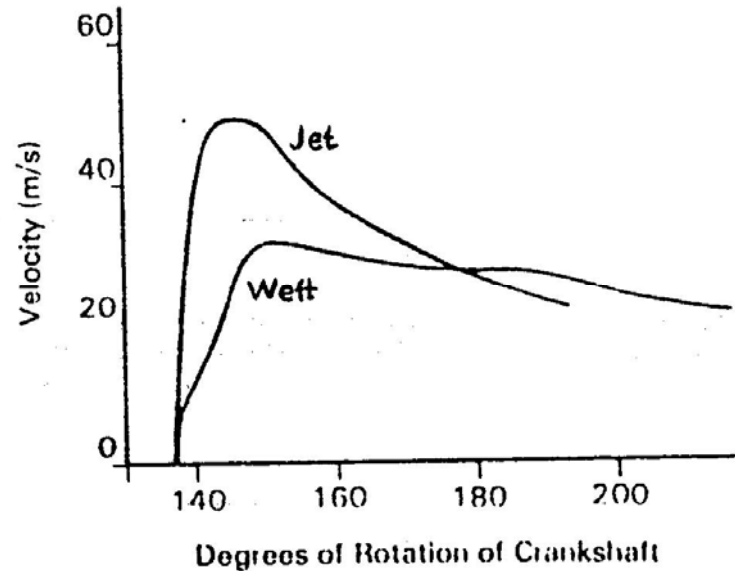
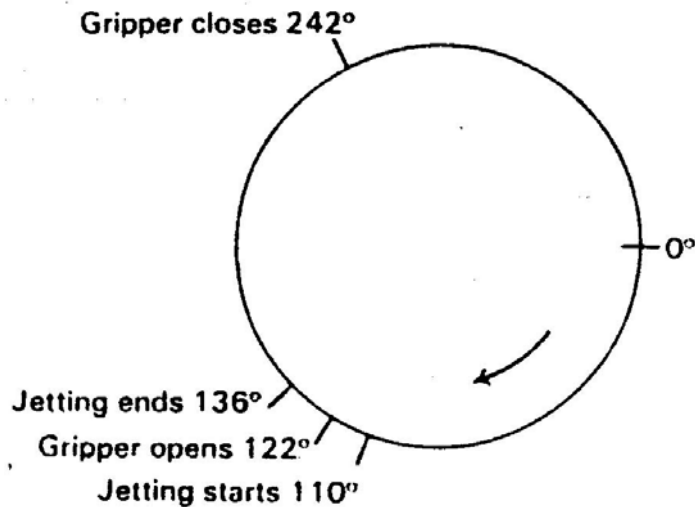
C_p : jet front and C_u : weft front

At t_x , the relative speed $v_R = v_p - v_u$ becomes negative. Beyond this point t_x , the weft thread is likely to curl and snarl



The timing diagram

A water jet is capable of maintaining its concentration and thus its force over a greater distance than an air jet, but there are no means readily available to assist the jet as it traverses the loom.



The weft thread is braked by the reed. The axis of the water jet is more or less parallel with the fabric fell. The reed moving forward towards the fabric runs into the wet weft thread, which adheres to it, and is braked by it and prevented from contracting in the length.

The working conditions

- The water quality:
 - Mechanical impurities must be filtered
 - Must not contain sediment forming additives (Fe, Mg, Ca, Si)
 - Hardness:5-10 in German scale
 - Must be harmless biologically and hygienically.
- The working conditions:
 - Operating temperature of water: 16-24 0C
 - Operating pressure of water:0.5-1.5 kg/cm²
- Design modifications of weaving machine:
 - The machine should be provided with an anti corrosive protective finish or the machine parts (i.e. Reed, temples, healds) should be made of corrosion resisting steels.

The working conditions

- Water extraction and final drying
 - The cloth may contain a great amount of water.
 - It is achieved through a cloth squeezing or a suction and then drying.
 - Such a system consumes 2 to 3 kW energy and unwelcome source of additional heating in the weaving room.
 - The waste water is usually removed into a drainage system.
- Working speeds:
 - The width and speed of water jet looms have been gradually increased.
 - The modern water jet weaving machines can have a speed of around 1500ppm while the maximum reed width is 3 m and the WIR is 1800m/min.

AIR-JET WEAVING

- Air jet weaving is a type of weaving in which the weft yarn is inserted into the warp shed with compressed air.
- The air-jet weaving machine combines high performance with low manufacturing requirements.
- It has an extremely high weft insertion rate.
- Due to its exceptional performance, air-jet machines are used primarily for the economical production of standard fabrics, covering a wide range of styles.
- Meanwhile, more and more special fabrics are also covered: heavy cotton fabrics such as denim, terry fabrics, glass fabrics, tire cord, etc.

The advantages of air-jet weaving machine:

- High productivity
- Low initial expenses
- High WIR
- Simple operation and reduced hazard because of few moving parts
- Reduced space requirements
- Low noise and vibration levels
- Low spare parts requirement
- Reliability and minimum maintenance

Air jet picking

- Air-jet picking is governed by the same rules and relationships as described before for the water-jet picking.
- However the viscosity of air is hundred times lower than the viscosity of water. Thus, it may lose its integrity easily.
- Therefore, a higher air jet speed is required to produce the necessary tractive force.
- Moreover, different types of insertion configurations are designed.

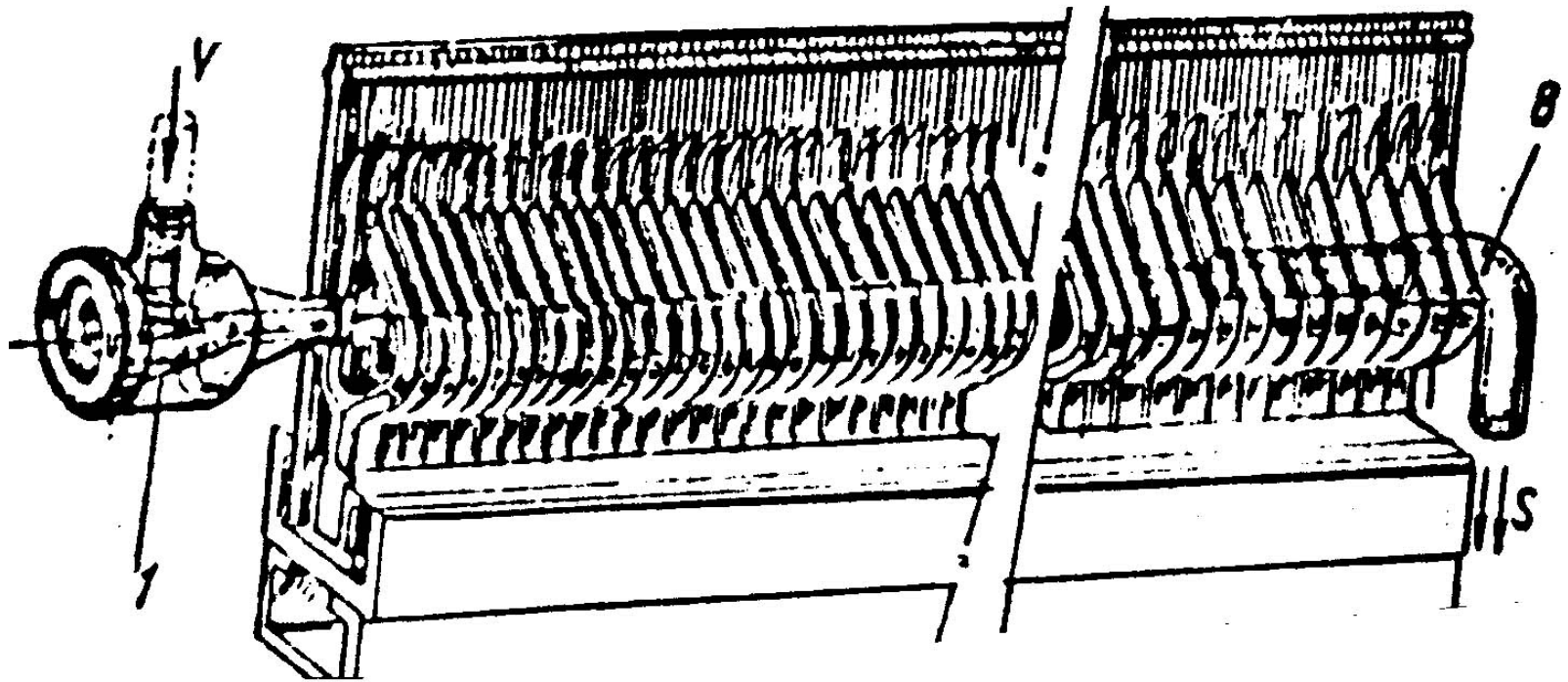
Insertion Configurations

- Three different systems have been used mainly on commercial air-jet weaving machines:
 1. Single nozzle, confuser guides and suction unit at the exit side
 2. Multiple nozzles with guides
 3. Multiple nozzles with profiled reed
- Although all three systems have been used in commercial looms, the System3 is the most common and standard configuration in the market.

Insertion Configurations

- The main nozzle applies the necessary driving force to initiate the insertion of predetermined length of weft yarn.
- The air jet flying in a free space entrains (becomes mixed) with the environmental air and loses its velocity on a relatively short distance.
- The integrity of the air is preserved by either a confuser or a tunnel (profiled) reed.
- Buckling of the leading end of the weft is prevented by applying a constraint at the insertion side of the machine and by maintaining the projection velocity by a series of back-up jets. This system is precisely timed and back-up nozzles are progressively opened.

System1:Single nozzle, confuser guides and suction unit at the exit side



- Air jet guide ducts (also known as confuser) is formed by a series of ribs (flat metal plates). They are located on the raceboard in front of the reed and penetrate between the warp ends during the picking.
- The confuser keeps the initial concentration of the air as much as possible.
- The leading end of the weft is stretched by a suction device

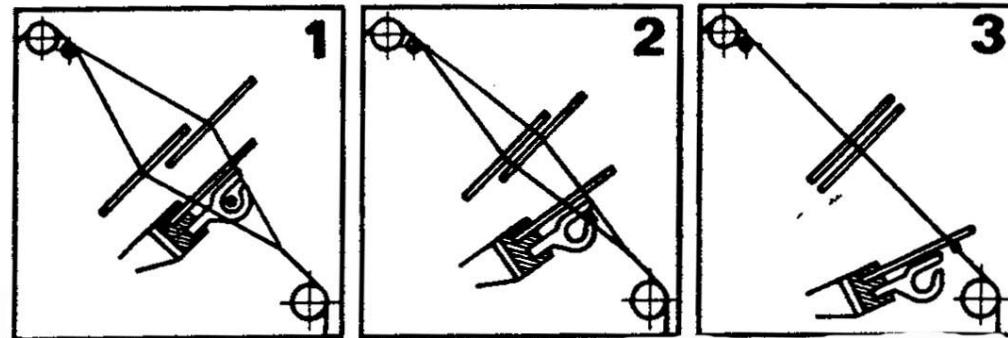
The disadvantage of this system is the weaving width limitation due to the lack of additional back-up nozzles to keep the air velocity high enough.



Confusor orifice



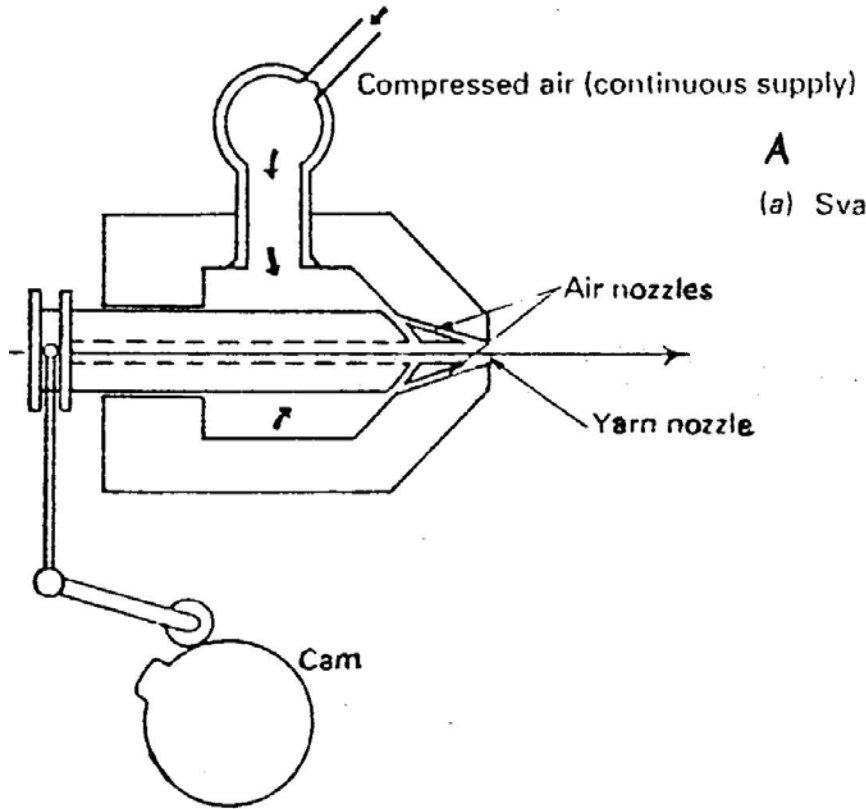
Shed formation



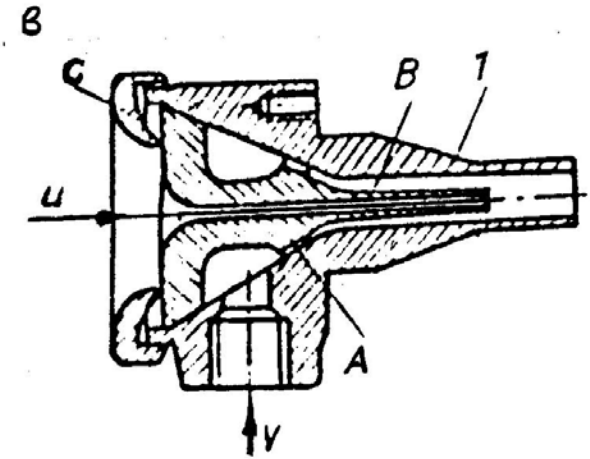
Elitex, 190 cm, 1200 ppm, WIR 1920 m/min

Air duct is conically expanded in the picking direction so that air molecules in the outer fringes of the jet can be deflected back into the main stream.

The main nozzle



The compressed air is continuously fed to the jet nozzle. The center barrel of the nozzle is then made to move outwards by a cam system, and this creates a gap through which the pressurized fluid will be forced.



The air V enters the nozzle body 1 and flows through milled grooves A round the nozzle core B in whose orifice the left thread is threaded in the direction of u . The core is tightened in the body by nut C. It is an open nozzle without any inside closures.

System2:Multiple nozzles with guides

- In addition to the main nozzles and air guide ducts, auxiliary nozzles are also used. They are located at certain intervals and they inject (blow) the air sequentially in groups in the direction of yarn movements.

System 3: Multiple nozzles with profiled reed

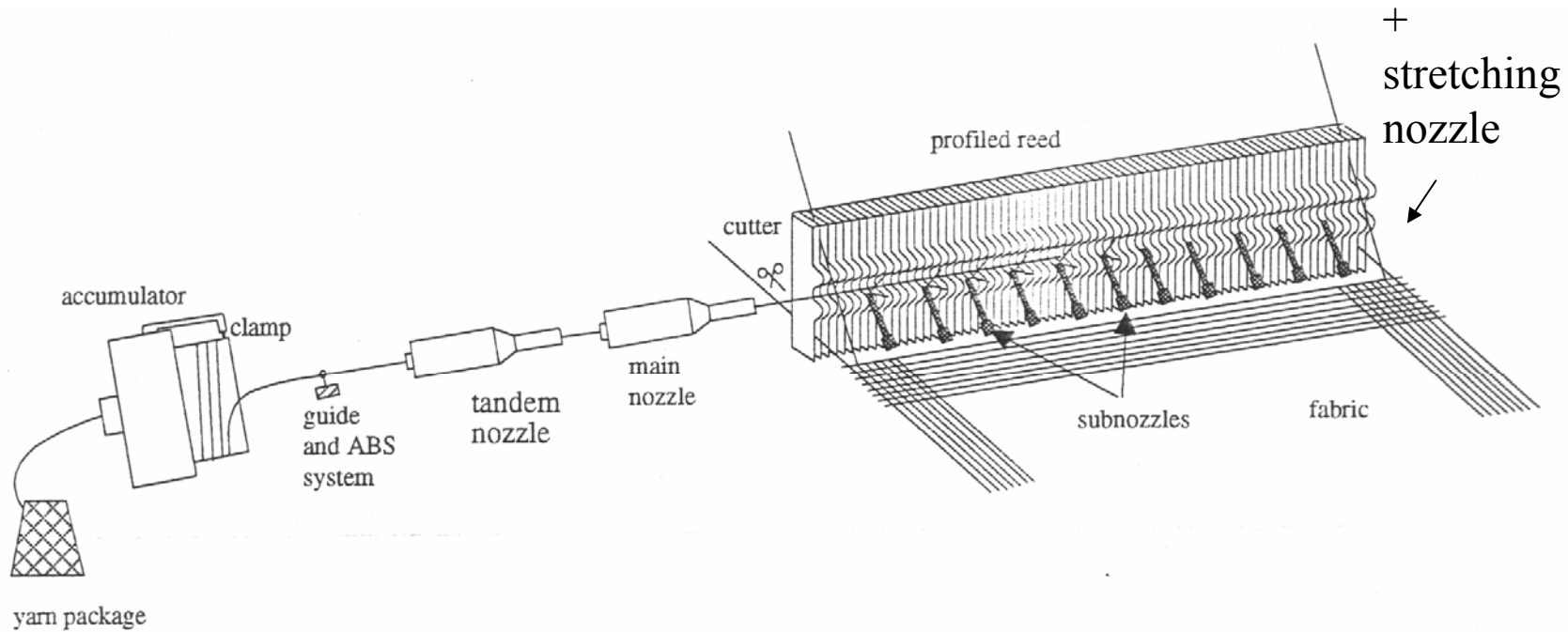


FIGURE 8.1 Schematic of air-jet filling insertion with profiled reed [1].

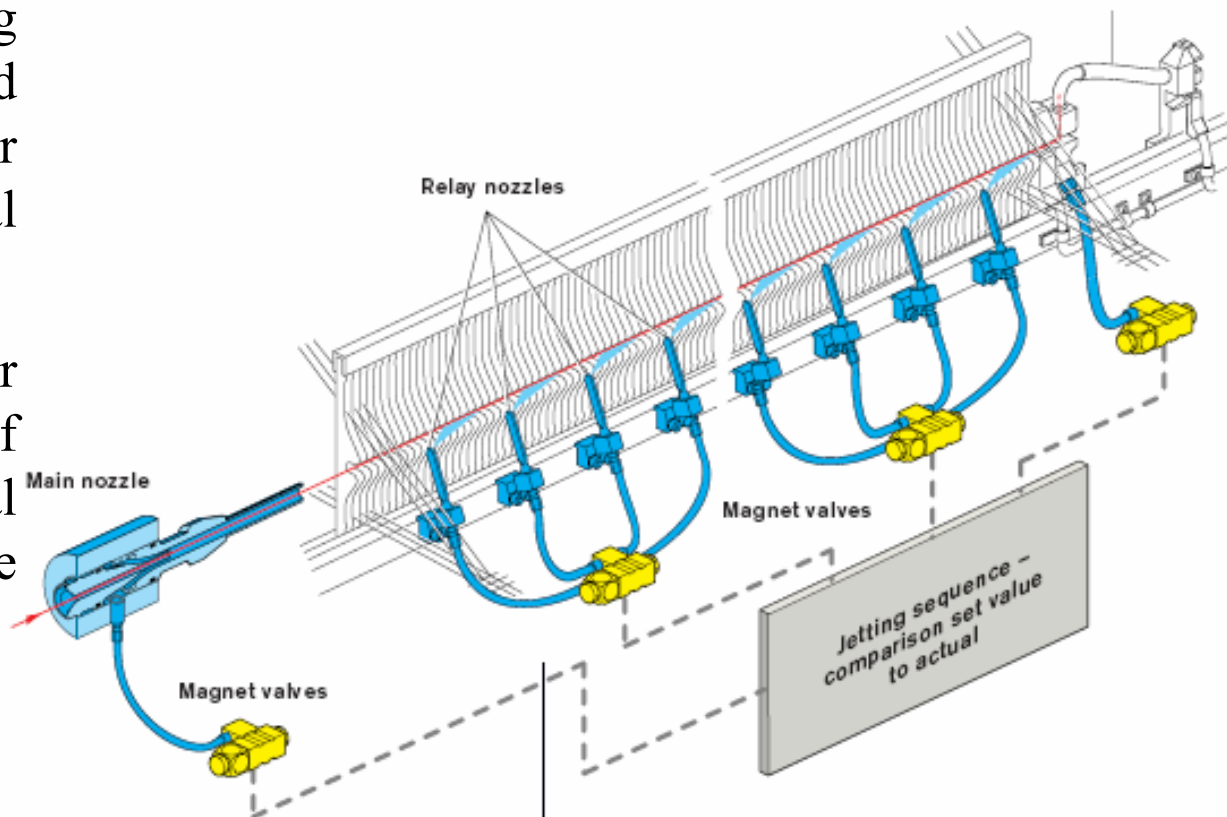
System 3: Multiple nozzles with profiled reed

- The profiled reed wires are used and the weft yarn is fed in to the reed tunnel via the main nozzle.
- The main nozzle (sometimes the main and tandem nozzle combination) provides the initial acceleration, where the relay nozzles provide high air velocity across the shed.
- Profiled reed provides guidance for the air stream and separates the weft yarn from warp sheets.
- Relay nozzles are located at certain intervals, say 50 mm, however, last four nozzles at the exit side are spaced closer, say 25 mm.
- Additional nozzles increase the air consumption.

The air jet weaving machines are supplied with compressed air maintained from a central source.

The preparation of the air before its distribution of the air to the individual weaving machine through a valve system:

- Filtering
- Compressing
- Cooling
- Drying
- Air tank
- Weaving Machine



The permanent control of the relay nozzle jetting sequence with a continuous standard value comparison (PIC[®]) assures weaving quality and precludes machine downtime. Defective or worn magnets are indicated immediately. Yarn-, speed- and width-related parameters for the control of the nozzles pick and pick are supplied from a data library. The timing of the electronically controlled filling scissor can be set on the display with the machine running.

Weft insertion in air jet picking

- The air flow from the nozzle.
 - The air flow through the shed.
 - The weft motion.
-
- The transporting medium has a complicated motion.
 - Air flow in weft insertion is unsteady, turbulent, and can be either compressible or incompressible depending on the velocity(for air velocities above 100 m/s, compressibility should be taken into account).

1.The air flow from the nozzle :

- The initial driving force applied to the weft is:
- F_d = driving force
- C = coefficient of friction between air and yarn
- d = yarn diameter
- l = yarn length in the jet subjected to jet pressure
- v = air velocity in the jet
- ρ = air density

$$F_d = (C \pi d) l v^2 \rho / 2$$

1.The air flow from the nozzle :

- $(C\pi d)$ depends on yarn characteristics:
- The hairiness and roughness influence C
- The yarn linear density and the material influence diameter d and its circumference.
- Air requirement per pick increases with linear density.
- The density of the air is also very significant and air requirement is gravimetrically specified, i.e. g/min. This is particularly important when machines are to be operated in elevated and high temperature environments.

$$F_d = (C\pi d)lv^2 \rho / 2$$

3. The weft motion through the shed:

- The equation of weft motion is

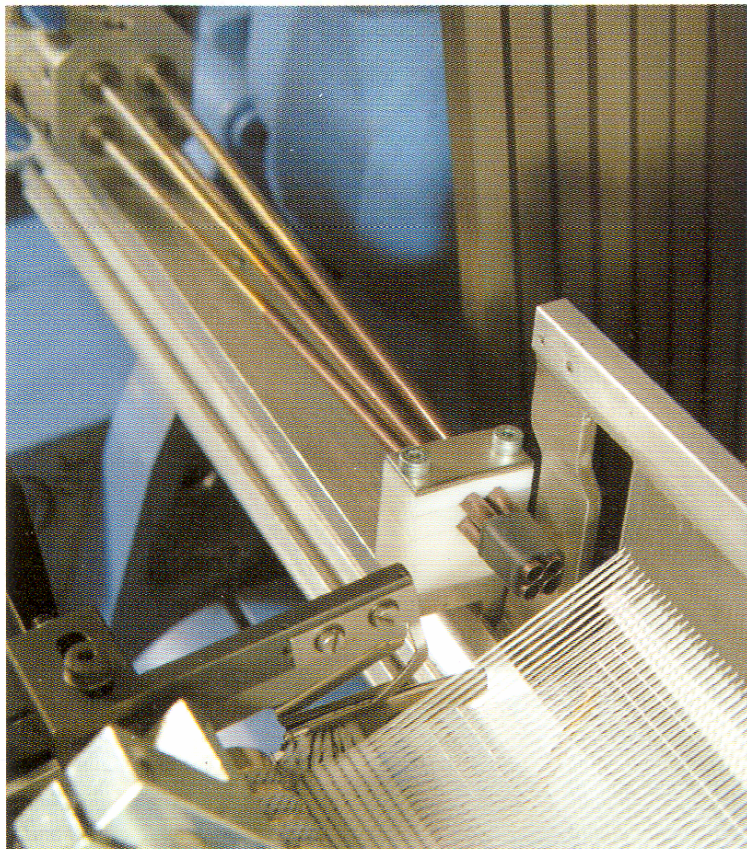
$$ma + \frac{dm}{dx} v^2 + S + F = T$$

- The force acting on the moving thread is proportional to:

$$\rho \times \mu \times d \times l \times (V_a - V_w)$$

JS900: the most modern fluid dynamic technology

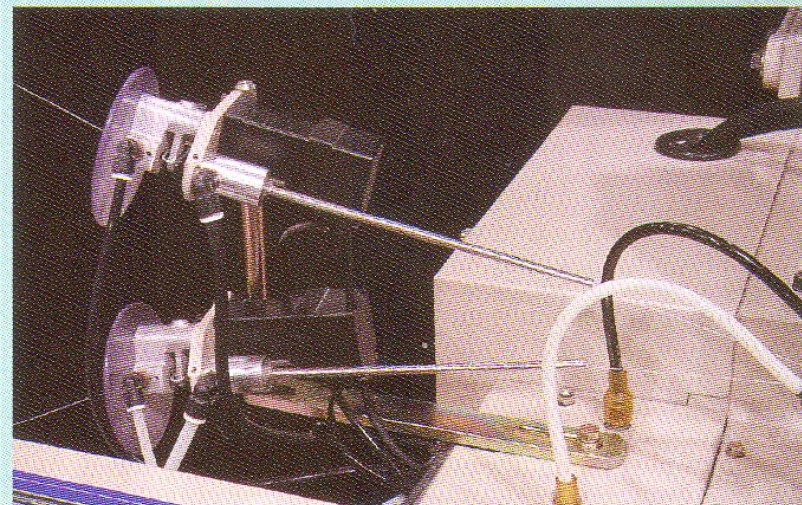
- High-speed main nozzles
- Fixed or mobile auxiliary nozzles
- Relay shower nozzles
- Stretching of the weft by multiple nozzle.

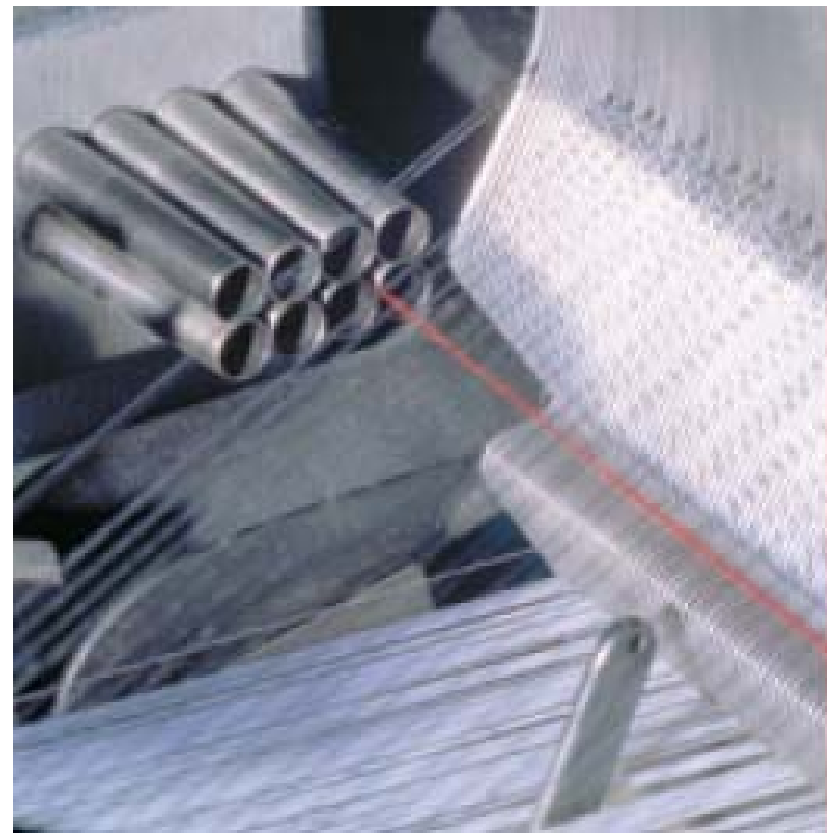
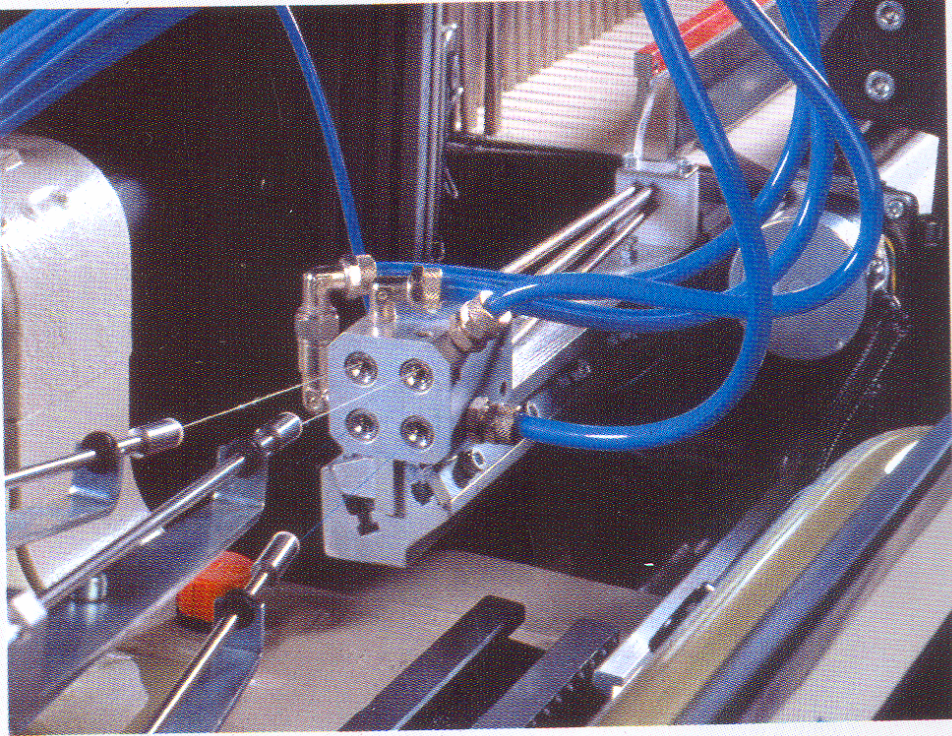


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■ Auxiliary main nozzle

By combining an auxiliary main nozzle and the main nozzle, filling is accelerated at low pressure to prevent yarn damage. Even at high speed weaving or extra-wide weaving which may give a load to fillings, it realizes stable filling insertion. The standard auxiliary main nozzle works with the main nozzle. Besides this, an independently-controlled nozzle to set air jet timing at-will is available.

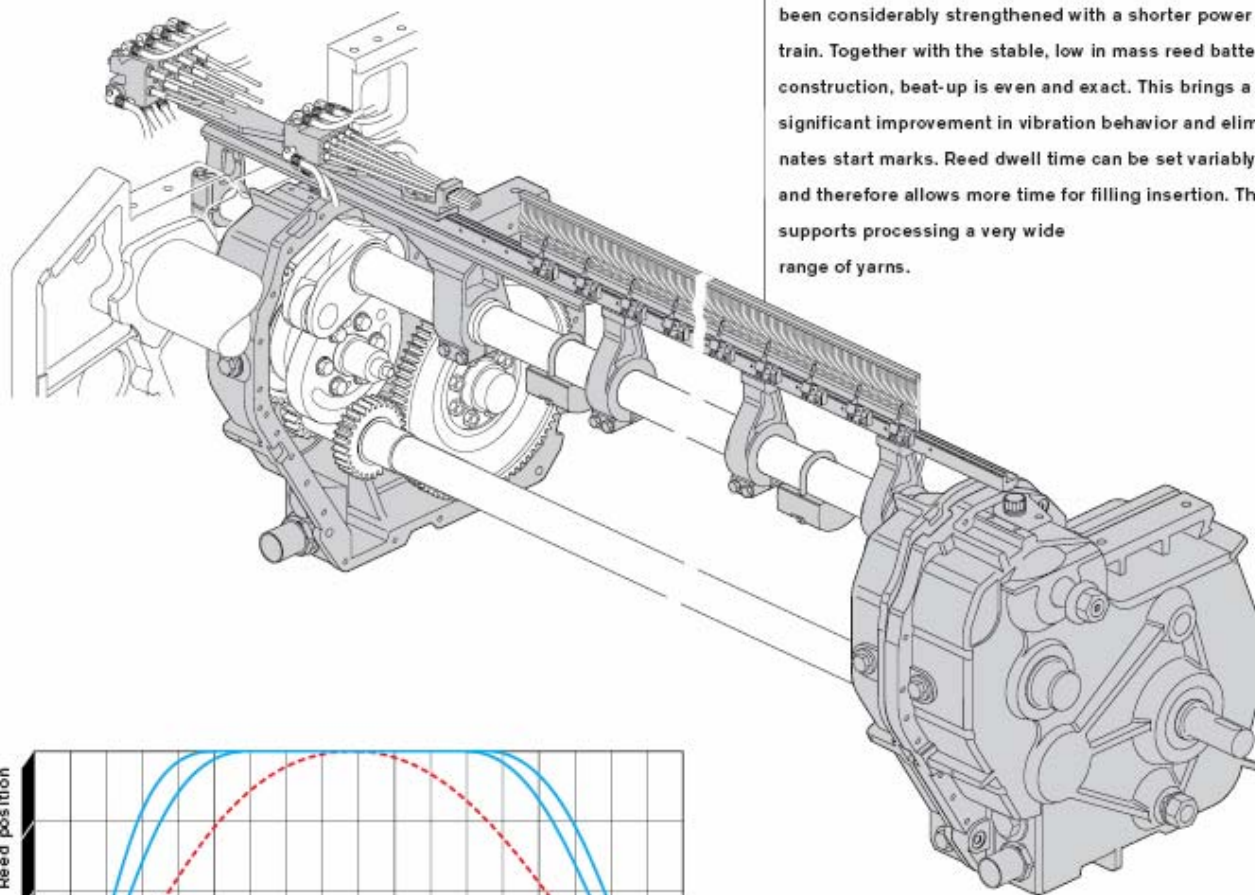




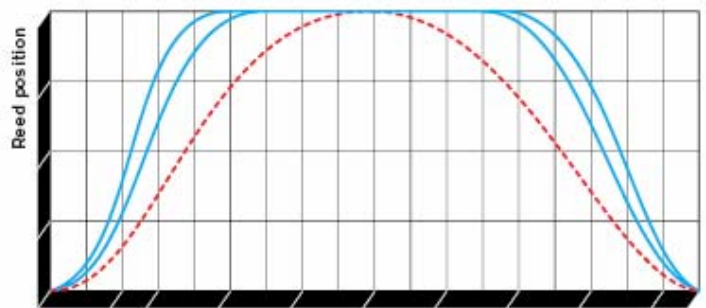




Air jet weaving machine



Bilateral reed drive with large, fast running connection shaft between the gears. In the AS-type these have been considerably strengthened with a shorter power train. Together with the stable, low in mass reed batten construction, beat-up is even and exact. This brings a significant improvement in vibration behavior and eliminates start marks. Reed dwell time can be set variably and therefore allows more time for filling insertion. This supports processing a very wide range of yarns.

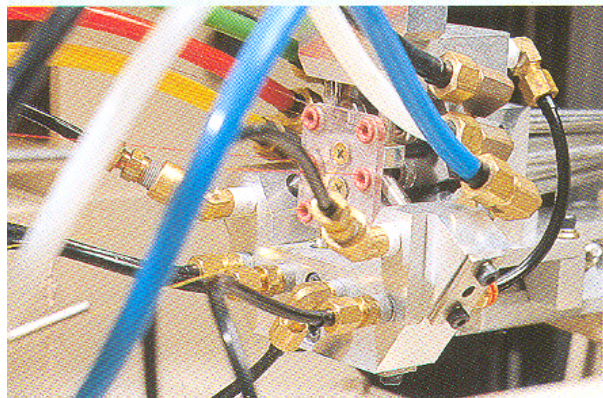
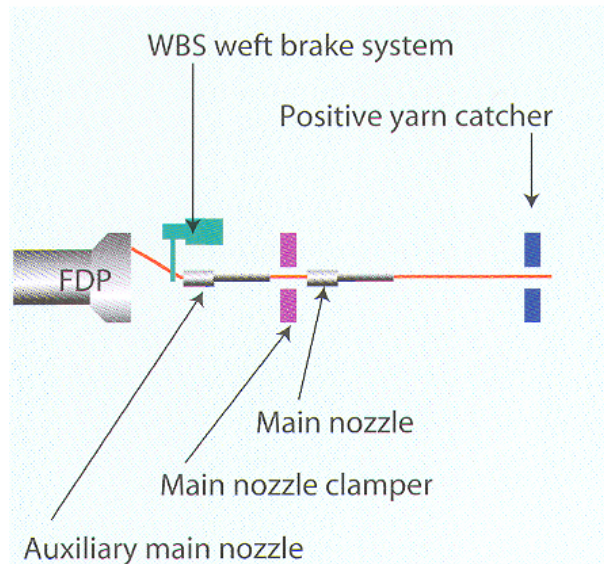


— DORNIER cam assembly with extended reed dwell time
 - - - - - Crank drive

Machine position in °

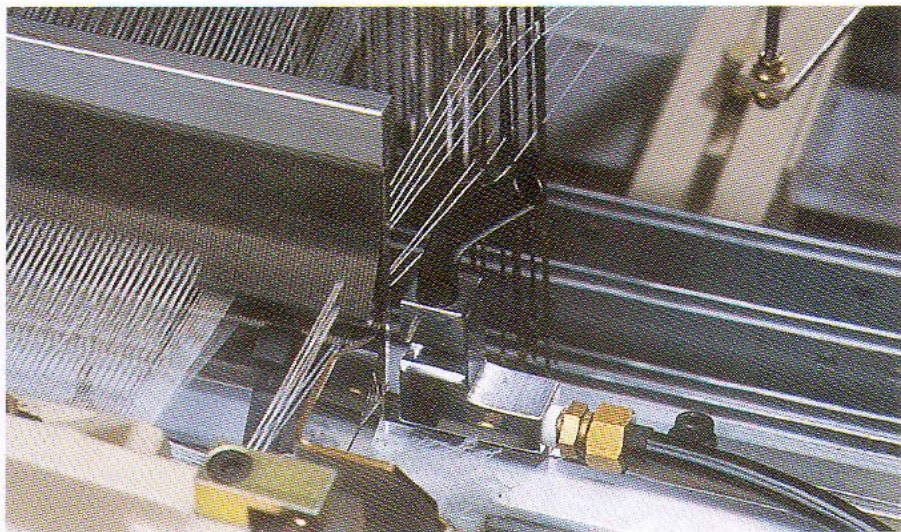
■ Weft stretching system Option

Combining the positive yarn catcher, the main nozzle clamber, and the WBS weft brake system depending on yarn kind facilitates weaving high quality stretch fabrics.

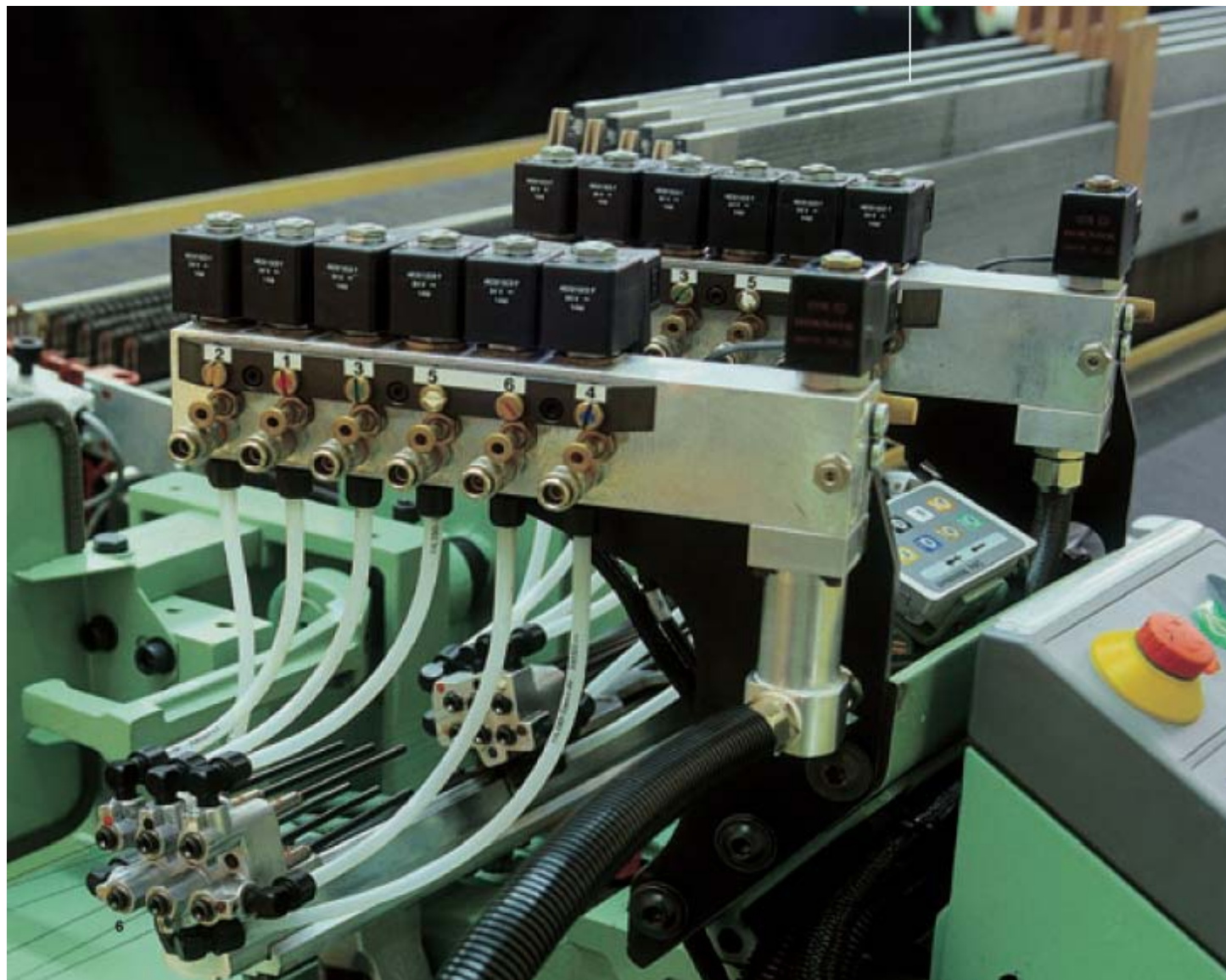


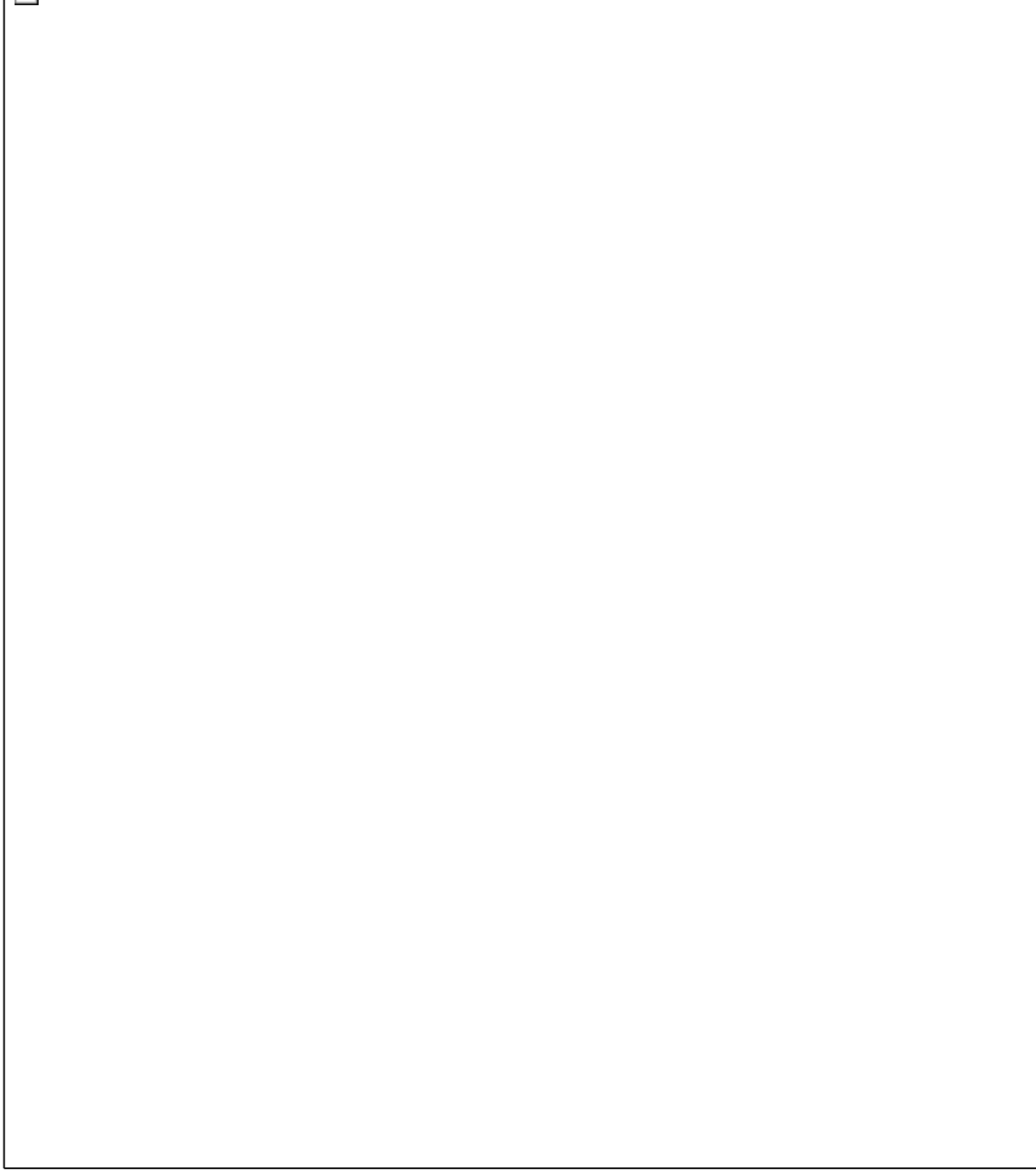
■ Stretch nozzle Option

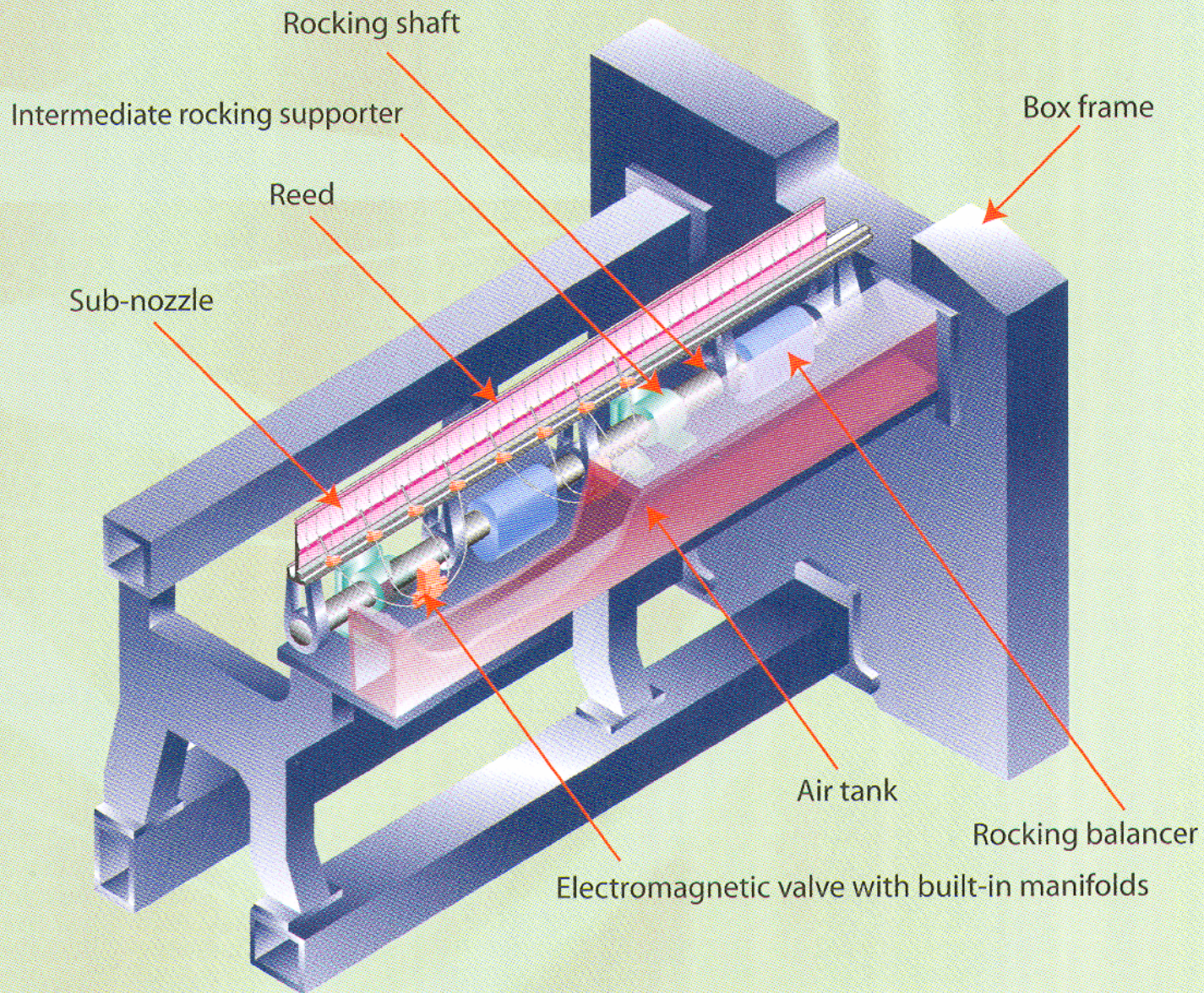
The stretch nozzle effectively prevents filling looseness. It holds the filling by air to eliminate any slack pick.

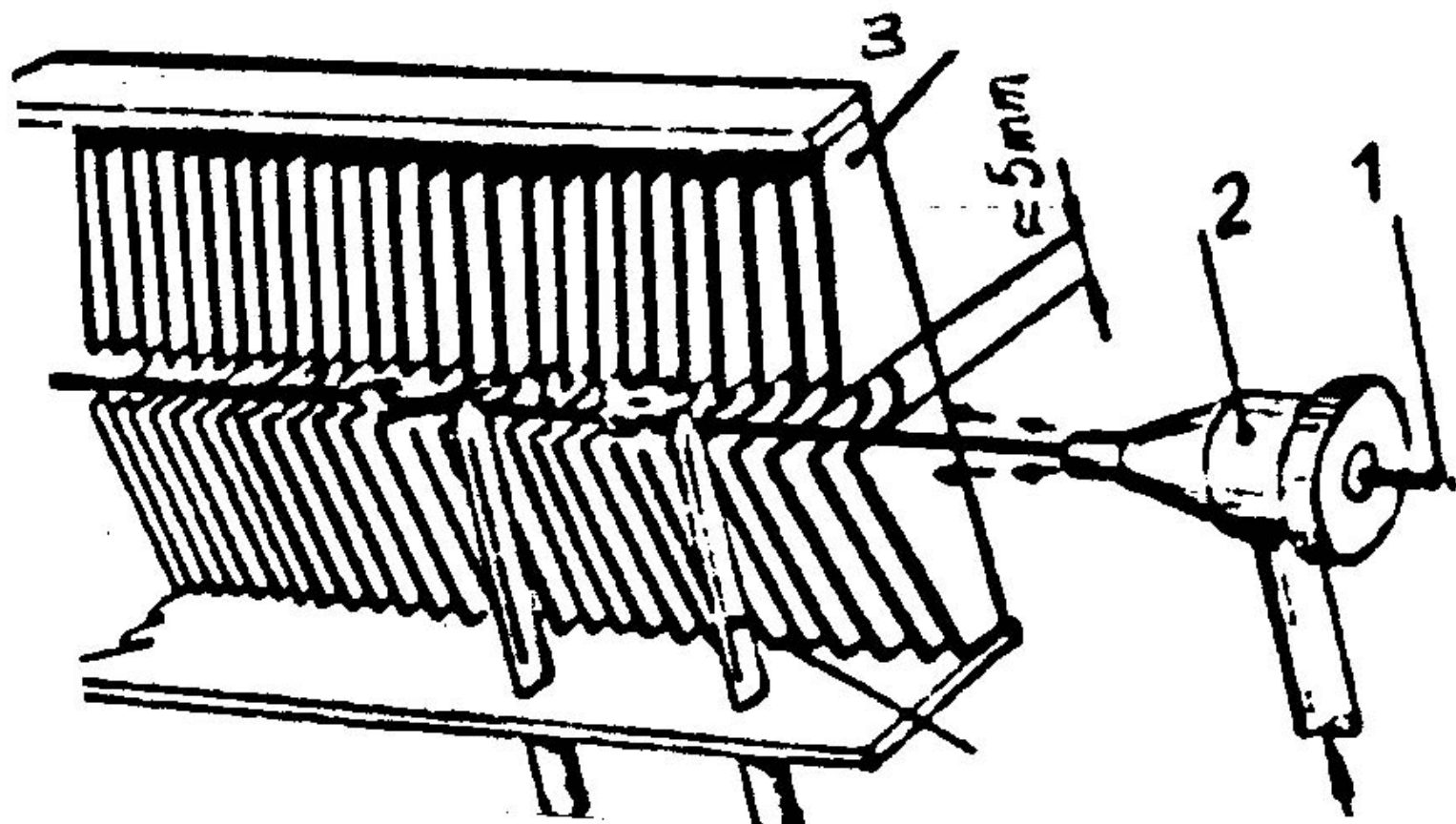


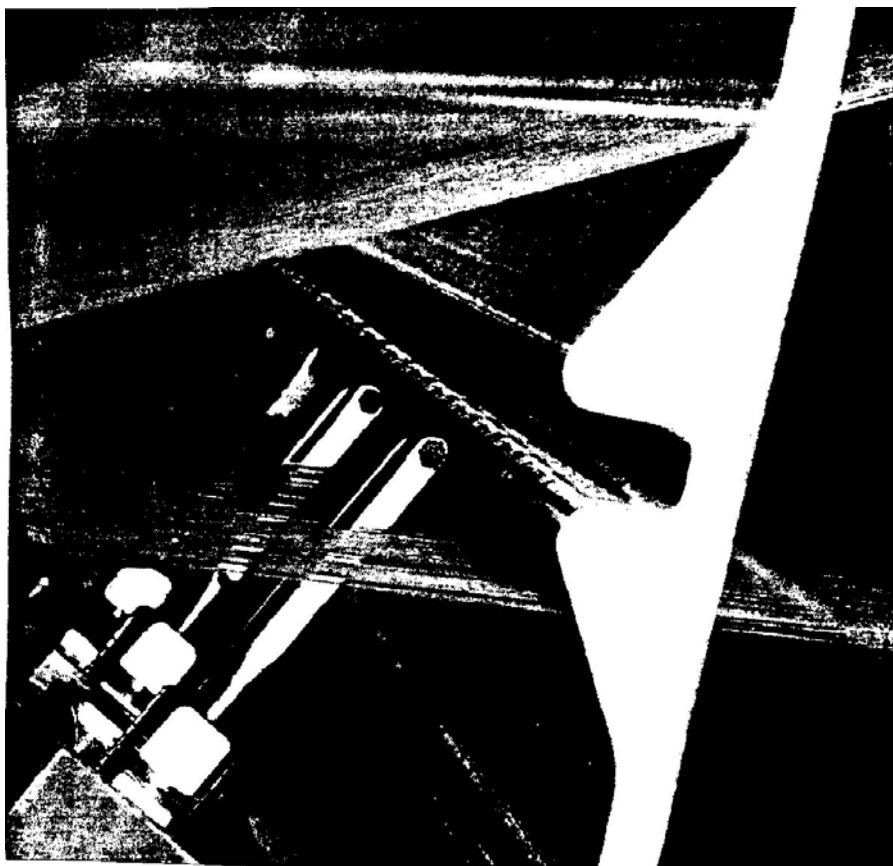
A new type of stretch nozzle for blowing air laterally is available to ensure the performance of the two-headed filling detector.

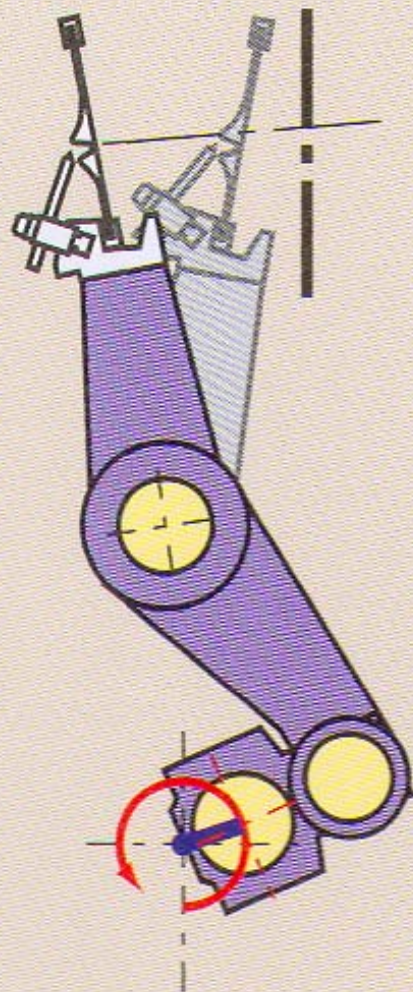




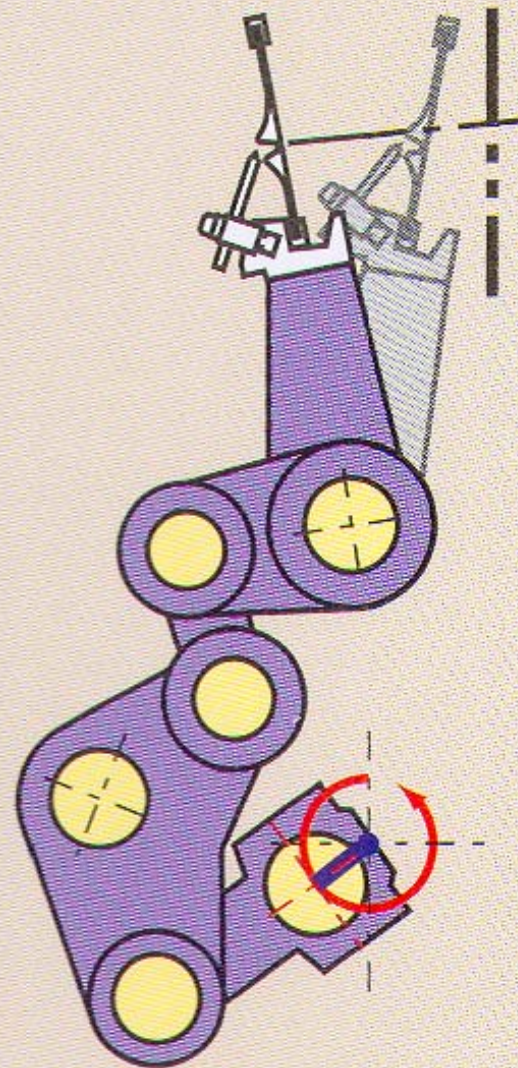




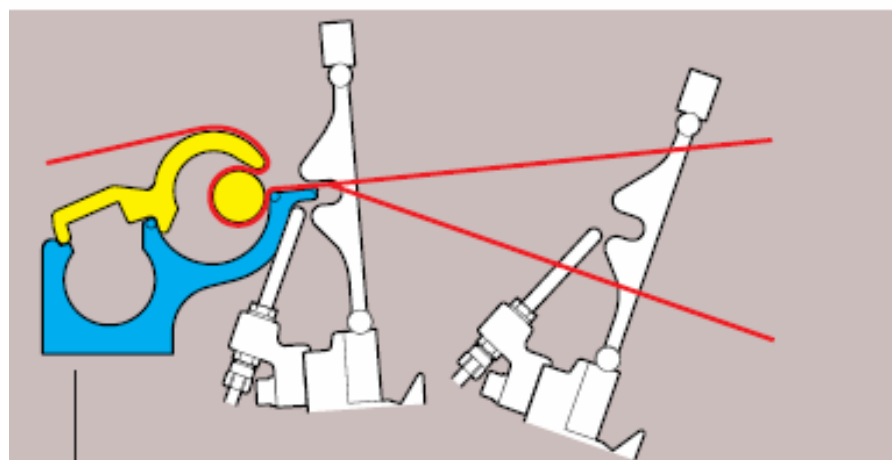
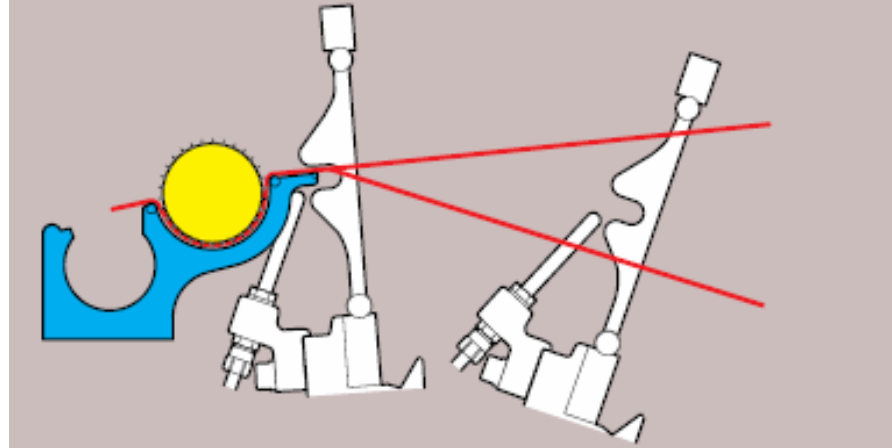




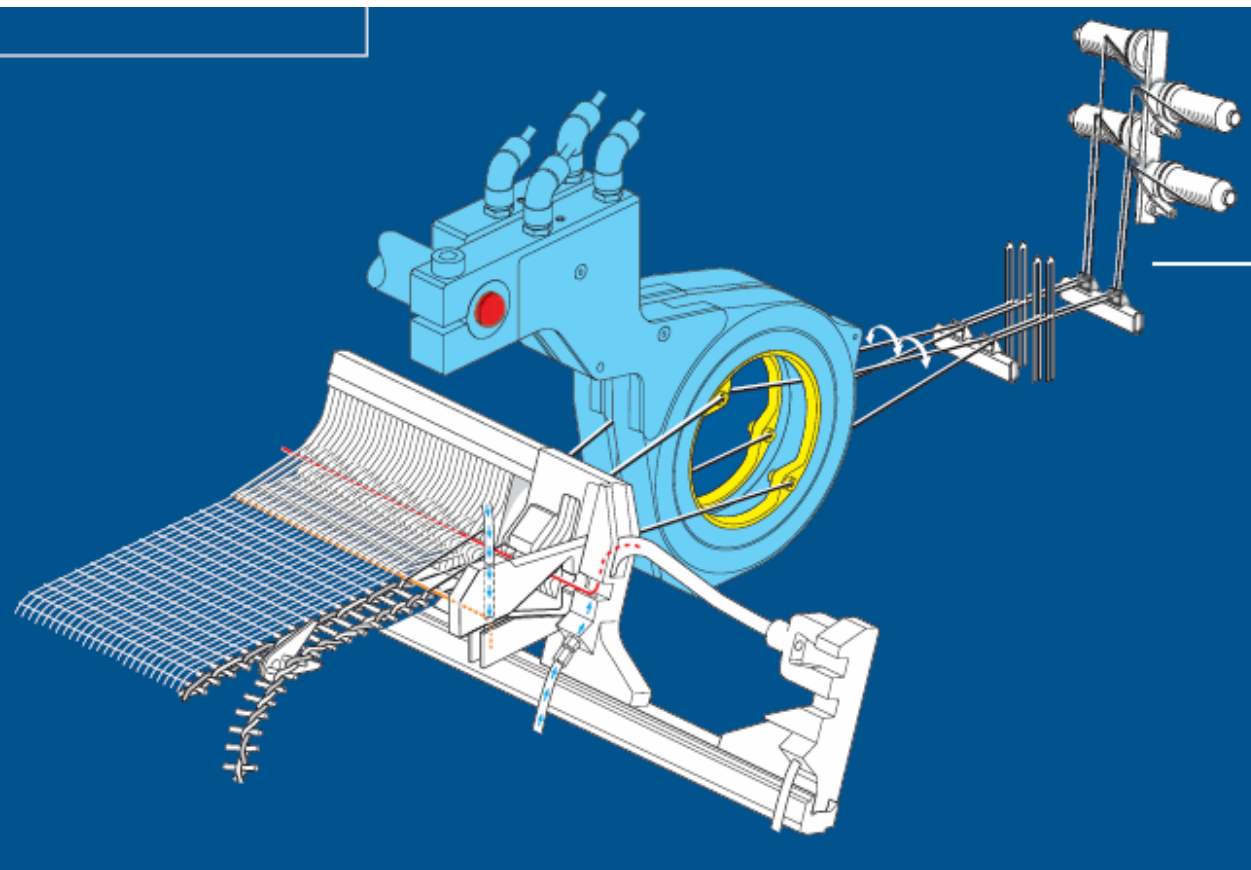
4-link beating motion



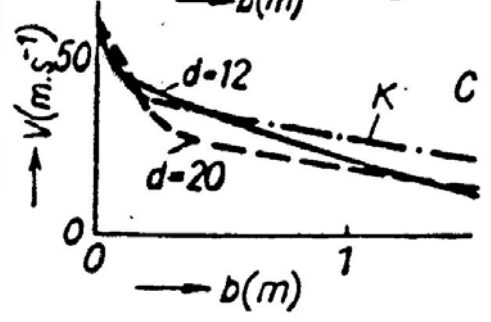
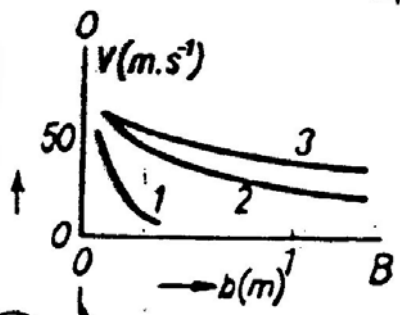
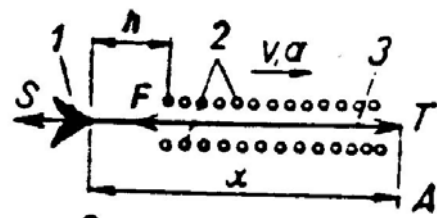
6-link beating motion



The width-independent DORNIER fabric support table guides the cloth precisely to reed beat-up. This allows optimum setting for the shed geometry without vertical shifting of the cloth fell due to heavy lifts caused by the pattern. When weaving high density fabrics, the thus possible asymmetrical geometry of the bottom shed supports attaining the desired fabric appearance. Burst fillings, warp end breaks, filling stops and loose pattern contours in design are avoided. A width-independent full-width temple is patented in combination with the fabric support table. It can be changed very fast to a commercial cylinder temple.



The modular, patented double disc leno MotoEco®. Two full-turn lenos with system-dependent direction reversal work side by side. One leno creates the fabric selvedge and the other one the catch selvedge with the option of material recycling. No extra shafts are required for the leno and catch selvedge spools are not required. The leno creates an intensive binding with exceptionally short thread ends and uses standard king spools.



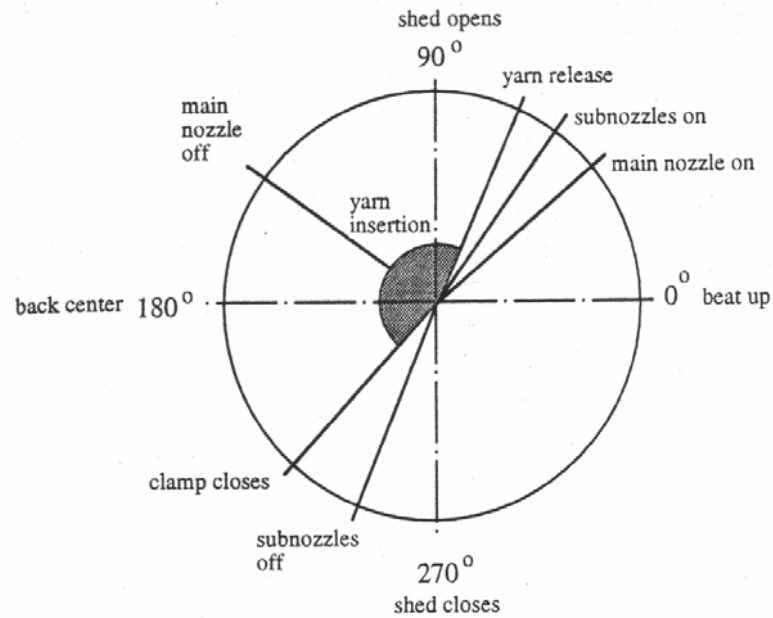


FIGURE 8.3 Typical timing diagram of an air-jet machine with multi-nozzles and profiled reed [1].

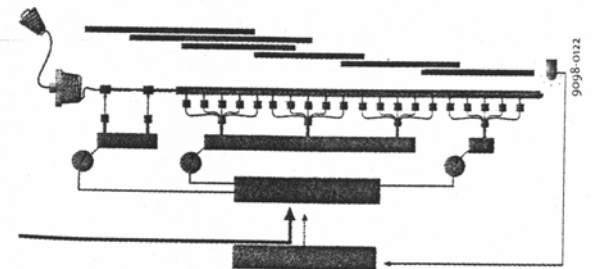
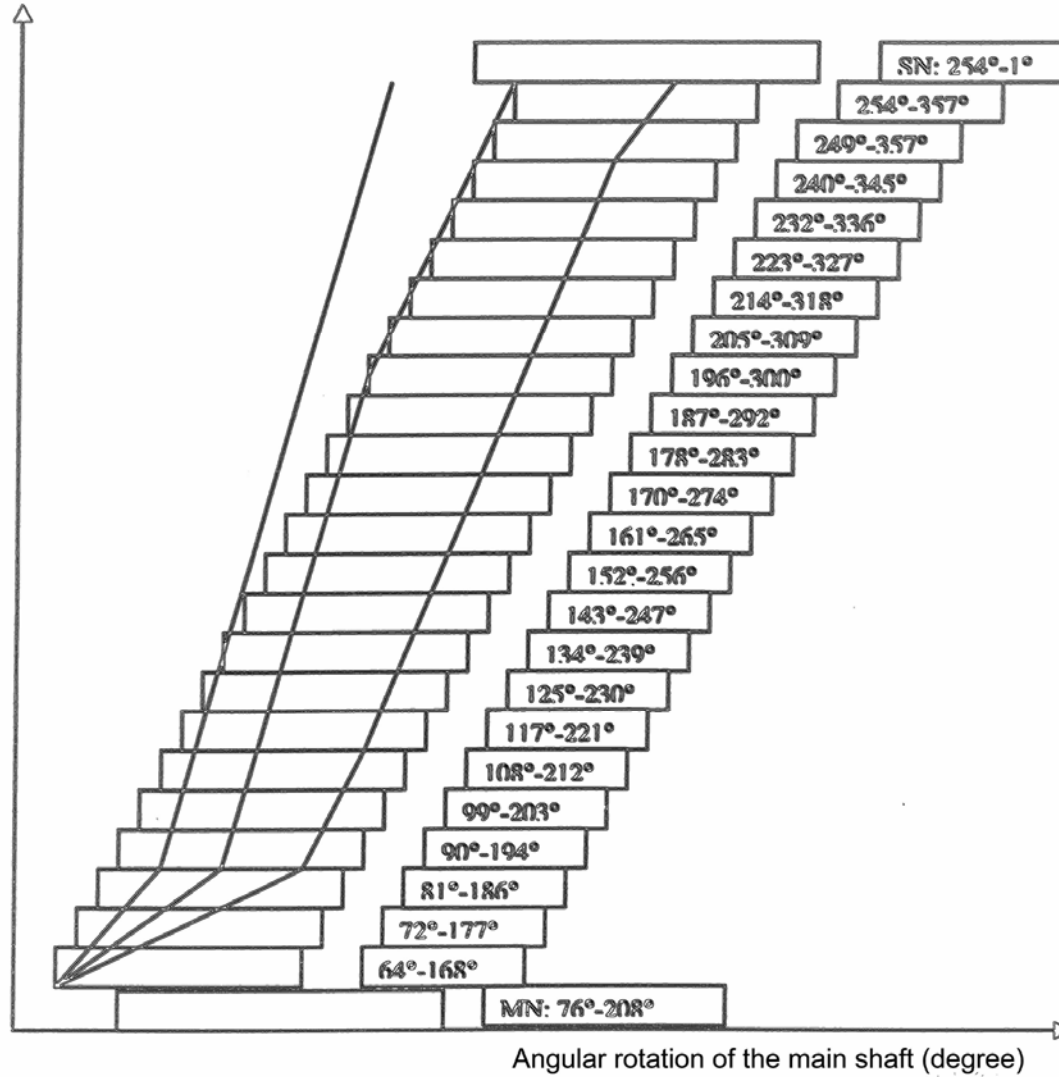


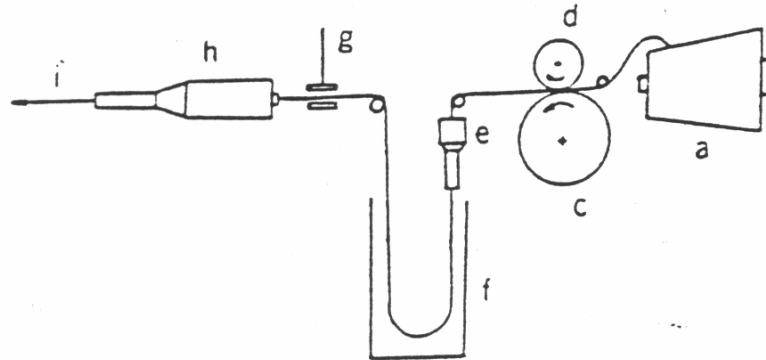
FIGURE 8.4 Programmable air blowing times with automatic correction at speed changes and automatic pressure optimization due to individual air supply.

Weft insertion path (mm)

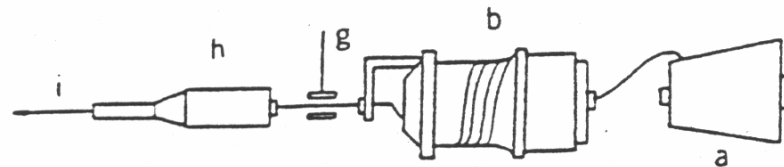


Yarn feeders

1. Loop storage



2. Drum storage



- a. Yarn supply package
- b. Drum feeder
- c. Measuring drum
- d. Feeding roller
- e. Auxiliary nozzle

- f. Storage pipe
- g. Clamp
- h. Main nozzle
- i. Yarn

FIGURE 8.6 Schematic of yarn storage systems [15].

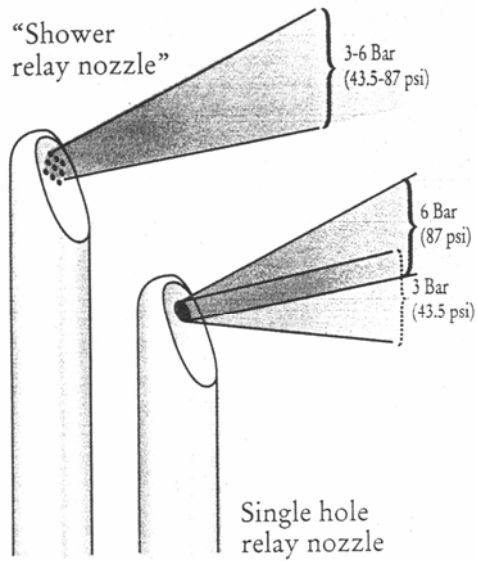
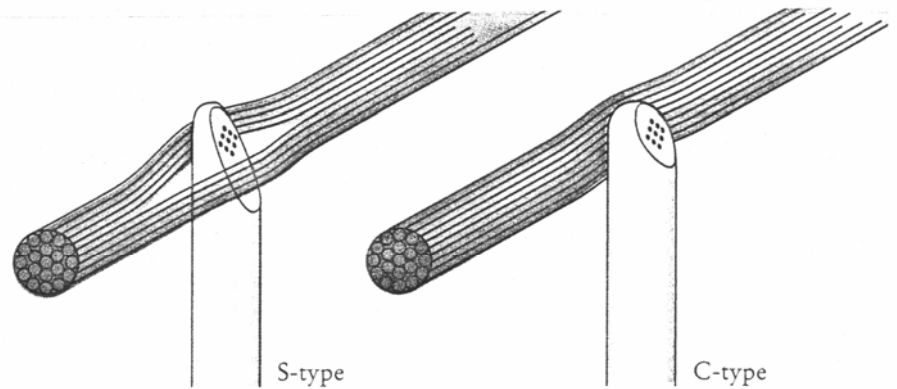


FIGURE 8.10 Multihole (shower) relay nozzle and single hole relay nozzle (courtesy of Te Strake).



For filament warp yarn the C-type shower nozzle avoids splitting of the yarn.

FIGURE 8.11 Relay nozzle tops (courtesy of Te Strake).

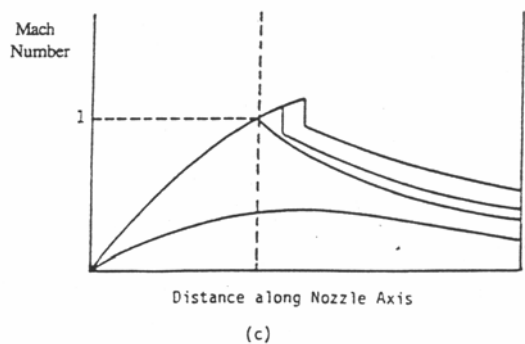
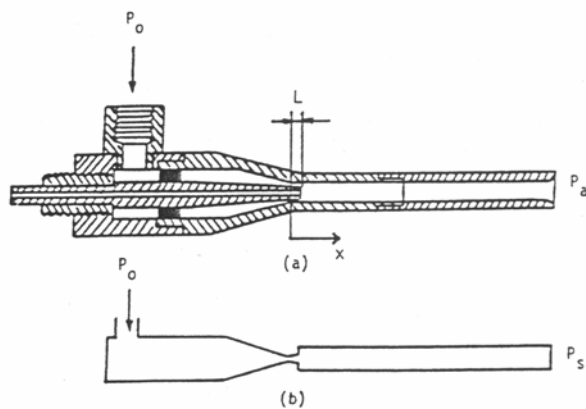


FIGURE 8.15 Schematic of a typical main nozzle used in air-jet weaving machines [25].

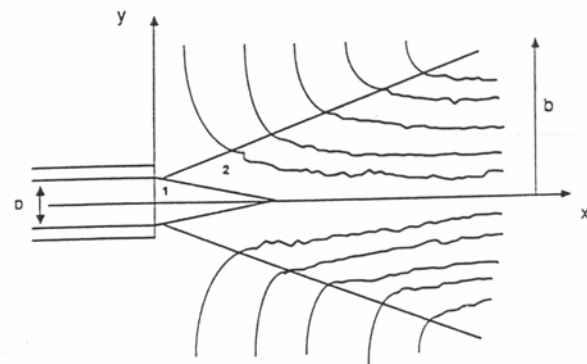


FIGURE 8.18 Free jet.

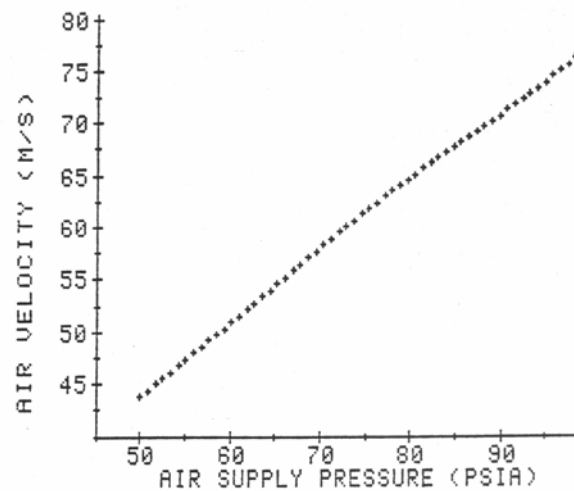


FIGURE 8.17 Effect of air supply pressure on air velocity [15].

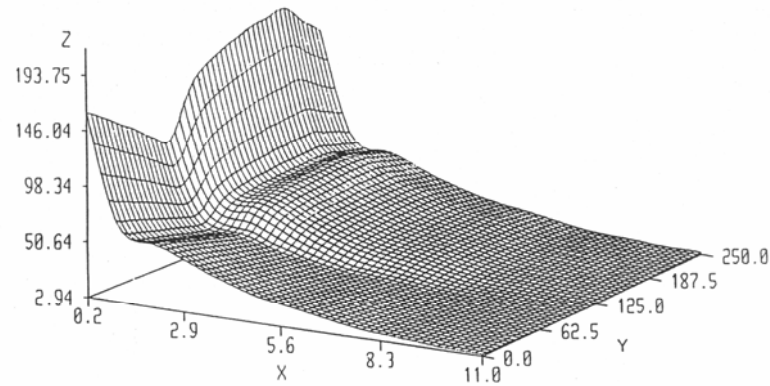


FIGURE 8.19 Air velocity distribution depending on time and distance along the insertion length [16]. X: distance along the insertion length (ft), Y: time (millisecond), Z: air velocity (m/s).

TABLE 8.2 Yarn tension values for drum storage [16].

	Yarn Tension (g)	
	Loop	Drum
Single pick:		
Average	10.898	11.907
At the end of the loop	186.572	
At clamp closing	80.957	48.974
When yarn straightens	115.136	77.636
Average of 40 picks:		
Average	10.396	11.958
At the end of the loop	55.810	
At clamp closing	40.380	42.48
When yarn straightens	46.093	26.513

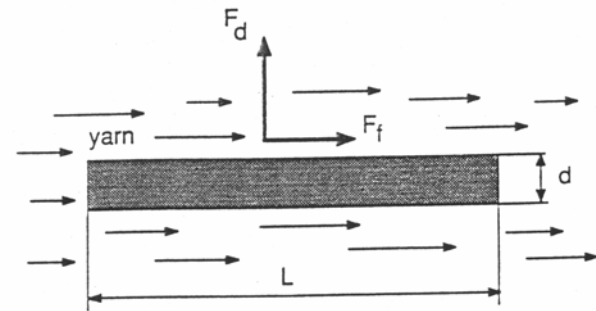


FIGURE 8.22 Forces acting on a moving yarn in air flow [16].

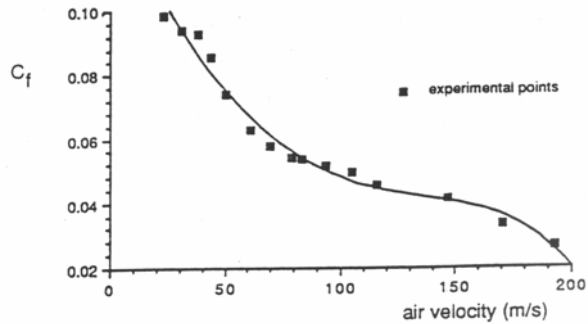


FIGURE 8.24 Air friction coefficient versus air velocity for a two ply ring spun cotton yarn (50/2 Ne) [16].

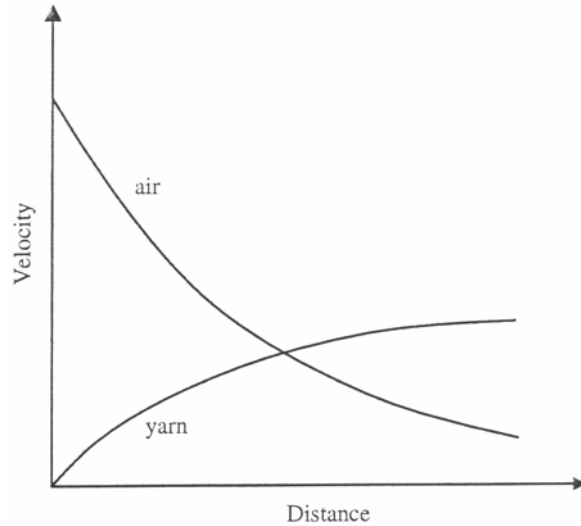


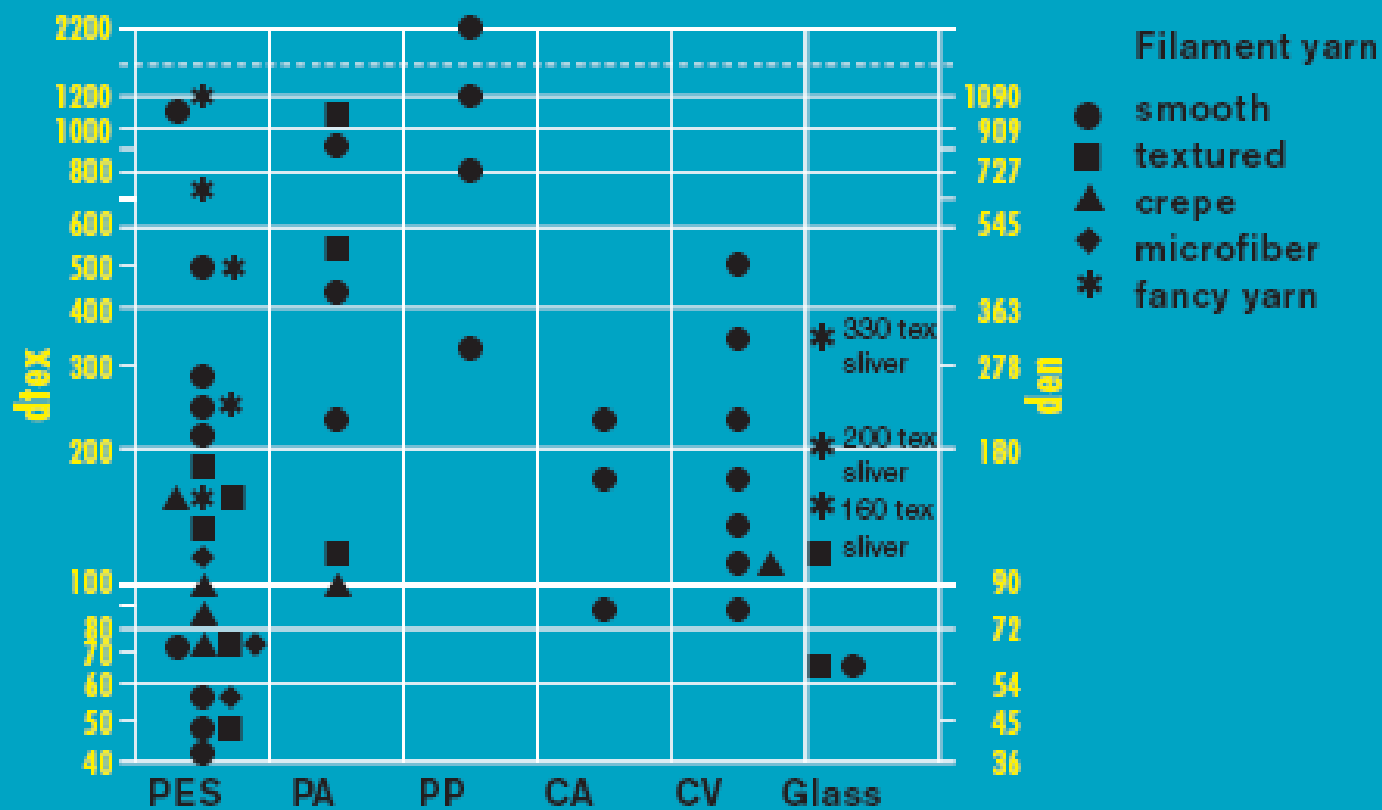
FIGURE 8.25 Air and yarn velocities with single nozzle [1].

TABLE 8.3 Data for air-friction coefficient measurement [16].

Air Velocity (m/s)	Tension (cN)	C_f
23.311	2.214	0.0986
31.145	3.767	0.0939
37.976	5.536	0.0929
43.904	6.815	0.0855
50.128	7.594	0.0739
60.979	9.653	0.0628
70.083	11.734	0.0578
78.821	13.894	0.0541
83.440	15.381	0.0534
93.871	19.904	0.0515
104.821	22.491	0.0495
115.581	24.996	0.0452
147.000	36.953	0.0413
170.490	39.819	0.0331
192.666	40.829	0.0266

Performance of Yarns in Air-jet Weft Insertion

- Air-jet weaving machines are ideal for cost effective production of bulk fabrics with a wide range of styles.
- Air-jet machines can handle both spun (natural, synthetic or blended) yarns and continuous filament yarns.
- Textured yarns are especially suitable, however monofilament yarns are not suitable.
- A wide range of fabrics from gauze fabrics to dense, heavy cotton fabrics, from patterned dress fabric to ribbon fabrics can be woven on air-jet weaving machines .
- The factors that essentially determine whether a yarn is suitable for the air-jet weft insertion are its count, structure and twist.



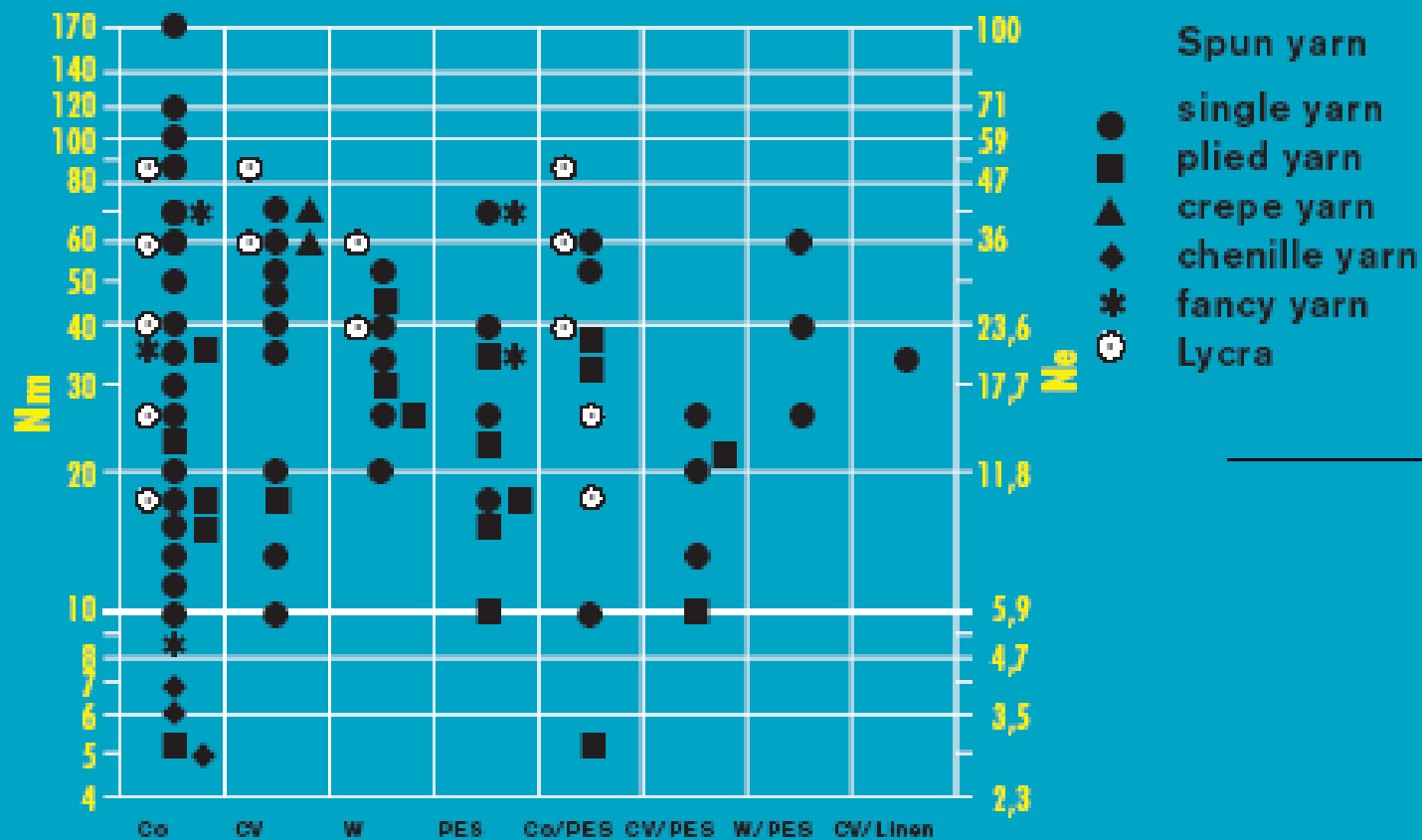


Table 8.4. Acceleration of open end OE and ring spun (RS) yarns 10 milliseconds after the yarn insertion.

Yarn Count (Ne)	Twist Multiple	Structure	Acceleration (m/sq.sec)
10/1	4	RS	968
10/1	4	OE	865
13/1	4	RS	1189
13/1	4	OE	1083
16/1	4	RS	1258
16/1	4	OE	1235

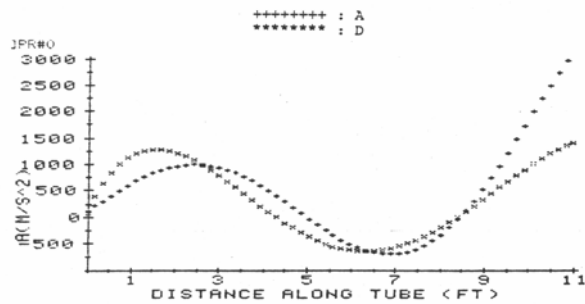


FIGURE 8.28 Acceleration curves of ring spun yarns with smaller difference in linear density [15]. Twist multiple: 4. Yarn A: Ne 10/1, Yarn D: Ne 16/1.

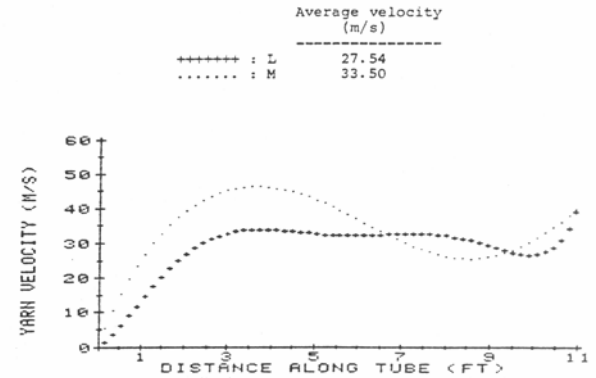
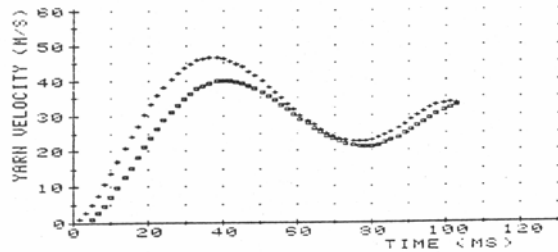


FIGURE 8.29 Velocity distributions of ring spun yarns with large differences in linear density [15]. Twist multiple: 4. Yarn L: Ne 6/1, Yarn M: Ne 50/1.



++++++ : Textured
 ***** : Straight filament

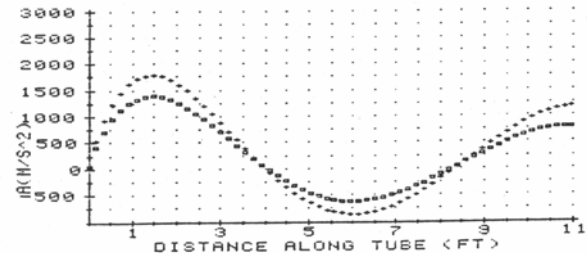


FIGURE 8.30 Yarn velocity and acceleration distributions for textured and straight filament yarns with a single nozzle [15].