NEW TECHNIQUES—DRYING/COOLING FOR PAPERBOARD APPLICATIONS

By:
James M. Rennes, P.E
Global Technologies, LLC
Green Bay, WI 54304
USA

ABSTRACT

The purpose of this paper is to introduce some new areas in which flotation technology is being incorporated into production lines to specifically address web handling and drying problems. Topics include the following:

- Web cooling
- Differential air temperatures for curl control
- Air turns for non-contact turning

INTRODUCTION

Today's manufacturers of coated paperboard and paper face an ever increasing requirement for the production of sophisticated functional products. The move towards higher value added products and the recent trend towards "on-machine" coating operations has in turn brought with it a requirement for advanced drying/cooling configurations and contactless web handling systems.

Advances in these areas have brought forth a myriad of new machine configurations not thought possible with older generation equipment. These possibilities are still emerging and some new layouts have emerged as a direct result of the new technology.

Today's competitive global market requires a re-thinking of traditional operational practices. What we did yesterday may not be applicable for today's requirements. New technology and refinements of existing technology should not be overlooked when considering modifications to existing operations. Many times the new technology being offered can give a marginal operation a competitive edge in the marketplace.

It is important to realize that when the respective drying and web handling equipment are brought together in the tight space configurations prevalent in existing machine configurations, new and innovative layouts need to be considered.

Key words: web cooling, curl control, high performance flotation drying, combined gas IR and air flotation.

Web Cooling

Web cooling is not commonly discussed due to the wide familiarity of the need to cool the web prior to downstream operations. Typically, cooling is done by either leaving an open draw between operations or in some cases, traditional chill roll arrangements are employed where practical. As machine speeds increase and space becomes even more of a problem, mills have had to look to alternative technology to handle the cooling requirements.

Cooling webs to temperatures below 130°F (55°C) prevents operational problems from developing on calendar stacks and provides a suitable temperature to rewind without the typical problems normally associated with high sheet temperatures. It is typical to find sheet temperatures hovering in the area of 160 to 180°F (70 to 80°C) in the "dry end" of a paperboard machine. A cooling operation needs to efficiently and economically lower the web temperature some 30 to 50°F (0 to 10°C) without damaging the coated surface and within the minimum space possible. This is especially true for board applications where the weight of the board makes an excellent "heat sink" and is more difficult to cool.

The development of air flotation drying technology provides non-contact web handling while offering the enhanced benefit of two sided drying. A diagram of a typical flotation dryer is shown in Fig 1. This same arrangement can be used to effectively cool a web by using ambient or chilled air instead of heated air.

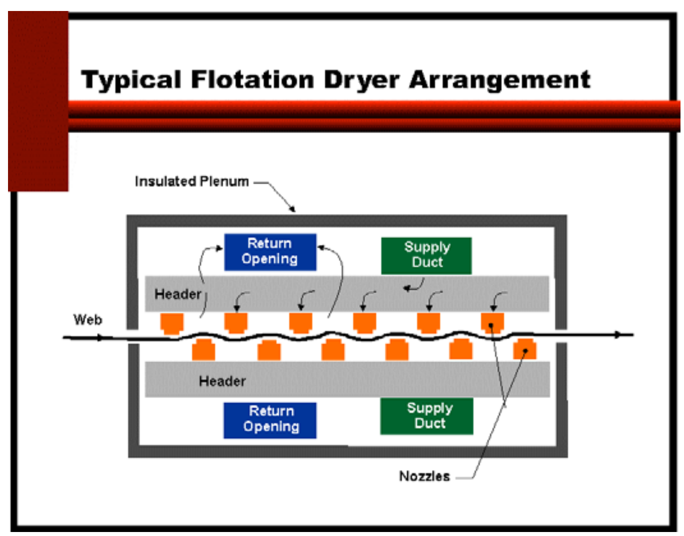

Fig. 1

The operation of a flotation cooler is quite simple. An air supply system delivers ambient air to the nozzles or air bars above and below the web. Arranged in a staggered configuration, the nozzles create a pressure pad that supports the web as it passes through the dryer. In a traditional flotation dryer, the supply air is heated by a gas burner or indirectly by a steam coil.

Air bar designs have evolved over the years and have resulted in a number of configurations. For coated paperboard, the predominate design is a two slot pressure pad air bar. The design of this air bar consists of two slots separated by a flat support area between slots. Air exiting the slots converges toward the center of the support area between the slots creating a pressure pad along the top of the air bar as shown in Fig. 2. A good dual slot air bar will convert as much as 40% of the nozzle supply pressure to cushion pressure which is used to create the supporting pressure pad. It should be noted that not all air bar designs are equal since some have reduced heat transfer capabilities and excessive fan power requirements.

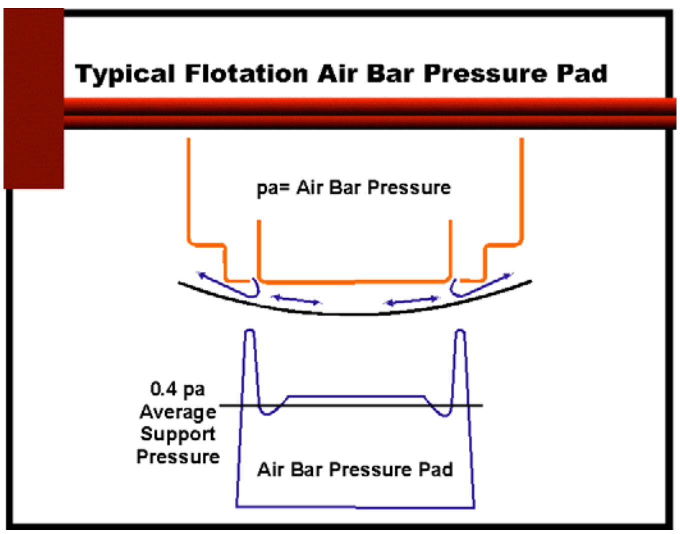

Fig. 2

The primary criteria for designing a good nozzle system lies in having the arrangement that provides superior web handling and drying characteristics. The nozzle system needs to maintain adequate clearance to prevent contact while the web is traveling through the cooler. Also important is the nozzle's jet stability to prevent jet flip flop which exhibits itself as a condition where all the air exits only one of the slots. Typical operating nozzle velocities range from 5,000 to 15,000 fpm (25 to 75 m/sec).

Materials of construction are typically a combination of mild steel, aluminized steel and stainless steel. Construction types can vary from panelized to all welded construction. Access to the cooler internal areas and air bars in "enclosed" coolers is through a retraction arrangement. Common retraction systems are the clam shell pivoting design from the gear side or a screw jack system which lifts the top half of the enclosure above the bottom half. Retraction heights are typically 16 to 20 inches (400 to 500 mm).

The performance of an air flotation cooler is dependent not only on the air bar design, but also on the exhaust air system. After leaving the nozzle area, exhaust air is collected and extracted. Cooler exhaust volumes are sized to keep the enclosure internal pressure slightly negative. Cooling rates for flotation dryers are controlled by adjusting air velocity as delivered to the web.

We'll use several examples to illustrate how flotation technology can be used to cool and stabilize a coated web efficiently and within a minimum space.

In our first example we have a paperboard web which has been coated twice and dried with gas IR following each coater as shown in Fig. 3. The first coater is a rod pre-coater followed by six rows of gas IR. A second finished coat is applied via an air knife coater with 8 rows of gas IR used to dry the coating prior to being calendered just prior to the reel.

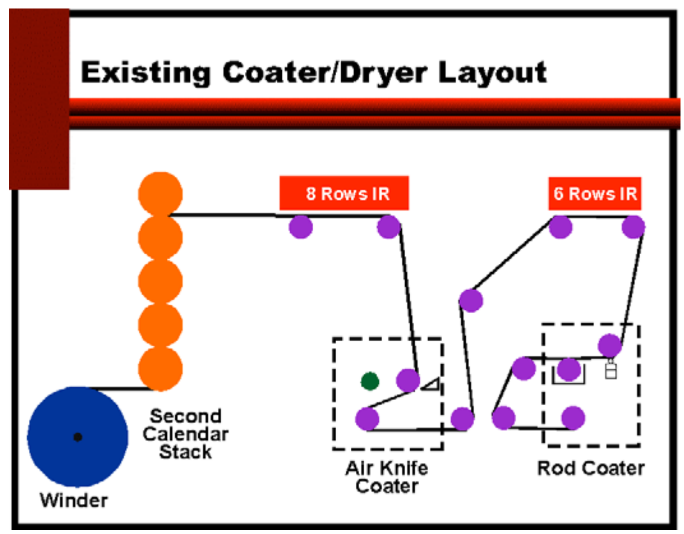

Fig. 3

The problem this particular mill was facing is roll picking at the outboard calendar stack prior to the reel at the design production speeds [450 fpm (137 m/min)]. The mill's initial solution to correct the problem was to slow up and this approach did indeed correct the immediate picking problem. However, the mill was losing valuable production and a better solution to the problem needed to be organized.

In the mill's view, the picking problem was due to a lack of drying at the coater dryers. Consequently, the mill took the approach of considering additional gas IR drying following the last coater and was discussing this arrangement with various IR suppliers.

A more rigorous analysis of the overall coating arrangement suggested that the mill had plenty of drying with the current gas IR configuration and the real problem was one of too hot of a coating surface temperature. Having a hot [170^{o}F (75^{o}C)] coating surface temperature entering the calendar stack was the real problem in this application and not a lack of drying.

In view of this, a drying profile was run on the operation with the results verifying that the existing operation had plenty of drying. The general applications data used to develop the drying curves is shown in below.

Cooling Applications Data:

Web Description	
Web Type	Paperboard
Basis Sheet Weight (OD)	47.40 lbs/ream
Ream Size	1000 ft^2
Base Sheet Moisture Before Coater	4%
Final Moisture Desired at the Reel	6%
Production Speed	450 fpm
Sheet Width	93 inches

Coating Data	Precoat	Top Coat
Coater Type	Rod	Air Knife
Dry Coating Weight	2.0 lbs/ream	3.34 lbs/ream
Application Solids	58.7%	40.2%
Sheet Temperature	250°F	n/a
Drying Arrgmnt.	6 rows IR	8 rows IR

Results of the drying analysis is graphically displayed in Fig. 4 and 5. Fig. 4 illustrates the relationship of temperature and average sheet moisture versus web path. Fig. 5 shows the relationship of sheet temperature and coating solids versus web path.

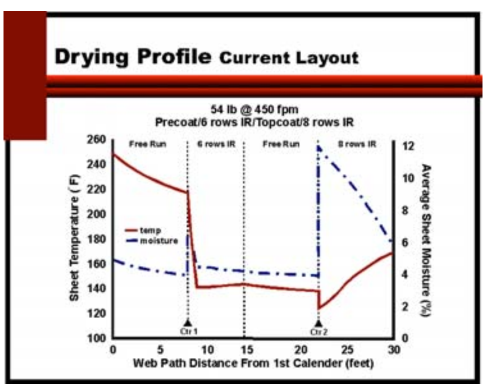

Fig. 4

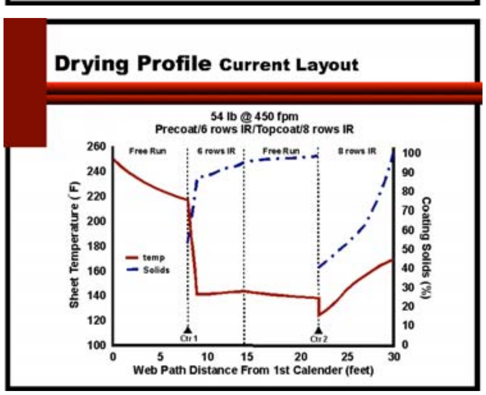

Fig. 5

Upon analysis it is very apparent that the solution to the problem was to add a short cooling section following the exiting gas IR arrangement and prior to the existing calendar stack. Fig. 6 shows the addition of a short cooling section following the top coat drying section. A general arrangement of the cooling system supplied is shown in Fig. 7 with an actual picture of the unit in Fig. 8.

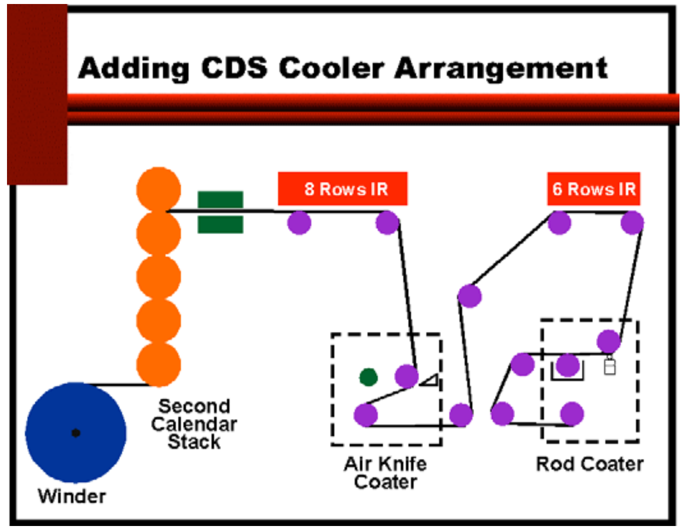

Fig. 6

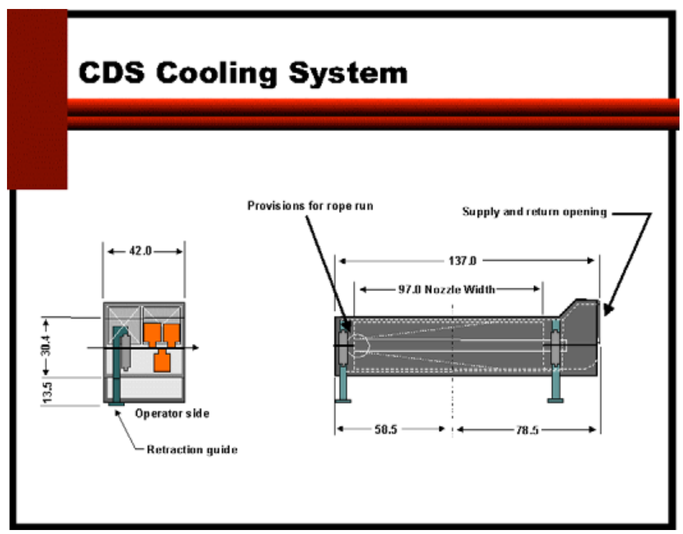

Fig. 7

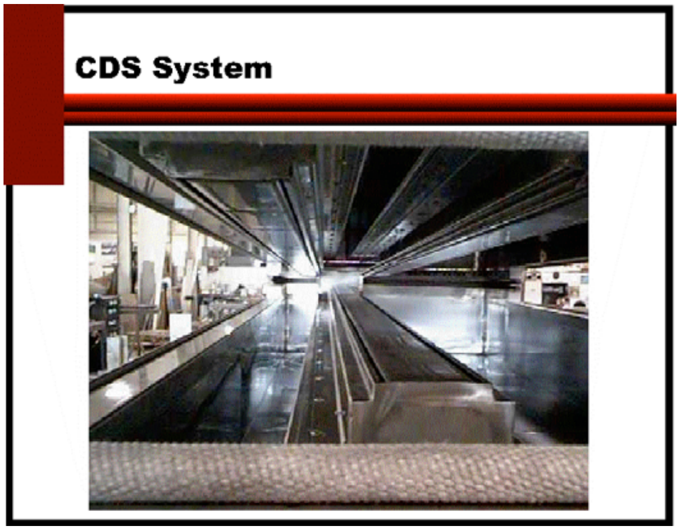

Fig. 8

The cooling section coupled with the existing free web run would do two things, lower the web temperature by 20^{o}F (-7^{o}C) and lower the overall sheet moisture by another 0.5%. Having a sheet temperature in the 150^{o}F (66^{o}C) range versus 160 to 180^{o}F (70 to 80^{o}C) would allow the mill to transverse the calendar stack at the desired production speed without roll picking. Only 42 inches (1067 mm) of cooling is required due to the large difference in temperature of the coated paperboard sheet and the ambient air used for the cooling arrangement. (Fig. 9 and 10)

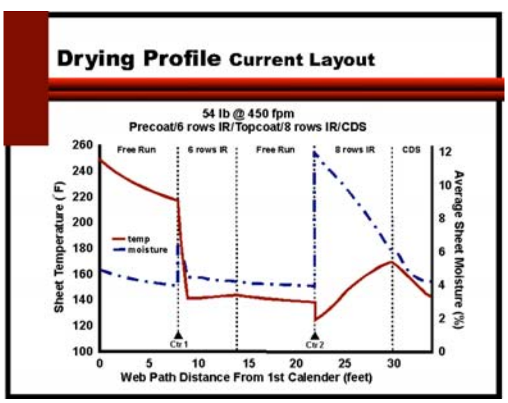

Fig. 9

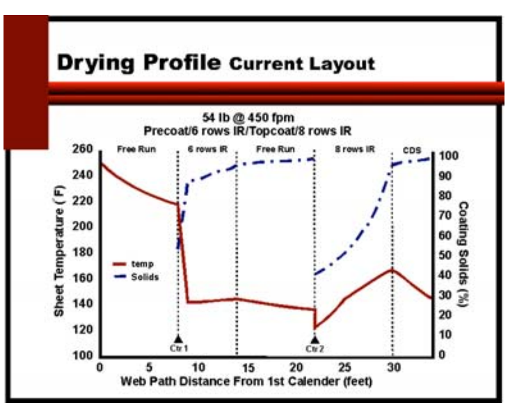

Fig. 10

As is typically the case with gas IR systems, the hot coated web leaving the IR needs to have a means to transport the moisture being evaporated away from the coated sheet. It is well known that IR systems are excellent devices to add sensible heat but are not so good at moisture removal.

In this particular example, the problem the mill had was one of having too much gas IR leaving the coated sheet temperature too hot and fluid thus picking off on the calendar stack rolls. Having a non-contact method of cooling, the sheet temperature eliminated any chance that the coating would be disturbed prior to contact with the calendar stack.

Looking back at Fig. 6 it can be seen that the web path required to enter the calendar stack from the top requires the cooling arrangement to be located some eight feet (2.5 m) off the floor line. The flexibility of the flotation cooling arrangement lends itself to this application quite nicely since the system can be located easily in this location. A conventional chill roll stand would normally be placed on the floor level requiring transfer rolls to position the coated web to the chill stand. Of course, this arrangement would suffer from the same problems the mill would experience with the calendar stack prior to the insertion of a web cooling arrangement.

Next we will look at an example which requires more cooling than in the previous example. In this case the mill wished to reduce the temperature of the coated paperboard from 150 to 120^{o}F (65 to 50^{o}C) prior to the winder. A location was chosen for the cooler immediately following the dry calendar stack as shown in Fig. 11.

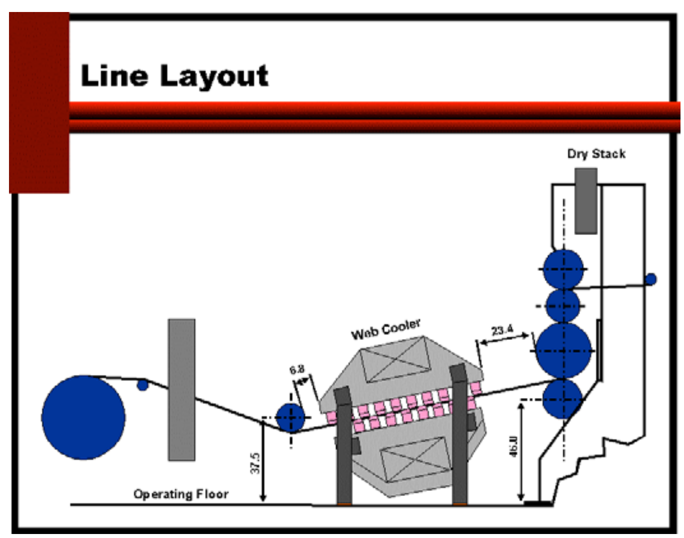

Fig. 11

The general applications data for this example is as follows:

Cooling Applications Data:

Web Type	Paperboard
Base Sheet Weight (OD)	56 lbs/ream
Ream Size	1000 ft^2
Base Sheet Moisture Before Coater	6%
Final Moisture Desired at the Reel	6%
Production Speed	650 fpm
Sheet Width	90 inches
Cooling Required	40^{o}F (150 to 110^{o}F)

To solve this request, a 5.5 foot (2 m) long cooler was selected and located as shown in Fig. 11. Using a tightly packed nozzle arrangement operating at ambient temperature, this arrangement was able to complete the cooling requirements set forth by the mill.

Fig. 12 illustrates the performance of the cooler for 56 lb/1000 ft^2 board. Note the reduction in both temperature and moisture. In this particular application, the mill merely wanted to reduce the sheet temperature prior to the windup to prevent problems with winding too hot. Having a reduction in sheet moisture was an added bonus.

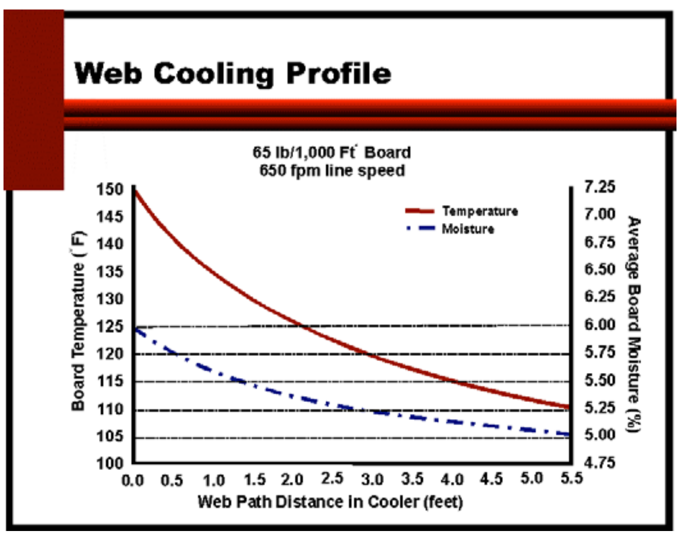

Fig. 12

Granted the mill could have easily used a chill roll stand to do the same job but this would have required the installation of transfer rolls to position the coated paperboard sheet to the chill stand. Additionally, the mill would have to drive the chill stand and supply a chiller unit whereas the air flotation cooling system can easily be placed in the exiting web line and is designed so the operators are exposed to no moving components unlike a chill roll stand. Additionally, the maintenance requirements of a flotation system would be less than a mechanical chill stand.

Using air flotation technology as a cooling system is a practical application of a conventional proven technology. A flotation cooler can be placed conveniently in the existing web line and functions to cool a coated web without having to contact the coated surface.

Curl Control

In paperboard production, one of the largest single sources of product waste is curl. Curl is responsible for jam-ups, off spec production, and loss of unconverted product.

Curl can be defined as the tendency for a flat piece of paper or paperboard to distort in a cylindrical shape as shown in Fig. 13. Curl can occur in the cross-machine direction (CD) or the machine-direction (MD). Cross-machine curl is caused by uneven drying; whereas machine-direction or roll-set curl occurs when paperboard that has been wound onto a core starts to take the shape or the set of the roll.

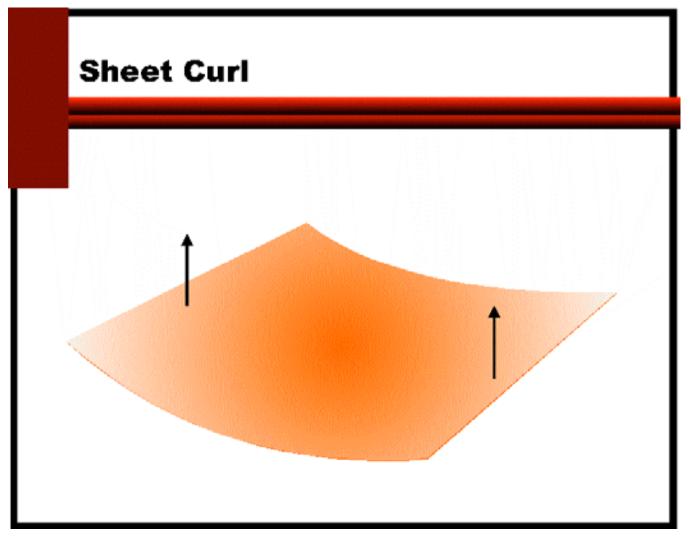

Fig. 13

Traditional attempts at solving this problem utilize mechanical decurl bars, "wet stacks" or homemade steam showers. Traditional steam showers are ineffective and provide more problems than benefits due to dripping, splitting, and streaking. Mechanical decurl bars provide limited decurling capabilities and often overstress the paperboard causing checking or surface disruptions along with de-lamination on multiple grades. Wet stacks leave the paperboard with high moisture contents which sometime need to be dried further.

For this discussion we are interested in cross-machine curl due to uneven moisture profile. This will cause fibers which have more moisture to be longer than fibers with less moisture. This will occur on the coated side of the sheet where coating moisture has dewatered into the base sheet as shown in Fig. 14. Henceforth, a paperboard sheet will therefore curl towards the dryer side of the sheet due to the fibers being shorter on this side.

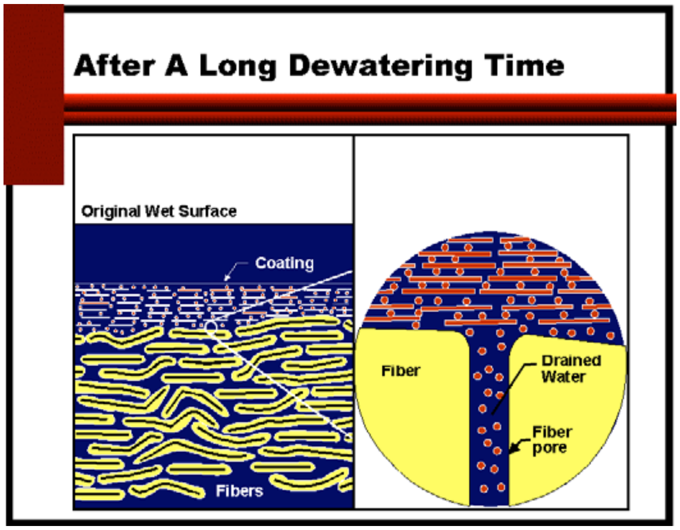

Fig. 14

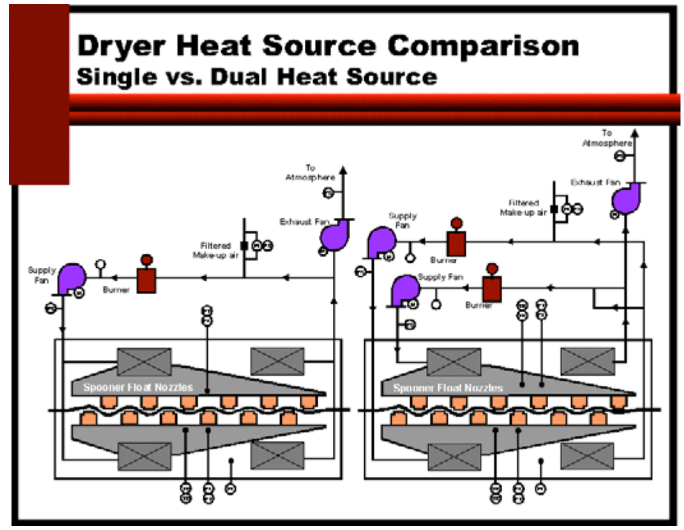

Fig. 15

While still in the coater, the excess water in the coating will commence to migrate into the paperboard by moving into the fiber pore structure and by absorption into the actual fibers. The movement of water into the base sheet is termed dewatering and is the primary mode of water movement prior to the actual drying process. It is important to understand the dewatering process and its effect on causing a paperboard sheet to curl. Dewatering rates will be a function of the composition of the base sheet, the coating and the corresponding temperature of the composite.

The object of curl control is to reset the fibers of the paperboard to a flat position while preserving both the structural integrity and surface qualities of the paperboard. The use of flotation technology to enhance sheet curl control has gained interest in recent years, especially in paperboard operations. Depending on the degree of curl, a dual heat source, air flotation system can be used to correct curl problems online.

Flotation dryers typically use a single heat source and fan system to provide heated air to both sides of the web. Using a dual heat source system as shown in Fig. 15 allows the use of differential temperatures on each side of the sheet.

The object of this arrangement is to operate the drying arrangement with increased temperatures on the “wet” side of the sheet versus the dryer side of the sheet. This will result in increased evaporation from the wet side causing the fibers to contract more than on the opposite side which is being subjected to lower temperature air.

As mentioned, this system is effective for moderate curl control and is more suitable for gas fired arrangements than for steam fired arrangements due to temperature limitation of steam fired systems. Properly designed systems can obtain 75 to 100^{o}F (25 to 40^{o}C) differential temperatures between top and bottom sections. It is difficult to achieve higher differentials due to the fact that the spent air streams have a tendency to mix due to the design arrangement of the nozzles and exhaust areas. Even with this consideration, a dual zone arrangement can effectively help control troublesome curl in paperboard operations.

Air Turns--The Solution To Non-Contact Turning Problems

Fig. 16 illustrates a typical size press arrangement using conventional chill or spreader rolls to turn the sized web into the steam cylinder section.

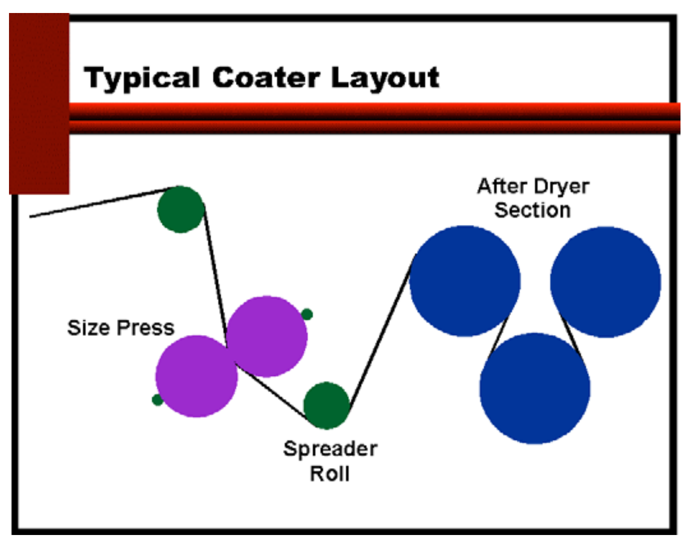

Fig. 16

The development and application of metering size press technology and other coating technology allowed mills to begin applying higher solids coatings at higher speeds. Consequently, problems were encountered with wet coating “picking” on the turning roll(s) and the lack of drying capabilities to “set” the coating prior to the introduction to the steam cylinders.

To address the quality problems being experienced required the development of non-contact turning in conjunction with determining how additional drying could be incorporated into the already tight space. The tight configurations of "on-machine" arrangements provided machine builders some difficult problems to solve.

Air turns were initially developed in the '70's and helped solve a wide range of problems of contactless web handling after coating and size press applications. In essence this product is a circular air flotation web handling system designed to allow a change of web direction without any surface contact. A typical air turn arrangement is shown in Fig. 17.

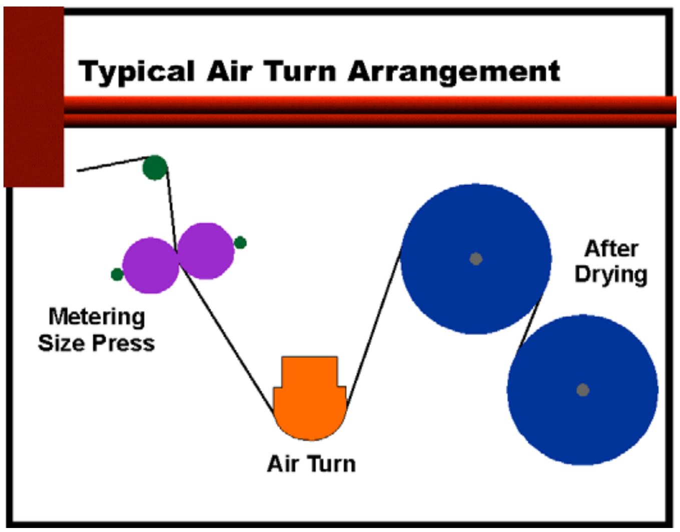

Fig. 17

Modern day air turns employ the proven performance of twin slot pressure pad flotation air bars which have seen extensive use in flotation drying systems in "off-machine" coating operations. The air bars provide a stable cushion of air extending across the full width of the unit. These cushions provide full support to the sheet such that the flotation height is the same in the center of the sheet as it is at the edge of the sheet irrespective of the width of the sheet.

In operation, these air bars generate supporting air cushion between the surface of the air bar and the coated web being processed as shown in Fig. 18.

The very best designs utilize regions of high and low pressure to bring about a perfectly symmetrical profile which in turn results in high clearance and firm web stability. Performance is directly related to the special aerodynamic effects brought about as the air exits from the slot outlets. The forces generated in the air flotation cushion need to be high in magnitude since these are used to effectively offset the force generated by the tension in the web. The modern air turn system embodies these features and benefits by using these same air bars arranged in a curve path as depicted in Fig. 19.

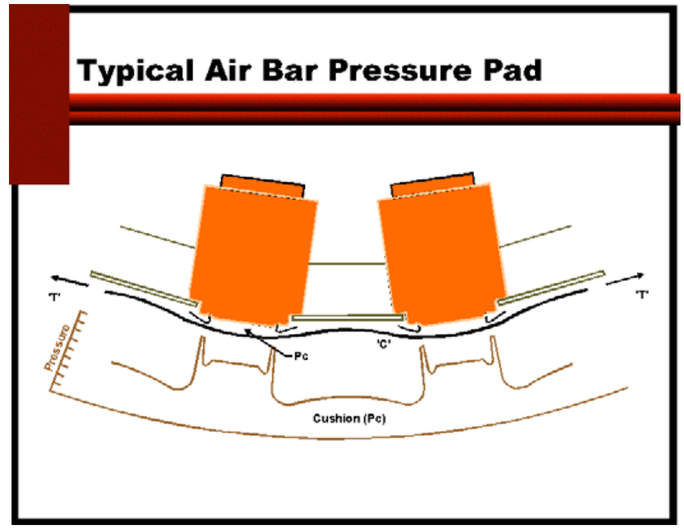

Fig. 18

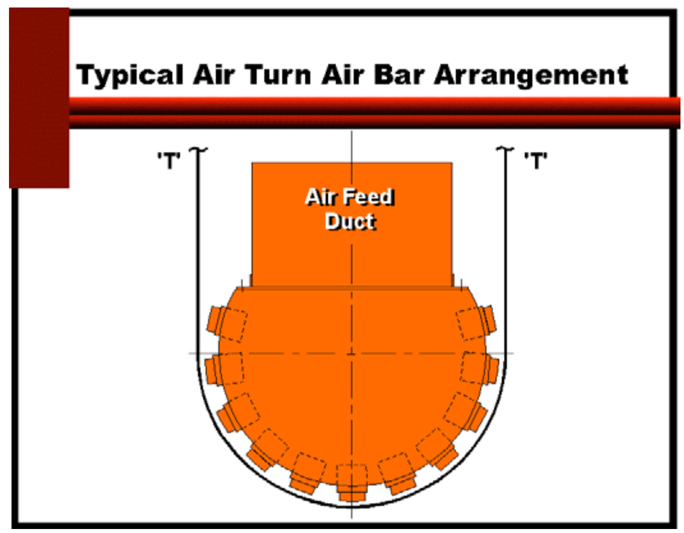

Fig. 19

The flow channel areas provided between the air bars control the escape of air from the air cushion at the end of the air bars which provides additional support and minimizes the fan power required to operate the system. The flow of air throughout the area between air bar channels also imparts a smoothing effect to the sheet reducing wrinkles and creases.

Modern air turn systems are designed to accommodate the following operating requirements typically found in coated paperboard applications:

- <u>Non-Contact Web Handling</u>
  The distance between the coated sheet and the surface of the air turn should be at least _ inch (6 mm) to insure trouble free operation without the possibility of contact and contamination of the coated surface during operation.

- ♦ High and Low Tension Capabilities
  With the operating tension ranges varying, the air turn needs to be capable of handling tension ranges of _ to 10 pli, while maintaining the clearance mentioned above.

- ♦ Web Turning Angles
  Due to many configurations available today, air turns need to accommodate wrap angles of 20 to 180 degrees.

- ♦ Air Turn Width and Diameter Flexibility
  Today's applications require flexibility in design to accommodate a range of web widths. Air turn radius's typically range from 21.65 to 31.50 inches (550 to 800 mm).

When used in conjunctions with the latest coater designs, the air turn provides increased product quality and runability of this new generation of equipment. Depending on the design attributes, coater configurations can result in either vertical or inclined orientations.

In an inclined arrangement the air turn is placed below the coater as shown in Fig. 20. In this configuration the coating can be applied to both sides of the sheet and turned in a non-contact fashion towards the after dryer section.

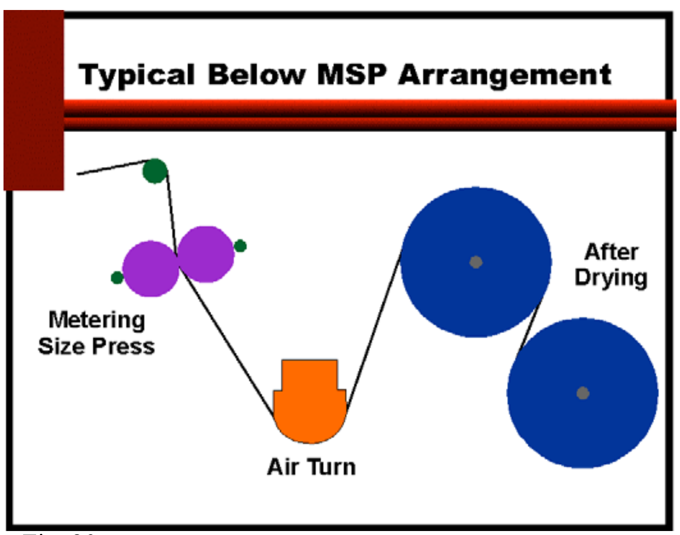

Fig. 20

Vertical configurations have the air turn unit placed above the coater and requires the non-contact turning of the web as show in Fig. 21. The successful development of this form of coating arrangement has largely depended upon the availability of a suitable air turn system.

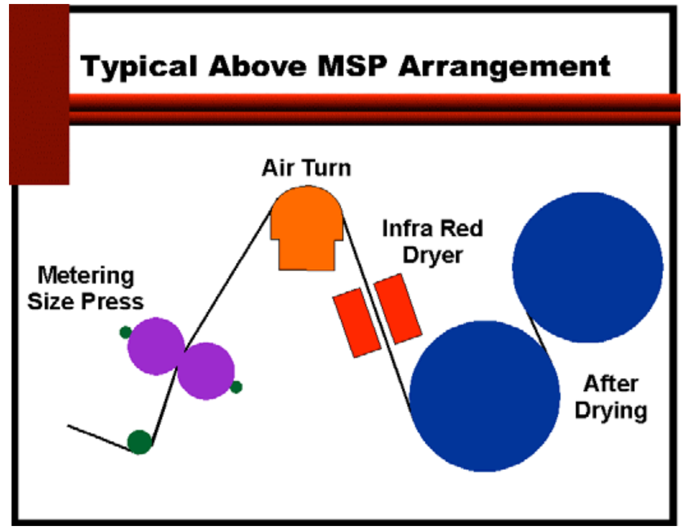

Fig. 21

Heated air turns

As has been mentioned, the primary development of the air turn was to overcome handling problems. It was not envisioned that air turns would have any effect on drying performance following the coating operation. However, mill supervisors, where air turns are in operation, notice that extra machine speed could be achieved following the introduction of the air turn unit.

This can be attributed to the impingement effect from the pressure pad nozzles that provide forced ventilation on the web sheet traveling over the air turn. The air turn, having ventilated the surface of the sheet, insures that the air boundary layer on the surface of the coated sheet is removed.

It is possible to use heated air turn supply air for the purpose of conditioning and/or drying the web as it passes around the air turn. In this arrangement, air turn supply air is normally drawn in from the machine room through a prefilter unit and then passed through an air to air heat exchanger before being delivered to the air turn unit (Fig. 22). If a gas IR system is used, the exhaust air can be used as a source of energy.

On leaving the air turn, the air is simply discharged back into the machine room at the temperature which it leaves the air turn. The primary reason for using heated air is to provide supplemental energy to the sheet which is being cooled from the evaporation of moisture from the surface of the sheet. Depending on circumstances, a heated air turn will result in a slight improvement in the drying rate [0.5 to 1.0 $lb/hr/ft^2$ (2.4 to 4.9 $kg/hr/m^2$)] from an unheated system. Actual practice will show that the overall coated sheet temperature entering the air turn, coupled with the angle of wrap, is of much greater importance to improving the drying performance capabilities of air turn systems.

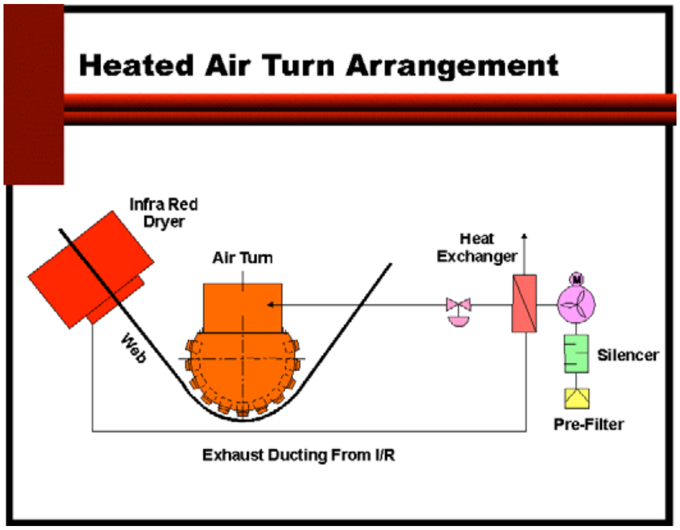

Fig. 22

Depending on the temperature of the sheet and the drying application, an air turn can develop single-sided drying rates over the surface of the air turn as shown in Fig. 23. Limited drying can, therefore, be achieved even when ambient air is applied and no form of IR heating is utilized prior to the air turn. In this situation, the temperature of the coated sheet is between 140 and 170°F (60 and 77°C) due to the on-machine nature of the application. The primary drawback to this arrangement is that the drying is single-sided and constrained due to the short effective drying length of a typical air turn.

Typical Air Turn Drying Potential

Sheet Temp.	EV Rate	Drying Rate
100°F (38°C)	1.0-2.5 lbs/hr-ft^2 4.8-12.2 kg/hr-m^2	1.7-8.3 lbs/hr-ftw 2.5 - 18.4 kg/hr-mw
170°F (77°C)	10-18 lbs/hr-ft^2 48.8-87.9 kg/hr-m^2	16-60 lbs/hr-ftw 23.8 - 89.3 kg/hr-mw

Fig. 23

LITERATURE CITED

1. K. Hagen, "Effect of Drying", Chapter 3 in Binder Migration in Paper and Paperboard Coating, TAPPI Press: Atlanta 1993, pp. 39-59.
2. W.L. Bracken, et., "Drying", Chapter 3 in The Coating Processes, TAPPI Press: Atlanta 1993, pp. 153-173.
3. D.W. Lawton, "Drying Systems for Coated Paperboard", 1995 Coated Paperboard Short Course notes, TAPPI Press: Atlanta 1994, paper 2-2.
4. E.Bowden, "Non-contact Drying and Turning—the 'On-Machine' Technology of the Nineties". Paper presented at the 44th Annual General Conference, 1990.
5. Mr. Trefz, "Theoretical Aspects and Practical Experiences for Film and Coated Offset Grades", *TAPPI Journal*, Vol 79, No. 1, January 1996.
6. J. Dunlop, "Contactless Web Handling and Drying", 1991 Coating Conference, TAPPI Press: Atlanta 1991.
7. G. Swift, "Drying Options Following Size Press Metering Coaters", presented at the PITA Water Removal Conference, York, UK, 5/6 December 1995.