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Part 2

THE APPLICATION OF PRESS-DRYING TO PAPER-MAKING

Interest in the application of press-drying to paper-making has arisen primarily because of the possible improvements to the physical properties of paper using high yield pulp furnishes and increasing amounts of hardwood fibres. A major proportion of the development work on press-drying has centred around the production of heavy paper grades, specifically liner-board.

The need for the increased use of hardwood in the pulp and paper industry has been recognised for a long time. At the present time, only 42% of the forested land in the United States is occupied by softwood timber which in turn supplies wood for 75% of the forest products. On the other hand, the lesser used hardwood species occupy 55% of the forested land area, but supply wood for only 25% of the forest products[41]. Satellite photography land surveys have shown that when softwood forests are cut, the tendency is for the land to grow back with hardwood species rather than the original softwood species. As a result, the amount of forested land being occupied by hardwood species trees has been increasing each year. The lesser demand for hardwood has resulted in a price differential where hardwoods are now $10-20 U.S. per cord cheaper than softwoods.

The current per capita use of paper products in the United States is approximately 272 Kilograms per year which translates to an industrial demand equivalent of 80,000,000 cords of wood for pulp and paper per year. The largest single product within this demand for pulp is the liner-board and corrugating medium used in the manufacture of corrugated boxes. The corrugated box industry presently uses 12.5% of all the wood cut in the United States[41]. The high demand for liner-board along with the low use of hardwood in liner-board pulp furnishes has made this single product the primary target for the application of the press-drying process. That hardwood pulps respond favourably to press-drying techniques by showing improvements in the strength properties of the end product, has been clearly demonstrated[20,30,31,42]. Softwood pulps also respond to press drying, but to a lesser degree. Present paper machine layout has demonstrated some related press-drying process characteristics for special applications; for example, recent work has been done in relocating a breaker stack closer to the wet end of a dryer section to compact the web and obtain higher Mullen strength. This type of breaker stack application has been successfully applied to liner-board and newsprint machines to produce products with increased Mullen strength. Present day dryer section design calls for approximately 2.63 KN/m dryer felt roll tensions resulting in normal pressures of about 3.4 KPa on a 1.52m diameter dryer drum. This low normal pressure, or z-direction, restraint is not sufficient for the densification of the web during drying. The fundamental approach of applying z-direction compaction and restraint during the drying of high yield, hardwood webs has been demonstrated in experimental devices but has not been fully commercialised at this time.

The pulping process has also proved to be of importance in bringing out the best response to press-drying in producing high strength paper and paper-board. The Kraft process for hardwood and softwood has been shown to be capable of producing pulps at 65% yield that respond well to press-drying. High yield chemically modified TMP pulps in which the glass transition point of the modified lignin fraction has been lowered without significantly removing the hemicellulose fraction also respond very well to the press-drying process. TMP process pulps which normally produce relatively low strength paper can be effectively press-dried to increase the physical strength of the paper-board, however, not sufficiently to meet standard liner-board specifications in the U.S.

High freeness pulps at 600-700 CSF have also been effectively press-dried to produce acceptable liner-board. In this case, pulp refining need only be a defiberising operation and not a fibre fibrillation action in order to obtain the necessary strength properties in the end product. The reduction in the amount of pulp refining needed to obtain a furnish that can produce a desired end product may further add to the economic advantages of the press-drying process.

Machine Variables

The effect of machine speed on the press-drying process is the most prominent of the machine variables and much more work will have to be done in this area to understand and optimise fully the press-drying process. As machine speed increases, the dwell time of the wet web in the pressure zone in any single dryer unit decreases with the result that less web compaction and less drying takes place. Thus, in order to achieve a desired web dryness in a press-drying section at high speed, more press-drying units must be added to the section. These additional nips are activated as machine speed increases resulting in a greater number of nips being applied to the web at shorter time intervals with the effect that the springback of the fibres in the web (which is a function of web temperature and time) is overcome and increased compaction of the web is achieved[7,43].

Applied Process Variables

Press-drying is most effective when the moisture content of the web is between 50% and 20%. If the moisture content of the wet web entering the press-drying section is above 50%, an effect comparable to sheet crushing in a wet press can occur. Predrying the wet web with a standard dryer section to bring the sheet down to a 50% moisture content before entering the press-drying section would avoid this problem and at the same time preheat the web. The process can be continued below 20% moisture content, but, although beneficial, it becomes uneconomical from a capital investment standpoint. In a commercial application, the drying of the sheet after the press-drying section would be accomplished using standard dryers.

Initial nip pressures on the order of 4000 KPa may be needed to compress the web, although a normal pressure of only 14-34 KPa may be required to hold the web in the compressed state during the drying cycle(43). A wire or a dryer fabric can be used to induce the desired 14-34 KPa normal pressure against the dryer drum but the design limitations of a wire (particularly of its seam) can be exceeded if the diameter of the dryer drum is too large.

The Development of Press Drying Equipment

Static press-drying can be done easily in the laboratory with the equipment shown in Figure 13.

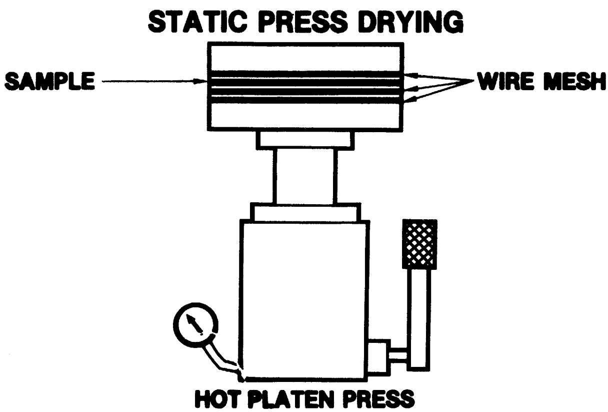


Fig 13

With this apparatus, a handsheet is placed between stainless steel wire mesh screens with four or five screens in the bottom position, and one on top thereby creating a sandwich which allows the escape of water vapour without the destruction of the web.

The platens are heated to between 15° and 400°C while different pressures are applied to the handsheet. With this system, it is possible to study the effects of press-drying on a wide variety of different pulps.

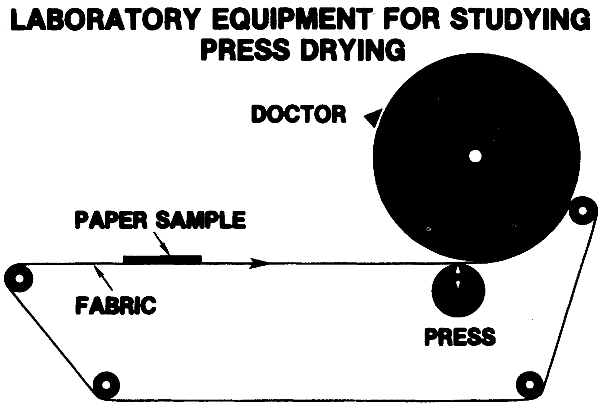


Fig 14

The transition from a static press-drying experiment to a system for the dynamic press-drying of paper presents a challenge in design. Figure 14 shows a dynamic press drying machine used in a laboratory for handsheet evaluation[45]. The machine is a low speed unit with a steam heated drying drum that has been chrome-plated to prevent fibre sticking to its surface. A fine mesh dryer fabric is used to provide a normal or z-direction force against the web as it is held in contact with the dryer drum. The handsheet is retrieved by hand after each pass and reversed for subsequent passes to give a two sided drying effect.

An off-line pilot plant press-drying system which can be used to study the effects of dynamic press-drying on a continuous web is shown in figure 15. In this system, a roll of wet paper is fed into the nip between the pressure roll and the dryer drum. A tensioned dryer fabric is used to hold the sheet against the dryer drum during the drying cycle. A take-up reel rewinds the web after each pass through the system. Handsheets can also be fed to this machine in a similar manner as with the machine shown in figure 14.

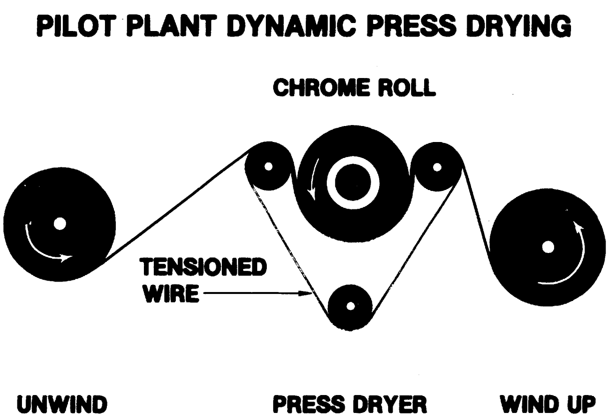


Fig 15

The pilot plant in figure 16 shows the adaptation of a press drying unit to the U.S. Forest Products Laboratory experimental paper machine in Madison, Wisconsin. The machine is a 300mm wide machine and is capable of operating at speeds of 0.3 to 3 mpm. In this installation, the wet web is taken from the third wet press of the paper machine directly into the press-drying unit. The sheet is sandwiched between two metal wires in a Uni-run type configuration. The web is passed around each of the dryer drums which in turn are each held in contact with the adjoining drums. The contact between the drums creates nips capable of producing a caliper reduction of the web while maintaining a z-direction restraint without relocation during the entire press-drying cycle. Heat transfer in this system is accomplished by hot air impinging upon the wires and the wires in turn passing the heat onto the web by conduction. Steam is also applied internally to the five dryer drums.

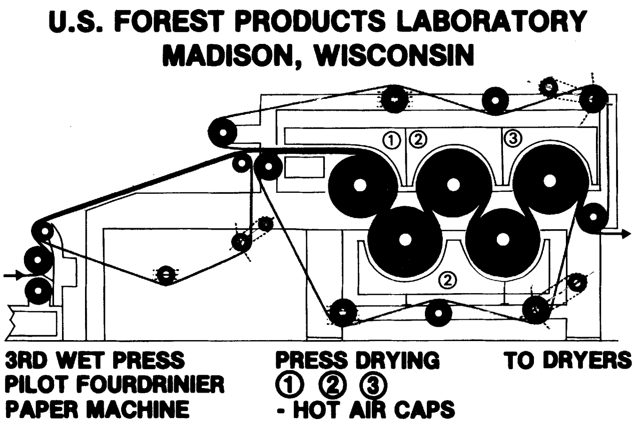


Fig 16

The pilot plant installation on the experimental board machine at the St. Anne's Board Mill in Bristol, England is shown in figure 17. This press-drying unit has been primarily used in the development of dry-formed paper-board. In the St. Anne's system, the wet web, containing starch, is pressed against a large machine glaze dryer which contains a number of press rolls behind the dryer fabric for the compaction of the web against the dryer surface. Bonding of the web takes place as the web is dried and the starch sticks the fibres together.

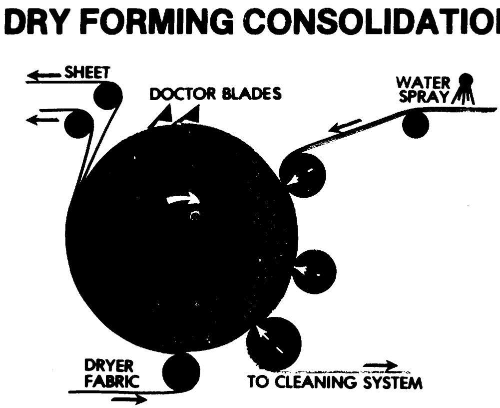


Fig 17

The Transition from Static to Dynamic Press-Drying

When the transition from a static to a dynamic press-drying system is made a number of problems becomes evident. The moisture content of the web entering a dynamic press-drying system should be in the neighbourhood of 50% with the sheet already hot so as to allow the easy release of water while it is still in its liquid phase. The pressure nip of a dynamic press-drying unit tends to cause puddling at low speed with the sheet crushing as the speed of the machine is increased. The use of a belt such as a wire mesh belt or a dryer fabric in the nip of the press-drying unit allows water to be absorbed by the felt in a manner similar to that of the felt in the wet press section of a paper machine.

The running of a metal wire mesh through a press nip can cause many problems in operation as machine speed is increased. It is extremely difficult to maintain the dimensional stability of a wire especially when the press dryer is run without paper in the nip, which occurs quite frequently. In the resulting distortion of the wire, the edges of the wire get `baggy' and wrinkles develop which eventually result in the need to discard the wire. Additional problems arise with wire mesh belts in the area of the seam. Stainless steel wires are difficult to seam while phosphor bronze wires tend to stretch and have a seam which is not strong enough to withstand the high tensions involved in the press-drying process. On the other hand, synthetic dryer fabrics can be made to withstand the high tensions of press drying while remaining deformable in the nip. Synthetic dryer fabrics can be fabricated with a pin seam making for easier installation and replacement on the machine and which will not mark the paper sheet. Synthetic dryer fabrics however, elongate under high temperatures and tensions and additional fabric stretch accommodation is required in the machine design.

The initial experiments with dynamic press-drying yielded results in which the physical strength of the sheet was only about 60% of that obtained in static press-drying experiments. These results were obtained at slow speeds on experimental press-drying units, however, and it was later found that speeding up the machine improved the results considerably, even though the density of the sample handsheets remained quite similar. Examination under a Scanning Electron Microscope of the sheets dried at very low speed revealed a degree of internal delamination causing fibre separation and resulting in degradation of the physical properties. This is attributed to the very high heat transfer rates possible with the press-drying process. At low speed, an excessive amount of heat is transferred to the water in the wet sheet which vaporises and builds up internal pressure in the sheet. When this internal pressure exceeds the z-direction restraint, the sheet tends to blow apart and delamination occurs. To prevent this the rate of drying can be controlled to allow bonding to take place.

Fig 18

The wire mesh size itself can be a variable in the static press-drying of paper-board. The knuckles of the wire compact the web more than the area around a wire knuckle. This is shown in the figure 18 cross section photomicrograph of liner-board where the indentation of the upper surface by a wire knuckle has compacted the fibres beyond recognition into one solid mass. This `spot bonding´ effect of static press-drying is not seen in dynamic press-drying where the web is subjected to a change in wire pattern at each succeeding nip resulting in a more uniformly compacted web.

The Application of Press-Drying To Different Paper Grades

	Standard TAPPI Drying	Static Press-Drying	Dynamic Press-Drying	Commercial Liner-board MD/CD
Basis wt. g/m^2	217	214	208	203
Caliper μm	361	264	206	310
Tensile KN/m	10	13	12	16/7
Stretch %	4.7	2.6	6.1	2.6/4.0
TEA J/m^2	35	24	47	24/19
Elastic Modulus GPa	4.19	4.50	2.28	3.58/1.62
Mullen KPa	848	875	1048	738
Ring Crush N/m	3070	4320	30040	2770/1960

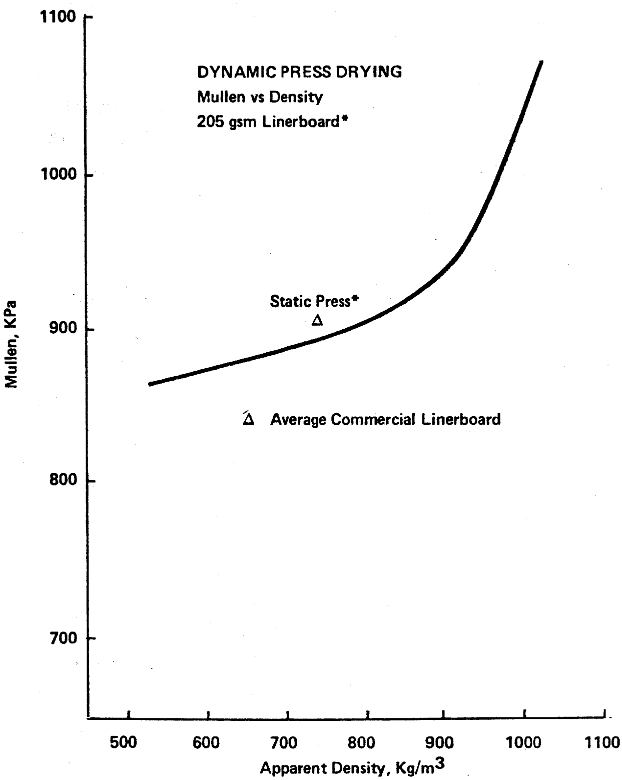
Pulp Furnish	Freeness	Yield
Hardwood - 60%	600 CSF	66%
Softwood - 40%	515 CSF	67%
Combined	580 CSF	

	Dynamic Press Drying Conditions	Static Press Drying Conditions
Equipment Used ---	See Figure 15	See Figure 13
Nip Pressure ---	175 KN/m	22068 KPa
Dryer Temperature --	160°C	160°C
Dryer Fabric Tension	4.4 KN/m	
Speed	0.46 m/sec.	
Avg. No. of Passes --	8	Time - 30 sec

The commercial liner-board was composed of 10% hardwood and 90% softwood

Table 2

Comparison between the Physical Properties of Handsheets and Commercial Liner-board



*Pulp Furnish	Static Press Drying Conditions
55% Mixed Hardwcods at 66% Yield	Pressure – 2068 KPa
45% Southern Pine at 66% Yield	Temperature – 160°C
Combined Freeness 650 CSF	Time – 30 sec.

Dynamic Press Drying Conditions varied by changing Nip Pressure, Dryer Fabric Tension and Number of Passes. Dryer temperature held at 160°C. Initial Moisture Content at 50%.

Fig 19

Table 2 compares the physical properties of liner-board samples dried under both static and dynamic press-drying conditions with commercially produced liner-board. The effect on the physical properties of the very high density of 1000 Kg/m^3 for the dynamic press-dried sample is illustrated. The high stretch shown by the dynamic press-dried handsheet is reflected in the high TEA and Mullen strength and is believed to be due to free shrinkage in the handsheet as it is repeatedly reversed and fed into the nip. This would account for the lower elastic modulus also. When the web is fully restrained in the x, y and z directions with the equipment shown in figure 16, a high stretch and high elastic modulus can be obtained. The curve shown in figure 19 shows how the Mullen strength of dynamically press-dried liner-board increases with increased sheet density in relation to static press-dried and commercial liner-board.

Static press-drying experiments on bleached, light-weight papers produced a surprising result in that the initial sheet samples appeared to have a more uniform visual `look through´ formation. Figure 20 shows two handsheets which were prepared in precisely the same manner, however, with one sample being dried with the standard TAPPI drying method, and the second with a static press-drying system. In this comparison, the static press-dried sheet presented a visibly better appearance which was one of a uniform formation[46]. Close examination revealed that the surface had been embossed by the wire meshes used in the static press-drying system as shown in figure 21. The surface embossing of the sheet with a 200 mesh/inch wire screen produces the effect of scattering surface light thereby giving the illusion of a good, uniform sheet formation. This same effect was quoted by H. Corte[47] in his paper presented to this symposium in 1973. In attempting to reproduce this phenomenon, it was found that 100 mesh/inch wire did not change the appearance of the sheet, nor did 150 mesh/inch wire, however, a 200 mesh/inch wire did provide the proper embossing needed to give the effect of improved formation. The use of this phenomenon in an industrial application is unknown at this time.

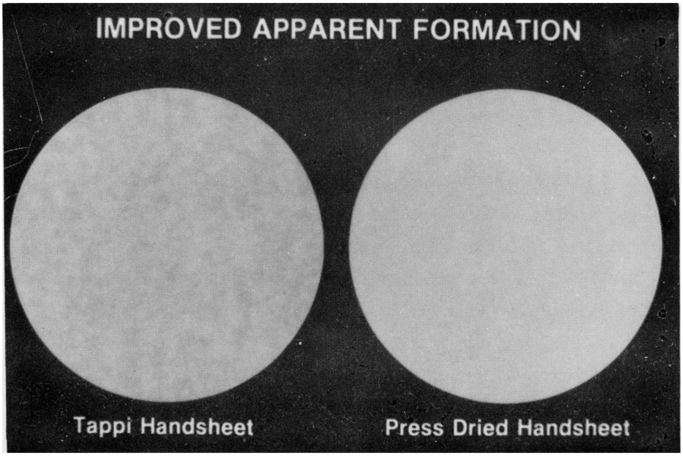


Fig 20

Table 3 shows the physical properties of 100% Aspen pulp with TAPPI standard handsheets made from the 700 CSF pulp. The press-dried handsheets were statically pressed in an apparatus similar to that shown in figure 13 and pressed at 150°C platen temperature using 200 mesh/inch stainless steel wires. The physical properties are significantly changed in the press-dried samples.

The commercial application of press-drying to making corrugating medium would appear at first to be a good idea. However, since most corrugating medium already contains 100% hardwood no wood price savings can be realised for this grade. A high-yield kraft cooking process could be utilised instead of the NSSC process, and be more compatible with the softwood kraft recovery process. The use of secondary fibre for corrugating medium is becoming more popular world-wide and the application

	Standard TAPPI Drying	Static Press Drying
Basis wt. g/m^2	35	32
Caliper μm	66	53
Mullen KPa	20.7	41.4
Gurley Porosity sec/100cc	0.8	2.5
Opacity %	59.6	55
Tensile KN/m	0.81	1.3
Stretch %	0.67	0.85
TEA J/m^2	3.0	6.2
Elastic Modulus GPa	0.148	0.151
Brightness % Felt	81.9	79.7
Wire	82.0	78.4
Smoothness (S U) Felt	280	220
Wire	245	150
Scattering Coefficient	351	316
Density Kg/m^3	528	597

<u>Pulp Furnish:</u>

100% Aspen Hardwood

Freeness: 700 CSF

<u>Static Press Drying Conditions</u>

Equipment Used - See Figure 13
Nip Pressure - 2760 KPa
Dryer Temperature - 150°C
Time - 30 sec.

Table 3
Comparison of Light Weight Paper Physical Properties of Handsheets made from 100% Bleached Aspen Hardwood Pulp

of press-drying could enhance the properties of this product. Table 4 shows data comparing dynamic press-dried 100% Kraft hardwood high-yield furnish with TAPPI dried handsheets and commercial medium.

	Standard TAPPI Drying	Dynamic Press Drying	Commercial medium MD/CD
Basis wt. g/m^2	131	126	129
Caliper µm	371	168	239
Scott Internal Bond KJ/m^2	101	303	393/378
Tensile KN/m	2.6	4.2	6.8/2.8
Stretch	1.5	2.8	1.4/2.6
TEA J/m^2	2.5	7.4	5.3/4.9
Elastic Modulus GPa	1.68	0.73	2.49/.857
Mullen KPa	138	296	248
Ring Crush N/m	905	1170	1460/992
Gurley Porosity sec/100cc	1.0	14.8	15.1

<u>Pulp Furnish</u>

100% Mixed Southern Hardwood

Freeness : 600 CSF

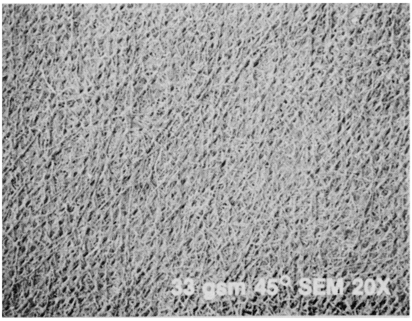
Yield: 67% Kraft

<u>Dynamic Press-Drying Conditions</u>

Equipment Used - See Figure 15
Nip Pressure - 26.3 KN/m
Dryer Temperature - 140°C
Dryer Fabric Tension - 5.3 KN/m
Avg. No. of Passes - 6
Speed - 0.5 m/sec.
Initial Moisture Content at 50%

Table 4
Comparison of Physical Properties of Handsheets with Commercial Corrugating Medium

IMPROVED FORMATION



ILLUSION OF PRESS DRIED LIGHT WEIGHT PUBLICATION PRINTING PAPER

Fig 21

Commercialisation of the Press-Drying Process

The selection of the grade to be made by press-drying is of primary importance to the cost effectiveness of the total mill. A high hardwood content sheet would be site-specific to ensure adequate supply of hardwood for that grade. A high-yield kraft pulping process, for instance, must be integrated with the existing pulp system in a retrofit situation or designed from the ground up for that yield. It is generally accepted that above 65% yield the energy efficiency of the integrated Kraft mill design begins to fall because of the decrease in the amount of dissolved wood solids sent to the recovery furnace and burned for steam and electricity generation. This factor plays a large part in the design of new mills since energy cost-effectiveness is of prime importance to an integrated mill system. A higher-yield cooking liquor however, calls for lower oil consumption in the lime kiln and this is a direct saving in purchased fossil fuel energy.

There is a risk involved whenever a change is made to the design of a highly developed paper machine such as those built today to make liner-board at high speed. The risk of machine wrecks is very high when introducing a nip and a tensioned fabric in the dryer section of a high speed machine. Even today we tend not to put on bottom dryer fabrics since a wad of wrinkle will break out the fabric resulting in machine lost time and expensive replacement of these dryer fabrics. With a nip in this position, a web break resulting in a wad of high basis weight board going through could very possibly break the journals of the pressure roll and the felt rolls, tear out the felt and perhaps even drop a dryer drum into the basement. Such machine wrecks are extremely hazardous and cause excessive down-time. In scaling-up the press-drying process, such risks must be carefully considered. The design features shown by the Forest Products Laboratory machine where the sheet is sandwiched between two wires is perhaps one way to circumvent disastrous wrecks in the press-drying section.

The very high drying rate of 120 $Kg/m^2/hr$ obtained by press-drying will introduce design problems in heat transfer and condensate removal that are within today's experience in building dryer sections. The drives to the press roll, dryer and felt system need to be synchronised and perhaps even a draw control will be required between each of the press-drying units as a result of the high drying rates. Threading the sheet through the press-drying section and handling broke with the nip present is going to present design and operating problems. Fibre picking and sticking to the dryer fabric when conditions get out of control and paper of high moisture content enters the press-dryer section will also be a problem. The construction materials will present a challenge to modern paper-making engineering. High temperature and high pressure resistant roll coverings that are resilient and can bounce back from identations will be needed. The roll design for minimum deflection in these positions can be handled readily with today's know-how, however, special dryer fabrics need to be developed to handle this type of operation.

One of the applications for press-drying that may prove to be very effective in the foreseeable future is in a low production paper machine of simple construction for developing countries similar to the design shown in figure 22. This design allows the wet sheet to be run immediately into the dryer section and dried with the aid of lightly loaded press nips. Progressively more pressure would be applied as crushing became no longer a problem. Data obtained from the St. Anne's Board Mill 500mm wide pilot plant paper machine indicate that a machine such as shown in figure 22 three meters wide would occupy a floor space of twelve meters in the machine direction, with the four dryer cans 1.22m in diameter. This machine could produce a 100 g/m^2 product at one ton per hour.

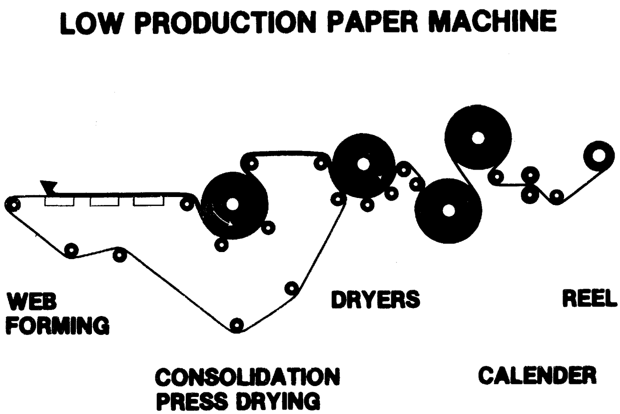


Fig 22

Press-drying has the potential of obtaining certain economic advantages such as increased usage of lower cost hardwood, utilisation of high yield pulping processes, and lower refining costs. Although higher drying rates will allow a shorter dryer section, however, the increased cost of a press-dryer section is expected to offset the capital saving. The risks in operating a press-drying section will challenge the best of current paper-making technology to minimise down-time. The opportunity to produce certain paper and paper-board physical properties by the techniques of press-drying that have not been attainable by standard methods and the commercialisation of these properties remains to be exploited.

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