The Latest Developments In The Construction Of Paper Machine

Zbigniew Kikiewicz

A well design wet part of paper machine will not only remove water efficiently but will do so without decreasing sheet qualitis. Taking into account above two factors it was given the design of new headbox. High Consistency Former and two presses—"press with wider pressing zone".

The construction of two new devices "the air press and air drainer" is described.

It was found, that during blowing the air through the sack and hand towelling paper their dryness was raised to 45% and 70% respectively.

The effect of the air pressure, and air flow volume for different values of the blow time on the drainage efficience is discussed.

On the basis of the obtained results the paper machine equipped with new air devices is designed.

During the past 15 years a considerable number of new methods for wet forming of paper sheets have been developed.

The driving force behind the new wet forming and pressing methods is the necessity to find wet sections of paper machines that afford :

—lower capital costs
—increased production capacity
—easier control and maintenance
—improved paper quality

The basic principles of the draining mechanism in wet stage have been described and presented on many occasions and in many languages.

Some of the most interesting methods that could be used on production paper machines will be described in this paper.

When the development of different forming methods is considered, it is also necessary to consider corresponding development in the field of paper machine parts.

According to the available information (1) it is possible to draw some conclusion with respect to the partial costs of water removal at different speeds of paper machines. On fig. 1 are shown the

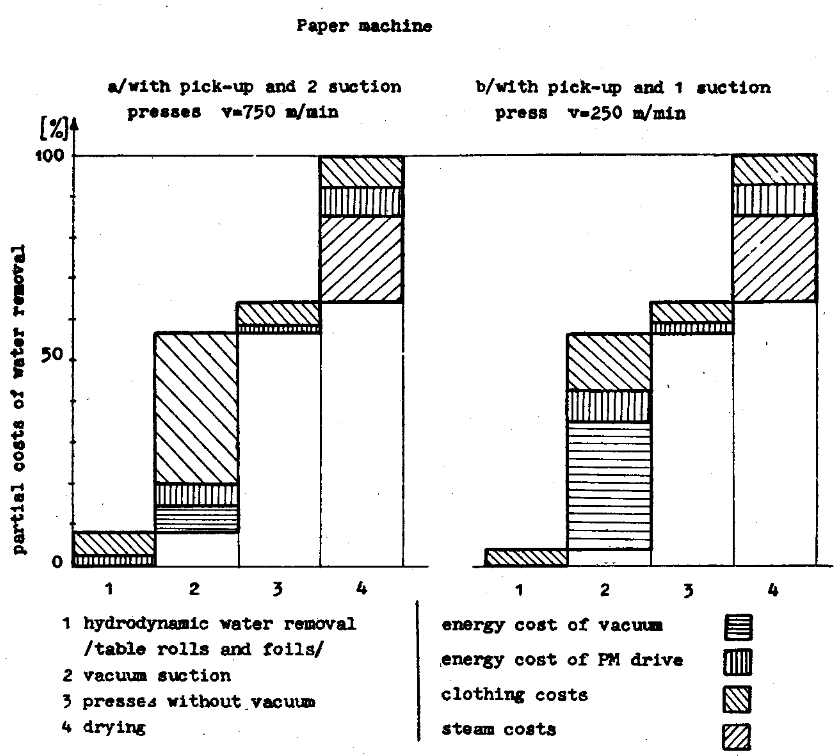

Fig. 1—Partial costs of water removal

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partial costs of water removal on paper machine sections : table rolls and foils, vacuum suction, presses without vacuum and drying. It is evident that independent of the speed the drainage by means of vacuum section there is about 50% of total costs. Moreover the clothing costs take the general part at higher speeds.

The water removal by means of drying process is almost the same at a different speeds.

Based on above fig. 1, it is possible to draw the general conclusion, that the drainage mechanism in wet stage affect in the highest degree the costs of the paper web consolidation. Therefore the new constructions, introduced in wet part of paper machine can give a considerable profits.

High-consistency former

A unique new construction of headbox is High-Consistency Former, which is now being tested under commercial conditions and marketed by A. Ahlstrom Oy of Finland.

The first commercial-scale HCF was operating at Ahlstrom's Kauttua mill at the following parameters :

Stock consistency :	2–3.5%
Flow from slice :	1500–2700 l/min.
Overflow in header :	10%
Pressure loss :	0.8 bar
Slice setting :	3–6 mm
Production capacity :	84 tons/day =32 tons/day per meter width.
Grade :	coating base paper 68–240 g/m²
Wire speed :	100–250 m/min.
Drainage length :	1.5 m

The basic research on HCF has been started five years ago at the Swedish Forest Products Research Laboratory in Stockholm (STFI).

The conception of the HCF headbox tested at STFI during 1974 is very interesting. Figure 2 shows the consistency headbox.

In the HCF headbox the sheet is essentially formed before it leaves the slice. Pulp enters the distributor at 1. It is then fed into cylindrical pipes at 2 through holes of a special design. The last section of these pipes is flattened and flow is spread out across the width of the machine. At the same time the flow is accelerated and at high velocity hits the wall in space 3. In this small volume, there is some lateral mixing of the flows from various holes. Then the pulp is accelerated downwards and hits the bottom plate. The impact causes the formation of small eddies which disperse the fibres. The dispersed suspension then flows into the channel 4 where the continuous net work is formed.

The authors (Dr. Wahren, Bo Norman and Tapio Waris) indicated great possibilities: HCF headbox can be used to form heavy sheets on very simple formers. This could lower the capital costs of new Paper Mills.

This is (80% less water) a tremendous reduction in water use and water recirculation; the white water system is virtually done away with.

Because of good internal bonding of the medium achieved in HCF and due to the excellent pore structure it will be possible to produce in future fine papers, boxboard and corrugatingboard.

The HCF headbox can easily increase the output to 20% of an existing Paper Mills. It seems, above

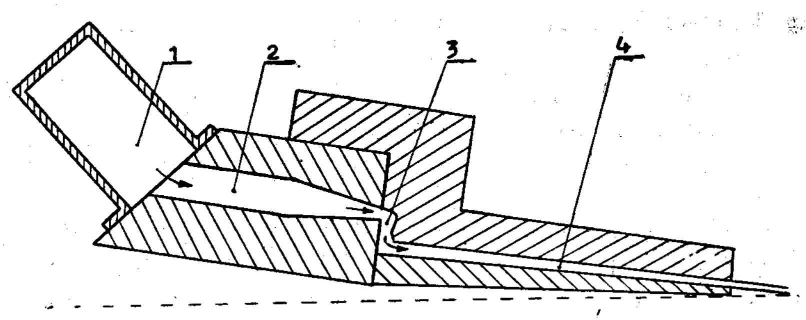

Fig. 2—The high consistency headbox
1-distributor, 2-pipes, 3-space, 4-channel.

described headbox could give in future very big profits in maintenance and construction machines.

Presses with wider pressing zones

According to Wahlstom's theory and available information (3, 4, 5, 6) there are difficulties to increase above 50% the consistency of paper after press section.

It is generally agreed that from the theoretical point of view it is possible to get 70–80% dryness of wet paper at high mechanical pressing (300 kg/cm).

In the fourth pressing zone (3, 4) of various presses in use, such as the plain press, the suction press and the grooved press there are negative phenomenon at which the water flows back from the felt to the paper web (fig 3).

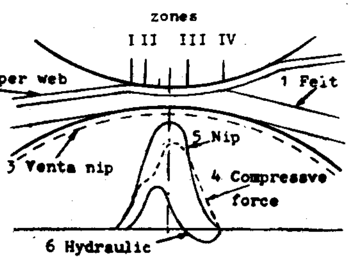

Fig. 3–Press nip pressure distribution
1-felt, 2-paper web, 3-venta nip, 4-compressive force, 5-nip, 6-hydraulic

In order to decrease the influence of this negative phenomenon on the pressing efficience it was designed two types of new presses patented by Beloit No. 3748225 and by West German No. 2338414.

These two presses, shown on fig. 4 and 5 has much more longer pressing zone II and III than zone IV.

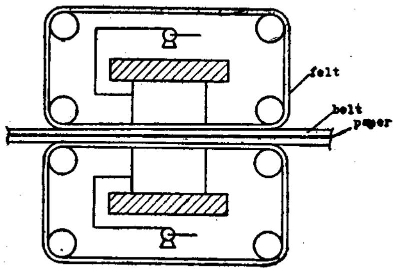

Fig. 4–Press construction with wider pressing zone (pat. USA).

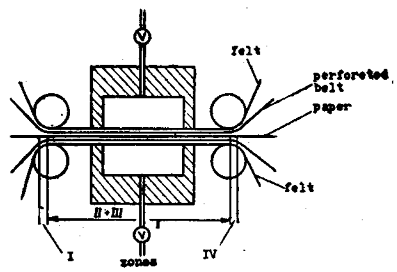

Fig. 5–Press construction with wider pressing zone (pat. German)

According to the German's patent there are perforated belts between felts and paper web, which are made from plastic or acidproof steel. During long time at the II and III zone the water can flow slowly from the paper web through the slots of the belt into the felt.

Because the time in the IV zone is very short the speed of the flowing water from the felt back to the paper will tend to increase. The increasing of the speed is almost proportional to the increasing of resistence of perforated belt. Therefore during short time in the IV zone only a small quantity of water will flow back from the felt to the paper.

Using such press at the width of pressing zone 300 mm and at the increasing of the pressure during pressing time it would be possible to get the paper dryness about 60%.

New method of paper drainage*

According to the laws of filtration, time necessary for a removal of water from pores of a wet sheet, is a function of its compressibility and filtering properties, of physical parameters of air and the difference between pressure values on both sides of the sheet.

If we designate as p_1, p_2—pressure values on top and bottom of the sheet and as p—atmospheric pressure, then there are two possibilities :

1. $p_2 < p_1 = p$
2. $p_2 < p_1 > p$

In the first case (typical for suction box) the available time is not sufficient to force all water out of the sheet pores.

However it becomes theoretically possible in the second case, where the pressure difference is due to a higher air pressure, acting on a given surface of the sheet. Such action may be obtained by establishing on overpressure zone in a chamber over a sheet. This process may be combined with a simultaneous mechanical pressing.*

*This new method was patented and investigated by dr eng. W. Kawka in Poland.

For some kinds of paper/absorbing papers, filtering boards the main object of the manufacturing process is to get and maintain high porosity of the sheet, with its strength properties being of somewhat less importance.

All this considerations made Dr. Kawaka to start the investigation on the sheet drainage by the air blowing method. A pilot device shown on the fig. 6, called an air press, has been designed and constructed.

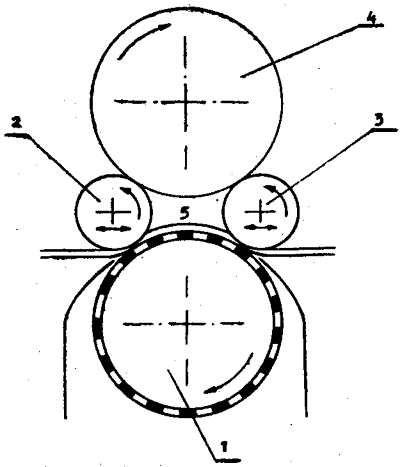

Fig. 6–Air press
1–wire cylinder 2, 3, 4–rolls, 5–chamber.

The unit operates by creating a closed pressure area between four rolls.

The bottom roll is covered by a base wire and a phoshore – bronze wire No. 24. The other rolls are of steel with rubber cover, of 20° PI hardness.

Driven two rolls, 350 mm in diameter are carried in antifriction bearings, mounted in the device frame. Two other rolls are 180mm diameter and are able to control their load.

During our experiments wet paper sheets of 0.4 width x 3 m length approx were run through air pressure between rolls 10 kg/cm, air pressure in chamber form 0 to 3.0 at and blow time from 0.2s to 1.2s at, each passage of the sheet.

There are treated the fibrous for next papers :

—sack paper, 70 g/m²
—filtering paper. 65 g/m²
—hand towelling 29 g/m²

The results of draining sack paper shows fig. 7.

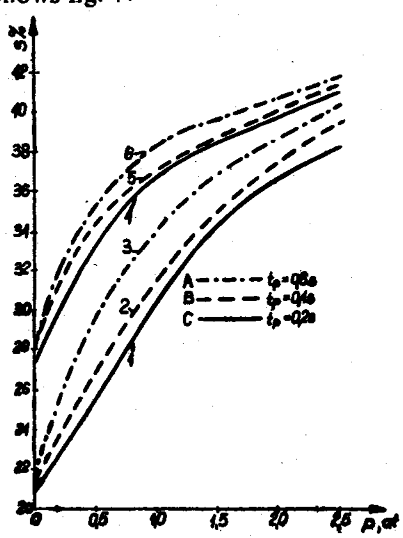

Fig. 7–Relation between the sheet final dryness (s) and air pressure (p) for different values of the blow time (t) and the sheet original dryness (s) sack paper of 70 g/m² basis weight.

As can be seen form the graphs, air blowing through the sack paper results in a considerable increase of its dryness, amounting from 11% to 20%, depending on the sheet's original dryness, blow time and air pressure in the chamber. To get such curves on the paper machine at the speed 500 m/min. producing sack paper it would be necessary to provide an air press with a wire covered cylinder of 1600–1800 mm diameter.

Such an air press has thus the same drainage capacity as three plain presses.

The second unit to be developed was the cylinder, air drainer, shown on figure 8. To get better efficiency than at the air press, it was decided to introduce dynamic action of the blow air on the water particles in the sheet. It was necessary to increase considerably the speed of the air flowing through sheet. Pressure chamber with air gaps, replaced the former design, consisting of three rolls.

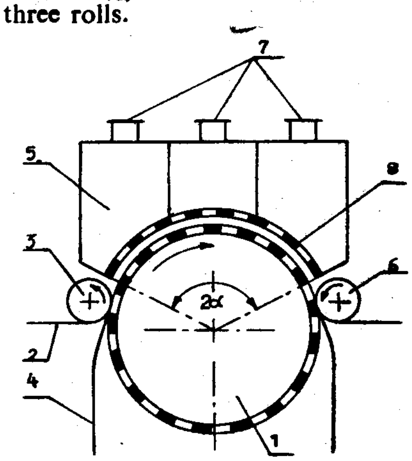

Fig. 8–Cylinder air drainer
1–wire cylinder, 2–porous belt, 3,6–transfer rolls, 4–cylinder walls, 5–blow chamber (box) 7–air connector, 8–chamber bottom

The pressure chamber, made of steel sheets, was divided into three compartments, to which air was supplied through pipe connectors. The chamber bottom made of accurately machined flat steel bars, was mounted in such a way, as to enable control of gaps between them from 0 to 1.0 mm. Total area of the gaps constituted 3 to 10% of the whole area of the sheet in the blowing zone.

Velocity of the air, outflowing from gaps in the bottom of pressure chamber (at 50 to 350 mm Hg air pressure) was from approx. 30 to 80 m/s.

During the experiment, a wet sheet of paper (of 0.4 m width x 3 m length approx.) together with a permeable belt were transported by means of rolls. Air outflowing from the pressure chamber was forced through the sheet and wire into the cylinder, from which it could freely escape with water into the atmosphere.

A sheet of 70 g/m² sack paper, at 36 to 38% dryness and sheet of 29 g/m² hand towelling at 36 to 38% dryness were run through the air drainer. Air was blown onto the sheet, through 0.4 mm gaps in the pressure chamber bottom, and at a distance of about 2 mm from the sheet.

Cold air at 20°C was used in this experiment. Final dryness figures, at various values of blow time (t) and chamber (p) are shown on the figures 9 and 10. As can be seen from the curves, final max. dryness for the hand towelling—exceeds 70% respectively.

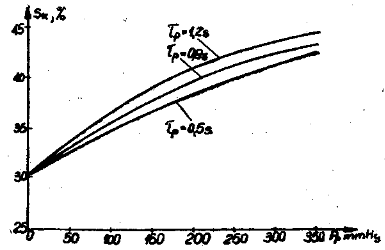

Fig. 9–Effect of the air pressure and blow time (t_p) on the final dryness of 70 g sack paper drained in a cylinder drainer. Original dryness—30–32% and air temperature 20°.

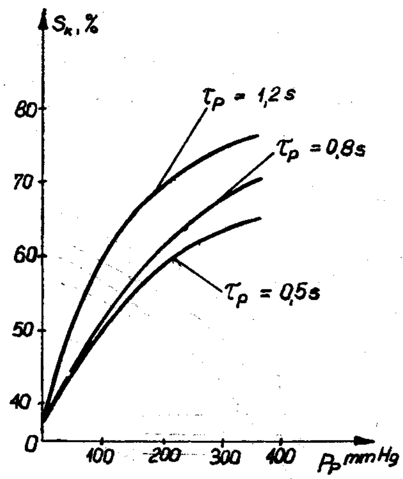

Fig. 10–Effect of the pressure (p) and blow time (t) on the final dryness (s) of 29 g/m² hand towelling, treated in a cylinder air drainer original dryness (s) 36–38%.

Intensity of the process and the air load depend to a large extent on the quantity of air forced through the sheet.

Next figure 11 represents : drainage intensity in kg of water removed from a hand towelling sheet in one hour per 1 m width and 1 m/s sheet velocity, as well as air drainage load in kg of water removed from the sheet in one hour per 1 m² of blow area, for different values of the air consumed (in m³/m².s) by the air drainer.

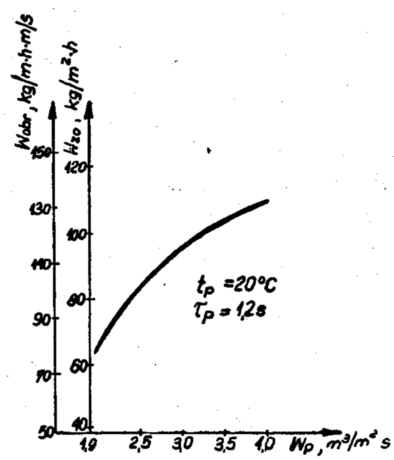

Fig. 11–Effect of the air volume flow rate (w_p) on the drainage efficience (w_o) and the air drainer load (w_z). Hand towelling of 29 g/m²; 36 to 36% original dryness.

Next figure 12 gives respective values for drainage of a sack paper sheet.

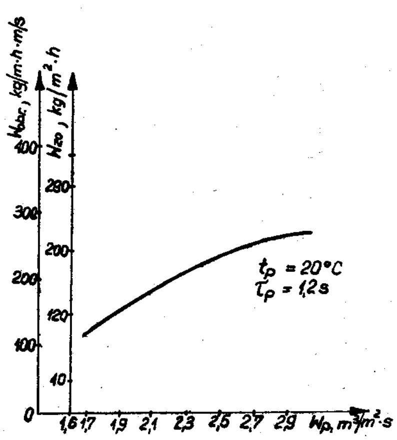

Fig. 12–Effect of the air flow volume (w_p) on the drainage efficiency (w_o) and air drainer load (w_z) for the 70 g/m² sack paper at 30–32% origional dryness.

As can be seen in next figure 13, the air consumption is proportional, or nearly proportional to air pressure in the blow chamber of an air drainer, when draining hand towelling (curve 1) or sack paper (curve 2).

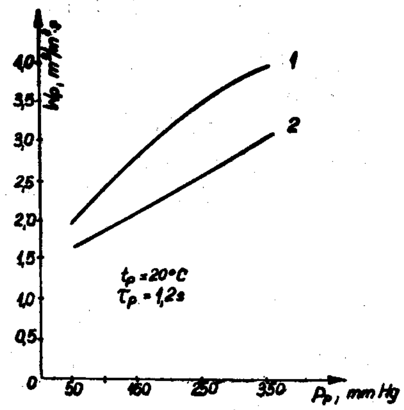

Fig. 13–Effect of the pressure (p_p) in the air chamber of an air drying station on the air consumption (w_p) in $m^3/m^2.s$.

1–hand towelling of 29 g/m^2. and 36–38% original dryness, 2-sack paper of 70 g/m^2 and 30–32% original dryness.

Next figure (14) shows air consumption, per 1% of dryness increase, for the hand towelling.

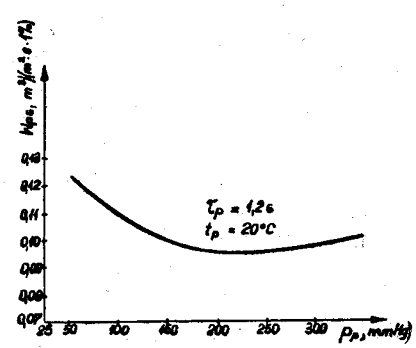

Fig. 14–Air consumption for 1% dryness increase of hand towelling for various values of air pressure (p_p).

Optimal air pressure p_p was found to be about 200 mm Hg for the towelling, when temperature was 20°C.

Air consumption figures for draining sack paper were in this case slightly lower.

It was found, that besides its design features, such as size of the blow gaps, their total area and distance from the sheet—the air pressure (p_p) in the blow chamber and blow time (t_p) have the greatest effect of the drainage efficiency. This finding is similar to that for the air press.

Paper drained with the air press or air drainer, when compared with the conventional draining and drying methods. shows improvement in the following fundamental physical properties :

specific volume
water absorption
air permeability
filtering ability
stretch

with slightly inferior static strength properties.

In order to determine the effect of the air blow method on the paper physical properties:—some of them were compared with similar properties of samples paper taken from a paper machine. Samples of paper were taken from that part of the machine (press section of dryer section), where the dryness would be comparable with that, obtained on the air press or air drainer. Then, both samples from the paper machine and air press or air drainer, were dried to about 94% in identical conditions.

Sack paper, drained by the air blow method, inferior by 15–20% breaking length and a stretch improved by about 15–25%, so the average products: of breaking load and breaking elongation were, for both samples similar. Air permeability was 2 to 3 times better. For the hand towelling specific volume was up by 25%, water absorption was up by about 50% and air permeability up—by more than two times. For serviette tissue—specific volume was 100% up and water absorbency—50% up.

The filtering ability of filter paper was up by about 30%.

For cellulose wadding—specific volume was 35-50% up and water taking up 20–30%.

A sulphite pulp drained on the air press did not change its freeness nor its beatability.

Taking into account the effect of the blow method on the paper and pulp properties, high efficiency of this method for the porous paper and the fact that the cost of creating the required pressure difference is considerably lower for the over pressure method; when compared with the vacuum method, we can assume, that this method is suitable for draining :

—porous paper. such as sanitary papers, absorption paper and particularly fine and thick filter papers. the main object in producing these papers being their high porosity with their strength properties being of less importance.

—chemical and mechanical pulp—on thickeners, as well as on wire and press parts of pulp drying machines.

Use of the blow method for other kinds of papers, as for example for sack and printing papers could be perhaps possible with simultaneous addition of appropriate chemicals, to raise filler retention in the sheet, and/or its strength.

By this way, we can expect to get a sack paper of higher air permeability and higher stretch, or a printing paper of improved printability (due to increased: specific volume, capacity and more uniform structure) with no reduction of their strength properties.

Other advantages of this method are easy control and full automaon possibility.

On the other hand, high air consumption is a disadvantage, although we must stress that the cost of compressed air required in this method is considerable lower, than the cost of steam, necessary to dry the paper.

The air blow method is particularly suitable and economic for the production of filter paper. A proposed machine arrangement for the production of such paper is shown on figure 15. Wire width of such machine would be about 3 meters and operating speed up to 300 m/min.

Paper machines producing filter papers, now in operation, have wire width below 2 meters and run at 50 to 100 m/min.

Due to low stock consistency in the headbox, and high amounts of water to be removed, the wire section should be of special design, with the wire running up, as in the case of such machine as : Hydroformer "No—Wo—Former" or "Delta Former". Characteristic feature of such a machine is, first of all, the fact that the sheet formation area is within machine beabox. Specific process of stock moulding and selective filtration takes place here. Suction boxes (2) are placed under the wire (1). Above the first box (operating with very low pressure difference), a loose tangle of long fibres is formed, because, in the process of selective filtration the long fibres first make contact with the wire.

Short fibres take place more or less vertical position (in relation to the wire surface) and are held in this position by the tangle of long fibres, settled on the wire. Three—dimensional fibre orientation is thus created. We can control all these phenomena, by varying vacuum in the subsequent suction boxes, which must have high volumes and large outflowing pipes, due to the high amounts of water, which is to be removed.

Formation is practically finished when the wire leaves the fibre suspension. The sheet is then run through an air blow unit, consisting of pressure chamber, operating at 0 05 to 0.1 atm. pressure and located on top of the wire, and through a suction box, located under the wire. A suction pick-up takes the sheet ofl the wire to an air press felt. The wire inclination should in general, be adjustable, to suit various furnishes. The double felts (4 and 6) air press provides

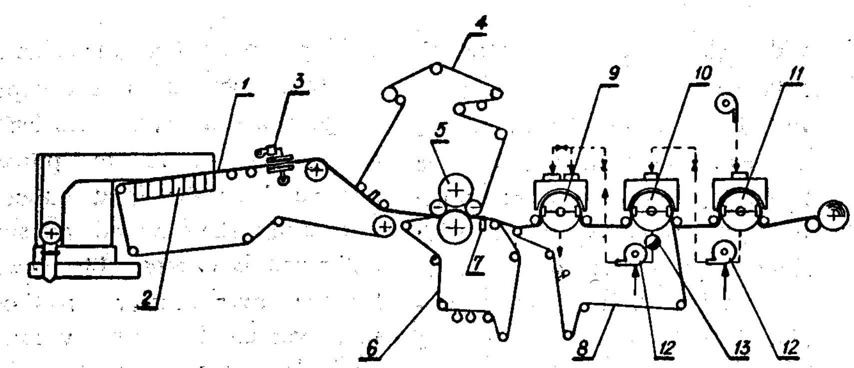

Fig. 15–Paper machine for the production of filter paper and boards.

1–wire, 2–wet suction boxes, 3–air blowing unit, 4, 6–porous belts, 5–air press, 7–suction box, 8–felt wire, 9, 10, 11–air drying stations, 12–air blowers, 13–water separator.

sufficiently wide pressing areas, to prevent excessive reduction of the sheet specific volume. The nip pressure of the lateral roles against the wire cylinder should be 10 to 20 kg/cm. Air heated to a temperature 70°C, can be used. Air pressure in the pressure chamber should be :

0.3 to 0.8 atm for draining thin papers.
0.5 to 1.5 atm for draining cardboards.

From Dr. Kawka's observations it was evident, that water removal in the air press is mainly due to mechanical displacement of water (amount of evaporated is relatively low), and the total volume of water removed is almost proportional to the air flow.

Felts, as thin as possible, should have high air permeability, which must be maintained on a high level throughout their working life; hence they must be conditioned effectively. The wire cylinder may by replaced by a drilled or honeycomb suction roll, equipped with a suction box, to increase efficiency of the air press. The sheet, at 45 to 55% dryness, held on the bottom felt (6) by means of a suction box (7), is then transferred to the drying wire (8), which carries it through two air stations (similar to air drainers already described). A third "unfelted" drying station should be used only for cardboard production. On machines, producing thin sanitary papers, the last station can be replaced by a drying cylinder (1500 mm in diameter) heated by steam or electric heaters, and used with a creping doctor.

Dryness of the sheet, entering the last drying station, would be relatively high. As, in this case, the water removal will be mainly dne to its evaporation and not mechanical effects' a dry, high temperature compressed air (180–350°C) is to be used. Air pressure in the air chamber can be from 0.1 to 0.2 atm, because the sheet at this stage is already sufficiently porous. To increase efficiency, open-work suction rolls may be used, as drying cylinders (9, 10 and 11).

Air circulation is shown in this figure (14) by a broken line. The air system comprises air blowers (12) and a water separator (13). The air blowers are to bring-in fresh air so that the temperature in the first and second drying stations be respectively 90°C and 120°C at 0.3 to 0.1 atm pressure. at 0.3 to 0.1 atm pressure.

The last cylinder drying station could also be replaced by a Papridryer. This unit operates at a very high air temperature (350°C approx.), and is very efficient. The air blowing devices may be installed in paper machines in different places and configurations, depending on the kind of paper to be produced. They are easy to control and suitable for full automation.

Figure 16 shows a paper machine to produce some kinds of board papers and thick filter paper utilizing high consistency former and new air blowing devices. After forming the sheet at the consistency in the range 2–4% there are suction boxes. Initial dewatering occurs under the influence of a slight vacuum. Drainage then

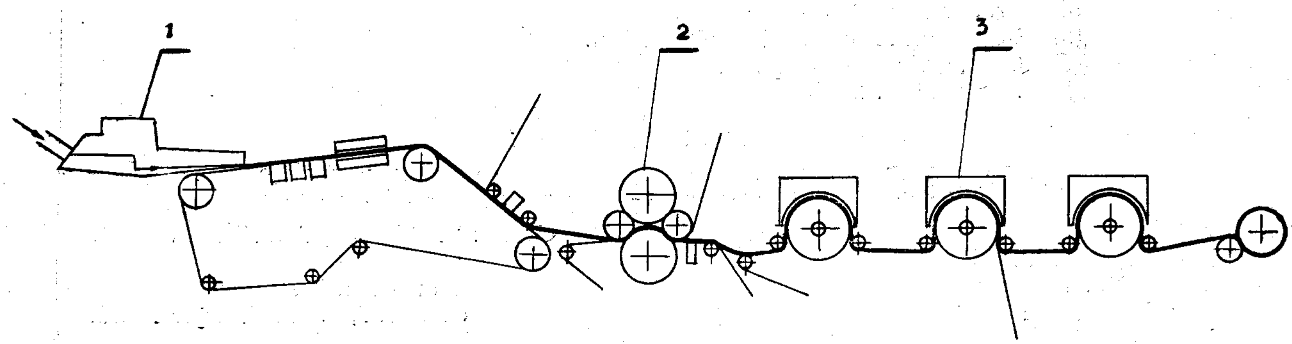

Fig. 16–1. high consistency former, 2, air press, 3, cylinder air drainer

take place on the air drainage devices.

In such way sheet formation and drainage take place over an extremely short distance, there is minimum space requirement for paper machine.

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