AIRKNIVES AND OTHER CONTOUR COATING SYSTEMS FOR PAPERBOARD

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Airknives are metering devices used to reduce an excess of previously applied coating material on a moving web to a uniform thickness.

There are two types of airknife operating methods. What we call "Air Brushing" is a gentle jet of low velocity, impinging on a vertical running coated substrate at approximately a right angle, providing a pressure dam which limits the amount of coating liquid passing by. Excess liquid runs back down the strip, under the influence of gravity, to a pond or a drip off point. The jet does not remove any liquid from the substrate. For coating paper, this method has largely fallen into disuse and will not be discussed further.

We call "Airknifing" the method where a jet of moderate to high velocity impinges on a coated substrate supported by a roll, at an angle on the order of 45 degrees opposed to substrate movement. The jet shears the liquid film, and removes the excess as liquid, spray, or mist. This excess is then collected in a blow off containment system.

The theory in removal of excess coating by the air doctor is called the filter cake theory. A coating is applied in excess to the sheet at the applicator section. Water in the coating immediately begins to migrate at the interface of the wet coating and the paper web so that the coating at this point immediately becomes semi-dry or plastic. As the sheet of paper passes under the airknife jet, the fluid coating is removed from the sheet by the air doctor and is sheared at the point where the filter cake begins. There is a zone in the coating cross section where the coating makes the transition from the fluid to a semi-plastic coating, and it is in this area that the air doctor shearing takes place. The exact point at which the shear takes place varies with the amount of energy that the air blast has. At a very high pressure or velocity of air from the air doctor, the air penetrates more into the filter cake or plastic area, leaving less coating on the sheet. It should be noted that the normal air pressure used in the air doctor is from two to nine pounds; however, when a plastic non-absorbent web is coated by the air doctor system, pressure in the range of two to ten ounces is used in the air doctor. This would substantiate the filter cake theory in that there is no filter cake formed in this case, and the air doctor is only shearing to a depth in the coating for which there is energy to penetrate it.[1]

Referring to Figure 1, shown on page 2, there are four main components in an airknife coating system.

1. The coating application system.

2. The airknife metering element.

3. The compressed air delivery system.

4. The coating exhaust and recovery system.

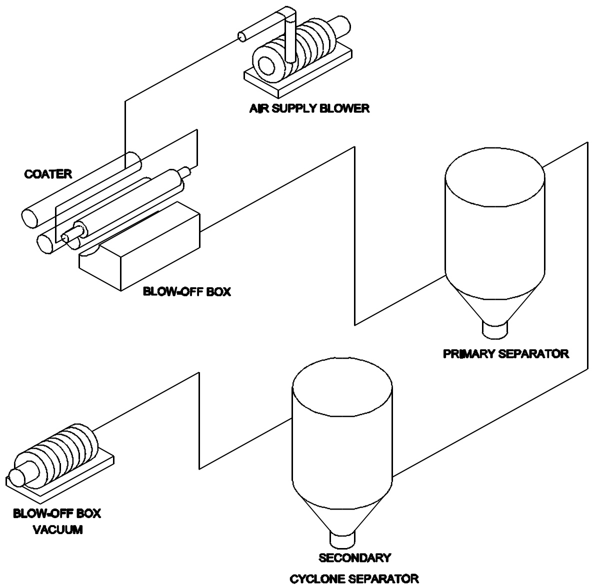

FIGURE 1

COATING APPLICATION SYSTEM

Since air knifing was invented in the 1930's, many different applicator systems have come and gone. Most methods used rolls, although a number of die or fountain applicators have been tried.

Today, three systems predominate. These are shown in Figure 2, page 3. Roughly 70% of the applicator systems used today are single roll systems, 25% are two roll systems and the remaining systems are three roll or other systems.

Single Roll

The single roll system is exactly that. It is a single roll normally rotating in web direction at a speed of 10 to 40% of the web speed, which picks up a crudely controlled amount of coating and applies it in excess to the web that wraps the roll. Usually this wrap will be from 3 to 4", and if well designed, it will maintain a puddle of coating at the nip point formed by the web as it touches the roll. The run back of coating should be laminar in nature and not a cascading effect in order to get a good smooth application of coating to the web and to prevent foam generation caused by turbulent flow and cascading of the coating off the roll. This system is the simplest available and also the crudest one in operation.[2]

It is used by the vast majority of airknife coaters in operation, and is used almost exclusively at speeds below 250 meters per minute.

Two Roll

The two roll system provides an additional metering nip to reduce and level the amount of coating applied to the web. It is the application unit of choice for moderately high speed, wide machines. These would be machines over 200 meters per minute in speed and/or widths greater than 3.8 meters.

Three Roll

The three roll system was developed for high speed air knifing (over 600 meters per minute) to further reduce and even the coating applied to the web. The airknife is generally limited to pressures below 9.0 PSI (62.1 KPA), which limits the amount of coating which can be metered off at high speeds. The three roll system extends the operating range of the airknife, but its tight tolerances and complexity has limited it to narrow width coaters (less than 3.8 meters wide).

Smoothing Roll

On many high speed systems it is a common

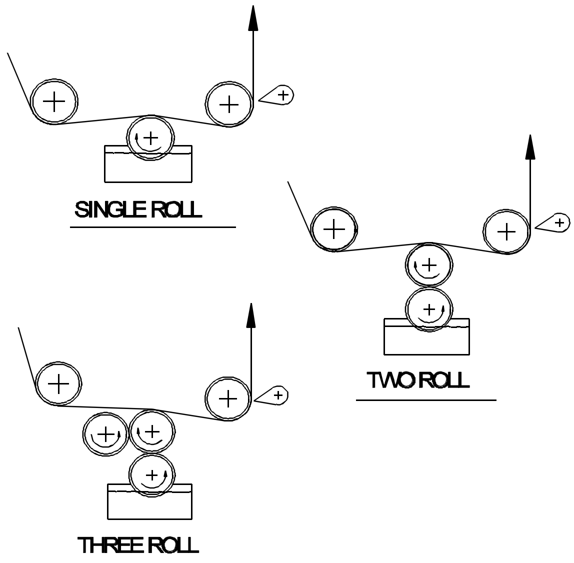

FIGURE 2

practice to use a smoothing roll on the coated side of the web.

This roll is run reverse to web direction and is usually designed with as small a diameter as is structurally possible. Wrap angle is about 5 degrees.

The primary purpose of this roll is to assist in the removal of the film split pattern on the web; however, the breaking of the foam generated from this process is also of significant importance. The roll also serves to reduce the effect of dwell time from the point of application to the point of action of the airknife metering device. Up to 90% of the coating is re-distributed, preventing rapid de-watering and preventing the formation of a filter cake. The danger of long dwell distances is water loss into the web to the degree that the airknife becomes a poor metering device, due to its viscosity sensitivity and a need to run at higher air pressures. The re-distribution effect of the smoothing roll before the air jet keeps the coating in suspension longer, allowing better coat weight control and reducing the effect of the long dwell distance.[3]

AIRKNIFE METERING ELEMENT

There have been numerous designs of airknives over the last 60 years. The technical differences of various geometries and lip designs are beyond the scope of this article.

All airknives fall into one of the three categories shown in Figure 3, below.

Non-opening airknives were developed first. Opening style and dual airknives were developed later to reduce cleaning time on paper machines that could not stop the paper when making scrap.

AIR DELIVERY SYSTEM

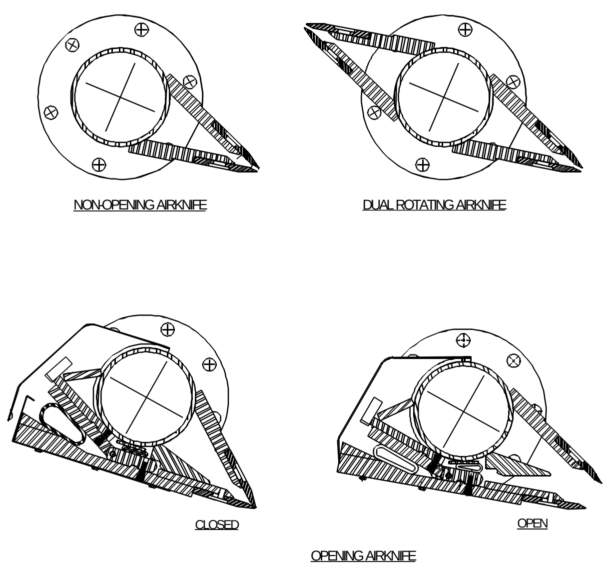

FIGURE 3

The air delivery system of a coater consists of four basic elements:

1. The blower
2. The aftercooler (if used)

3. The piping
4. Means of adjusting pressure and flow

Blowers

The blower for an airknife should always be a centrifugal type. These units deliver clean air, free of water and oil, and completely free of pulsation.

A blower should be sized according to the CFM required at the largest gap setting and highest pressure at which you expect to operate. Allowance should be made for pressure drop through the piping system and the after cooler (if used).

CFM requirements vary with airknife length, airknife gap, and pressure requirements. The following table shows the requirements per inch of opening at various airknife gaps for a range of pressures, as well as the formulas from which they were calculated.

Blower Requirements for Airknives

Cubic feet per minute (CFM) of free air at standard pressure of 14.7 lb. per square inch absolute and 70 degrees F per inch at .040", .035", and .030" nozzle openings.

Table 1

	CFM/INCH		
	.040"	.035"	.030"
PSIG	OPENING	OPENING	OPENING
1	5.9	5.1	4.4
2	8.3	7.3	6.2
3	10.1	8.9	7.6
4	11.6	10.2	8.8
5	12.9	11.5	9.8
6	14.2	12.6	10.8
7	15.3	13.6	11.6
8	16.6	14.5	12.4
9	17.3	15.4	13.2
10	18.6	16.2	13.9

Note:

CFM/Inch (.040" Opening)
F = 5.86 * SQRT (P)

CFM/Inch (.035" Opening)
F = 5.133 * SQRT (P)

CFM/Inch (.030" Opening)
F = 4.40 * SQRT (P)

Example: You have a 163" wide coater and you wish to increase the blower size to allow you to operate in a range from 3 to 5 psi at a gap of .035". The system has an after cooler with a maximum pressure drop of .5 psi and the loss through the piping system is .5 psi or less. From Table 1 we read the value corresponding to .035" gap and 5 psi to be 11.5 CFM per inch of length.

Therefore, at .035" gap and 5 psi, the airknife requires 163 (11.5) = 1875 SCFM. Note: 1 SCFM has the mass of 1 cubic foot of air compressed from inlet conditions of 68 degrees F and 14.7 psi absolute pressure. Any variation from these conditions requires that modifications be made to the blower calculations.

Since the system has an inherent pressure drop of 1 psi, we require a machine capable of delivering 1875 SCFM at 6 psi. This requires a 75 HP blower.

The After Cooler

The requirement for an after cooler depends largely on the amount of pressure boost provided by the blower. Air temperature increases roughly 16 degrees Fahrenheit for each pound of pressure increase. Generally, any airknife system operating over 3.5 psi (24 Kpa) could benefit from an after cooler.

Two methods of cooling the blower air are generally used; water cooled heat exchangers and water injection systems. Water cooled heat exchanger systems are used in most installations today. They cool the air, without it contacting the cooling water. A moisture separator is usually used at the exit of the cooler to remove any condensed moisture.

Water injection systems cool by injecting a small amount of water mist into the airstream. The air is cooled by the massive heat absorbed as the water evaporates.

The draw-back to this method is that any impurities in the water remain in the airstream. If the injection method is to be used, the preferred water source is chilled steam condensate. A moisture separator removes any unevaporated water.

The main benefit to this system is that it dramatically reduces water evaporation by the air jet and reduces drying in the blowoff pan. Since the air is at almost 100% relative humidity, it cannot absorb any more water. The air coming out of the heat exchanger has low relative humidity and as a result can absorb more water.

A properly designed injection system is less expensive initially, cheaper to operate and provides more benefits than the heat exchanger system.

Piping

The general rule with piping systems is to keep them as short as possible, with no sharp bends. To keep pressure loss to a minimum, piping from the blower should be at least 20% larger than the inside diameter of the blower outlet, until it splits off to each end of the airknife. The tee should be the same size as the main supply line, and made of hard pipe.

Flexible hose to each end of the airknife should be sized for flow equivalency.

Pressure and Flow Adjustments

Blowers can be throttled to adjust the discharge pressure or inlet volume, or both, to any selected point within the operating capability of the blower. This is usually accomplished by installing and adjusting a blast gate or butterfly valve on the inlet or discharge opening of the blower.

When the blower is throttled at the discharge to a selected volume under standard performance curve conditions, the blower will deliver the full discharge pressure for the inlet volume as shown on the standard performance curve. However, the throttling device will supply sufficient resistance to air flow to provide the desired effective overall discharge pressure beyond the throttling device as required by the process. When the discharge of a blower is throttled, any effective discharge pressure and inlet volume above the surge range can be attained, within the capability of the blower. However, the full input horsepower for the corresponding inlet volume shown on the standard performance curve is required.

When the blower is throttled at the intake to a selected SCFM and discharge pressure, the throttling device serves to create sufficient resistance to air flow to drop the absolute pressure at the blower inlet, so that the desired discharge pressure above ambient is obtained.

The air volume (SCFM) entering and passing through the throttling device will, however, increase in volume because of the drop in pressure across the throttling device, so that the inlet volume to the blower (ICFM) exceeds the SCFM. This condition lowers the input horsepower requirements. Therefore, it is recommended that the throttling device be placed on the inlet to the blower.

The third and most energy efficient method of pressure and flow variation is by varying the speed of the blower motor.

The volume entering a blower varies directly with the speed in RPM, but the input horsepower varies with the cube of the speed in RPM. Fairly large energy savings can be made by this method.

Another advantage of variable speed control is that it lowers the output temperature of the blower in comparison to the other two methods.

The chart shown below in Figure 4 shows the fan volume output plotted versus input power for inlet throttling, outlet throttling, and two types of variable speed controls.

COATING EXHAUST AND RECOVERY SYSTEM

As with airknives, there have been many different designs of exhaust and recovery systems. Modern systems all share the following characteristics.

1. Double wall stainless steel construction

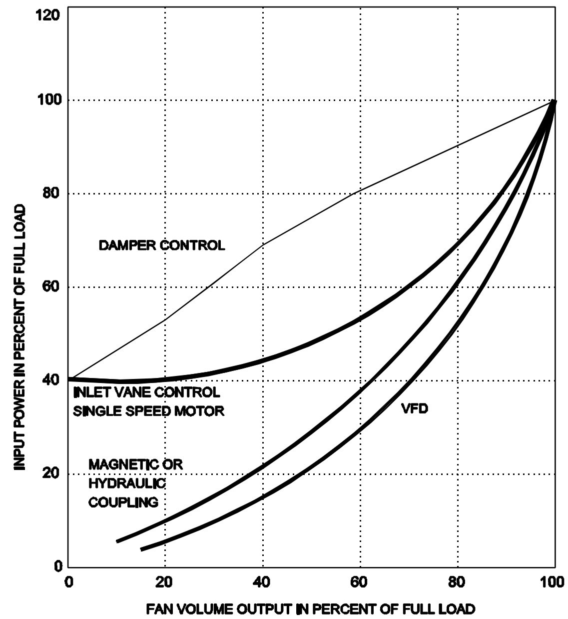

FIGURE 4

for water circulation. Chilled water circulates between the walls to chill any surfaces that contact air or coating. The moisture that condenses on these walls prevents coating build up.

2. A vacuum exhauster system that removes 3 to 5 times the amount of air produced by the airknife, from the pan.

3. Internal surfaces are smooth. Coating is separated out of the air stream gradually, without sharp velocity transitions that cause coating build up. Older designs used many internal baffles that removed coating by changing the air direction enough times to expend its velocity.

The major differences between modern systems concern the basic separation philosophies. Some systems use very large pans that expand the air within the pan until its velocity will only allow it to carry very minute coating particles.

Other designs use smaller pans that remove most of the liquid in the pan and separate the remaining coating out in a water cooled cyclone separator. Another system integrates the cyclone principle within the pan itself.

Almost all modern systems pass the exhausted air through a light water mist to remove submicron particles. In many cases, this water is recycled as coating make up water.

Airknife Set Up

One of the most misunderstood areas of coater operation is setting the airknife geometry.

Referring to Figure 5, below, the following information is required:

R = The radius of the backing roll.

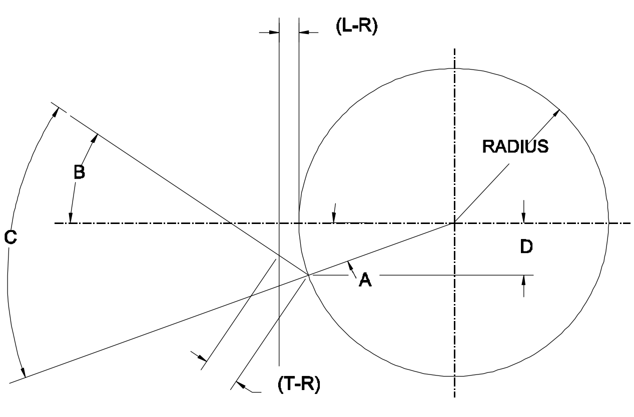

FIGURE 5

D = The distance of the impingement point below backing roll center line.

A = The angle below the horizontal center line of a line passing through the impingement point.

B = The angle above horizontal of the air jet center line. (This is not, repeat NOT, the metering angle.)

C = The angle between the center line of the air jet and a radial line passing through the impingement point. (This is the metering angle.)

L-R = The horizontal distance between the backing roll and the top lip.

T-R = The distance along the air jet center line from the tip of the lips to the roll. On most airknives this is almost impossible to measure. T-R, the metering angle C, and air pressure, control coat weight and appearance.

Step 1. Measure backing roll diameter, divide by 2 for roll radius R.

Step 2. Check distance D on both sides of machine. Make sure both sides are at the blow off pan manufacturer's recommended height and are equal. To establish impingement point on roll, check with air turned on.

Step 3. Calculate A, the angle of the impingement point below center line, by taking the inverse sin of distance D divided by the roll radius R.

Step 4. Find the center line of the air jet by taping a piece of string to the top lip of the airknife. Measure the angle from horizontal up to the string with the air on.

Note: Most air knives have an air jet that issues 5 to 7 degrees below their mechanical center line. Measure and record angle B so that you know its relationship to the angle measurement device on the airknife. This angle measurement device usually reads out the angle between the mechanical center line of the airknife and horizontal. Apply your correction factor to get angle B for any setting.

Step 5. Most airknives adjust lip to roll distance along the horizontal axis. The problem with this design is that if you move the airknife in or out, it decreases or increases, respectively, the airknife metering angle C by allowing the impingement point to move up and down the roll. Whenever you make a change of one parameter (angle or distance) with this design, you must correct the other to avoid conflicting results.

Some airknives move in and out along the air jet center line which allows either angle or distance to be changed without affecting the other.

Most airknives operate with Angle C in a range of 52^o plus or minus 3 degrees. Calculate angle B from angle C minus angle A. Set even on both sides.

Step 6. Set lip to roll distance L-R between 3 to 4.5 mm (.120 to .180") as measured by dropping feeler gages vertically between the lip and the roll. Remember to add the amount of your thickest paper to this distance if you coat board. Set equally on both sides.

Fine Tuning

Step 7. Of the two adjustments, angle and distance, you have the most latitude with distance. In general, operate as far back as possible, using about 90% of your available pressure at top machine speed. This will keep the lips as clean as possible for the longest time and still leave you some adjustment for process changes.

Step 8. The angle adjustment has the most effect on surface quality. In general, operating at too high an angle can cause vertical lines in machine direction. Operating at too low an angle can cause cross machine lines that are 1/2 to 1" long. Both conditions gradually fade away as you approach the optimum angle.

Between these two extremes are a number of conditions that can appear or disappear with a frustrating lack of consistency.

Mottle, orange peel, over-spray, and other conditions are all affected to some extent by angle, distance, coating solids, coating viscosity, sheet porosity, operating speed, sheet temperature, applicator roll speed, binder system and sheet tension.

If you make a change in angle or distance, make sure you correctly compensate the other adjustment to avoid masking the effect of the change.

The best trouble shooting procedure is to have a regular monitoring program in place to record the above variables for all grades during normal operation. Before adjusting the airknife, check to see if any other parameter is out of specification.

<u>Contour Coating</u>

The airknife is known as a contour coater. By that we mean that it applies a relatively uniform coating thickness regardless of surface roughness. This has made it especially useful for board grades that require even coverage rather than improved smoothness. It has also proven quite useful in applications of coatings that cannot accept mechanical contact or are themselves abrasive or corrosive.

The airknife has had a longer operating history than most coating methods. Its major market is now under attack. New rod coaters are coming on stream that are being used on the same grades that airknives have traditionally coated.

These new coaters use an air loaded rod against a backing roll. The contour coating is provided by the use of threaded rods that meter low viscosity, high solids coatings volumetricly. These coatings flow through the grooves of the rod, and then over the surface of the sheet. They form a slightly smoother contour coating than the airknife.

The major drawback with these systems has been the wear of the threaded rods. Titanium dioxide coatings (the major market for airknives) are extremely abrasive. Recent advances in abrasion resistance coating application systems have provided the solution to this problem. Today, threaded rod systems can replace almost any airknife with benefits ranging from higher solids to better uniformity and less off-quality paper.

<u>Conclusion</u>

The airknife is, and will remain, a valuable coating tool for many years to come. Recent inroads to its core markets have dramatically reduced the number of new installations that are made with airknives.

References:

1. Booth, George, "Coating Equipment and Processes"

2. Booth, George, "Applicators for Airknife Coating", 1985 Tappi Air Coating Seminar, Sept. 1985.

3. Barton, A. K. "Airknife Coating of Natural Kraft", 1985 Tappi Airknife Coating Seminar, Sept. 1985.