

Sept. 13, 1966

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3,272,176

AIR KNIFE

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2 Sheets-Sheet 1

FIG. 1

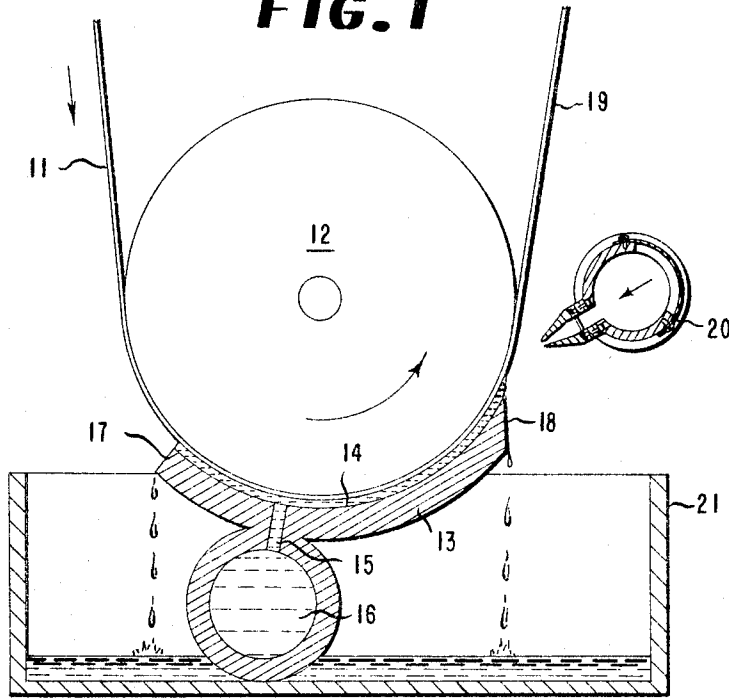
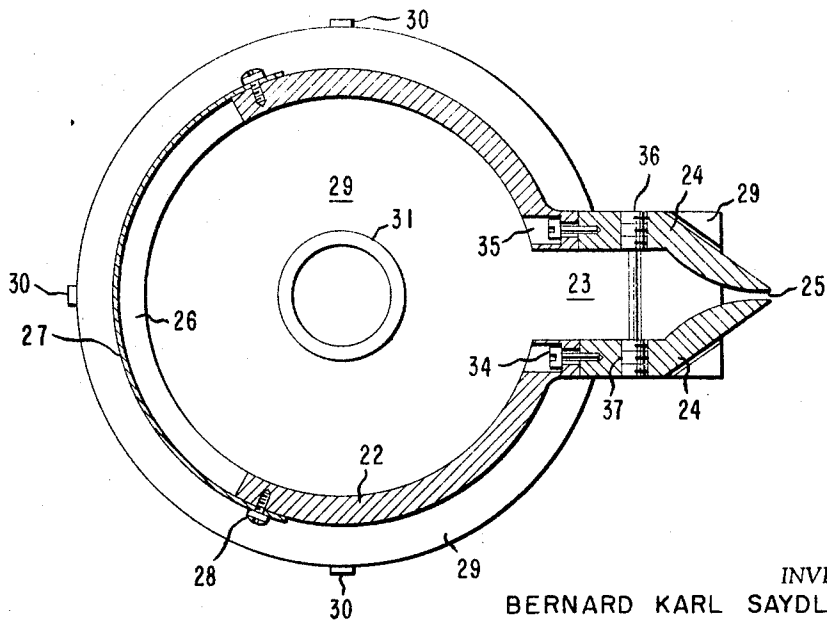


FIG. 2



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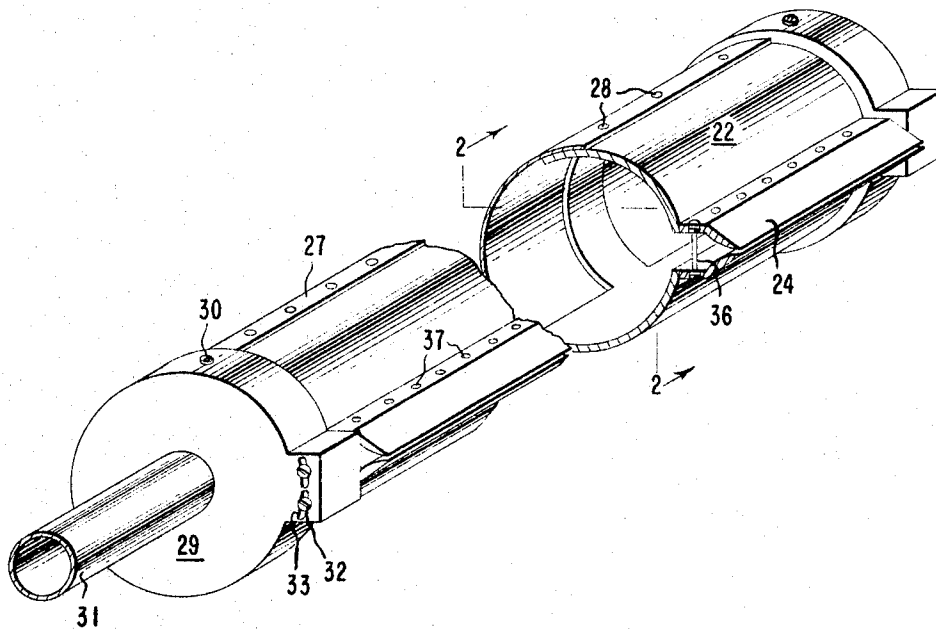
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AIR KNIFE

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FIG. 3



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1

3,272,176
AIR KNIFE

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8 Claims. (Cl. 118—63)

This invention relates to (a) an improved "air knife" or "air doctor," and (b) a coating apparatus equipped with such an air knife for smoothing and removing the excess of a liquid layer coated on web materials.

The use of air knives or air jets impinging on the coated surface to remove the excess coating and to smooth the remainder of the coating material to produce a uniform layer is well-known. This method of smoothing a coating is, of course, far superior to older methods using mechanical scraper blades or doctor rolls for this purpose. However, as the coating art has progressed and higher coating speeds have been sought it has been necessary to modify the design of existing air knives in order to overcome turbulence which, in turn, causes uneven coatings. Air knives have been designed so that a minimum of turbulence is encountered in the plenum chambers and the throats of the air knives in order to produce a uniform air stream that flows in a straight line without tending to diverge or converge. Also, by means of design modifications the air stream has been freed from pressure or density variations along its length from the orifice outwards. Another aspect of design improvement shown by the prior art has been to reduce the vibratory motion of the orifice lips caused by the air stream which in turn causes uneven layers. Other improvements have been directed to decreasing turbulence by controlling the stream of air after leaving the air knife lips.

While the above design modifications have brought about improvements in the coating art, many difficulties have become evident as higher viscosities and faster coating speeds have been attempted. During normal air knife coating, liquid in excess of the final desired coating weight is picked up by a moving web as it passes in contact with the surface of the liquid to be coated. The excess material is blown off by an impinging air stream. The uniformity or degree of smoothness with which the coatings can be applied by the air knife technique depends, in addition to the design of the air knife, on the viscosity of the material to be coated, final coating thickness, and the combination of coating speed and air knife pressure used.

One of the problems that still exists and is particularly troublesome is the character of the air jet as it leaves the air knife orifice. If this air is turbulent or the aperture from which it flows is not precisely controlled and maintained, defects such as streaks and nonuniformities in layer thickness will appear on the coated web.

Therefore, it is an object of this invention to provide improved apparatus for doctoring a liquid coating on web materials. Another object is to provide apparatus for uniformly doctoring and maintaining the desired coating weight of liquid coatings on web materials moving at high speeds. A further object is to provide apparatus for coating continuous webs utilizing an air knife that will eliminate streaks, variations in coating weight and uneven coating caused by turbulence. Another object is to provide an air knife that can be adjusted easily with precision and has sufficient rigidity to maintain the desired adjustment without deflection. Yet another object is to provide apparatus which is simple in construction, light in weight, and dependable in operation. A still further object is to provide apparatus for uniformly doctoring films coated with photographic emulsions and

2

auxiliary layers at high speed. Other objects will be apparent from the following description.

The novel air knife of this invention comprises:

(a) An elongated body having closed ends and forming a plenum chamber;

(b) A slot in a wall of, and extending lengthwise of, said chamber to form a fluid exit;

(c) A pair of lip members having their inner ends adjacent said slot and fastened to said chamber, at least one lip member being slideably fastened, and having their outer ends forming near their extremities a narrow orifice (one lip member can be flat and the other have a converging segment);

(d) Fastening means extending through a wall of the chamber into the inner end of at least one lip member (one member can be pinned or welded to the wall and the other provided with removable fastening means);

(e) A row of adjusting bolts extending between the lip members intermediate and perpendicular to the axis of said narrow orifice, said bolts having threads on each end for engaging coactive threads in the walls of the lip members, and means on each bolt for engaging a tool to turn said bolt (the threads may be inclined in either direction and of the same or different pitch but preferably are inclined in the same direction but of different pitch); and

(f) A fluid supply inlet or inlets communicating with said plenum chamber. The inlet pipe may extend the length of the chamber and be provided with a plurality of lateral perforations or openings.

The preferred air knife preferably also has—

(g) Large spaced openings in the wall of the chamber opposite said slot; and

(h) At least one plate covering said openings and having means for fastening the plate to the outer surface of said chamber.

The elongated chamber, while preferably cylindrical, can be elliptical or polygonal, e.g., square or hexagonal.

The coating apparatus of this invention comprises:

(1) A web-guiding roll,

(2) A coating device adjacent said roll for applying a fluid coating to a web guided by said roll, and

(3) Adjacent said coating apparatus, an air knife having the features described above and disposed so that the air jet impinges upon the coating and smooths it.

The invention will now be described with reference to the accompanying drawings wherein similar reference numerals relate to similar parts throughout the several figures.

FIG. 1 is a schematic diagram of an exemplary coating apparatus with a section of the air knife in reduced size.

FIG. 2 is an end view with parts in section of the air knife of this invention taken along the line 2—2 of FIG. 3.

FIG. 3 is an isometric view of the air knife shown in FIG. 2, with parts in broken section.

The invention will first be described with the air knife as a part of a coating apparatus.

Referring to FIG. 1, in an exemplary coating operation such as described in Brandsma et al. U.S. 3,063,868 a moving web 11 passes continuously around a coating roll 12. The guide roll has an arcuate coating shoe 13 whose entire length is positioned parallel to the axis of the guide roll and whose entire arcuate surface 14 is machined to a smooth finish and is spaced at a close and substantially uniform distance from the guide roll. The arc formed by the arcuate surface of the coating shoe is substantially concentric with the circular surface of the guide roll and under the circumstances has approximately the same radius as the guide roll. The coating shoe 13 has a slot 15 running parallel to the coating roll substantially to the entire length of the coating shoe.

The slot 15 connects the reservoir 16 from which the coating material is supplied to the web through the slot in more than sufficient quantity to entirely fill the space between the guide roll and the coating shoe.

The reservoir 16 is adapted to be supplied with coating material through openings at either or both ends by suitable pumping or gravity feed means. The location of the slot along the arcuate path of the shoe is not critical but is preferably located closer to the trailing edge of the shoe 17 than the leading edge 18. By trailing edge is meant that portion of the shoe which first meets the web as it travels around the guide roll.

When the coated web 19 leaves the coating apparatus the air knife doctor 20 of the invention is used to smooth the coated layer and remove the excess liquid from the web as is well known in air knife doctor operations. The excess coating material that overflow edges 17 and 18 can be collected in a suitable trough 21. Other accessories (not shown) are used to provide an outlet for the overflow trough and to recirculate the overflow liquid. Also, means for positioning the shoe 13 with respect to the coating roll 12 are necessary, and since these means and the other accessories are well known and do not constitute part of the invention, they will not be described further.

The air knife of the invention, as illustrated in more detail in FIG. 2 and FIG. 3, basically is an elongated air nozzle constituting of an air plenum chamber 22 for uniformly distributing the air. On both sides of slot 23 that extends the length of the chamber are attached lip members or blades 24 that converge to form a long, narrow aperture 25 through which the air under pressure is ejected.

The plenum's length is dependent upon the width of the material to be doctored and its size is that which will provide uniform distribution of the air. The plenum may have a series of openings (26) opposite the blades. These openings allow the cleaning of the plenum and blades from within the air knife without disrupting the aperture adjustment. When not open for cleaning, the openings are covered with a suitable covering 27 that is readily mounted to the plenum by machine screws 28. At each end of the plenum is a closure plate 29 fastened to the body by pins 30 and provided with lateral support means. For instance, a pipe support 31 is threadably engaged within a hole in an end of one or both plates. Where only one inlet is needed, a similarly shaped trunnion can be fastened or welded to one plate. Where a separate inlet is desired, a trunnion can be fastened to each plate. Also, one or both trunnions can be bored to provide an inlet. The pipe support can be attached to suitable means for positioning the air knife in operational position. The air can be introduced to the air knife by various means, such as through the pipe support. The end plates 29 are slideably attached to the lip members by machine screws 32 that are threadably engaged within tapped holes in the ends of the members and extend through slots 33 in the end plates 29.

Lip members 24 can be two similar angular, rigid, metal blades that when mounted converge to form the narrow aperture 25 at their apex. In the illustrated embodiment the inner surfaces of the blades provide curves convex to each other. This construction makes possible the provision of an air stream or jet through the aperture that is essentially non-divergent and has reduced turbulence. However, if desired, one of the blades could have a plane inner-surface and the other a curve convex to this opposed plane surface.

In the illustrated embodiment the blades are slideably mounted on the walls of chamber 22 so that they can be moved relative to each other, i.e., toward or away from each other, without warping or intentional distortion of the blades or plenum. Alternatively, only one of the blades can be slideably mounted and the other blade fixed to the chamber wall by pins, thus providing a fixed

reference for blade adjustment. This construction permits the use of heavier blades which allows greater machining precision and results in more rigidity. The increased rigidity reduces the potential of aperture deflection due to vibratory motion and other distortions. The blades are threadably engaged by a plurality of machine screws 34 that are inserted through bored slots 35 in the plenum. The dimension of these slots 35 is such that movement of the screw 34 within the slot is allowed in the direction of blade travel.

A plurality of adjusting bolts 36 are threadably engaged in tapped holes 37 in both blades and extend between the blades. The bolts preferably have each end threaded in the same direction but at a different pitch, so that the blades move relative to each other at a rate equal to the difference in pitch. This type of adjusting means allows micrometric control of the aperture 25, i.e., the adjustment can be precisely controlled well within .0002" of the desired setting all along the length of the aperture. At least one end of the adjusting bolt has a socket or screw slot that makes it readily accessible from the outside through the holes 37. The aperture adjustment can be easily made with a socket wrench or tool. The shank portion of the bolts can be square or hexagonal to engage a tool.

In an alternate embodiment, if it is desirable to use a light weight plenum instead of the heavy plenum tubing illustrated, the blades of the air knife can be slideably attached to appropriate end plates which in turn are attached to suitable means for positioning the air knife in operational position. It may be desirable to join such end plates together with suitable connecting members to minimize distortion. The plenum can then be made of any light weight material suitable for gas confinement.

Also the apparatus of invention can be modified by either attaching to, or forming integrally with, the lower lip of the air knife a recess and a curved or streamlined surface in the path of the air stream passing between the web and the leading lip of the air knife. A variation of this takes the form of a rotating curved surface positioned similarly to the curved surface described above or positioned in a socket and forming the terminal part of the leading or lower lip of the air knife in such a manner that the inner throat surface of the lower lip is tangent to the curved rotating member. These modifications control the jet of air after it leaves the lips of the air knife.

The various parts of the apparatus according to this invention may be constructed from one or more parts secured together to form the essential features as set forth in the claims. The plenum and blades may be constructed of metal, e.g., stainless or plated steel, brass, copper, but preferably of stainless steel to reduce the product contamination potential and increase corrosion resistance. Additionally, although the doctor is referred to as an air knife doctor, other gaseous fluids such as steam or inert gases, e.g., nitrogen, helium, etc., may be used depending on the nature of the coating.

The invention will be further explained by the following example involving the coating of a photographic emulsion.

A projection speed gelatino-silver bromochloride light sensitive photographic emulsion having a viscosity of 10 centistokes at 100° F., was coated on a polyethylene terephthalate film base. The emulsion was coated at a speed of 50 feet per minute using apparatus as shown in FIG. 1 of the drawing.

An air knife doctor such as shown in FIG. 2 having an aperture opening of 0.025 inch was used to doctor the coating. The air knife was set a distance of 0.035 inch from the web with the air stream directed to impinge on the coated web at an angle of 64° from the plane of the outrunning web. The stream of air had a velocity of 54 ft./sec. at 0.65 inch of water.

Twenty adjusting bolts were used to adjust the aperture opening. These bolts had one end having a nominal out-

5

side diameter of 1/2 inch and a pitch of 20 threads per inch 1/2"—20 UHF-2A THD). The other end of the bolts had a nominal outside diameter of 1/4 inch and a pitch of 24 threads per inch 1/4"—20 UHS-2A THD).

After doctoring a visible smooth and uniform coating having a dry coating weight of 1240 mg. per square foot was obtained. The coating was free from streaks and had uniform sensitometric properties.

The novel features of the invention are not limited to the coating operation described. Any liquid coating operation that coats a surplus of liquid on the web and removes the surplus and smooths the coating by use of a doctor, e.g., skim coating, dip coating, nip roll coating, reverse roll coating, extrusion coating, etc., can use the apparatus of the invention. The invention can be used in combination with the metering device of Le Claire U.S. 2,995,469, the taut wire or rod of Wamsley 3,038,441 or the coating apparatus of Heilman 3,025,828.

A variety of coating compositions may be successfully doctored from a supporting web using the apparatus of this invention. Such coating compositions could be either aqueous or non-aqueous, containing a variety of binders both natural and synthetic, pigments, light-, heat-sensitive, or magnetic particles, etc. The supporting web upon which the coating is applied may be, for example, film, paper, cloth or metal, which already may have received one or more coatings.

An advantage of this invention is that it produces coatings of excellent smoothness and uniformity. Another advantage is that the invention makes it possible to form and maintain a precise, non-diverging air jet. Another advantage is that the aperture adjustment of the air knife blades can be precisely controlled well within .0002 inch of the desired setting without intentional distortion of the blades. The absence of intentional distortion is of particular significance and permits the use of heavy, rigid angular blades that can be machined with great precision. In the air knives of the prior art, the use of such heavy blades was not possible since the aperture between the blades was adjusted by bending or warping the blades. A further advantage is that the adjusting bolts can have a very small diameter and be located further from the aperture than in the conventional air doctors of the prior art. This construction reduces the detrimental effect of the internal adjusting means upon the uniformity of the air stream, thereby reducing the streaking potential. Another advantage is that the inner surfaces of the blades and plenum can be easily cleaned without disrupting the operational adjustment of the air knife.

I claim:

1. An air knife which comprises
 - (a) an elongated body having closed ends and forming a plenum chamber;
 - (b) a lengthwise slot in the wall of said chamber forming a fluid exit slot, the outer surface of the body adjacent said slot having planar surfaces extending laterally from said slot;
 - (c) a pair of lip members disposed adjacent said slot the ends of the lip members having planar surfaces that interfit with the respective planar surfaces of the body when the lip members are attached thereto, at least one lip member being fastened to the body for slideable adjustment, thereof the outer portions of the

6

lip members forming an orifice near their outer extremities;

- (d) bored slots in the inner wall of said chamber adjacent the planar surfaces and coactive openings in the walls of the chamber communicating with the slots and engageable openings in the planar ends of the lip members;
- (e) fastening means of smaller dimensions than and extending through said slots and coactive openings and engaging the openings in the lip members, the fastening means for at least one lip member being adjustable whereby the lip member can be adjusted laterally and aligned adjacent the fluid exit;
- (f) a row of adjusting bolts extending between said lip members and perpendicular to the axis of said orifice, the bolts being threaded on each end and provided with means for engaging a tool for turning the bolts;
- (g) a fluid supply inlet communicating with said chamber;
- (h) large spaced openings in the wall of said chamber opposite said slot; and
- (i) a plate covering said openings.

2. An air knife according to claim 1 wherein each lip member is fastened to the body member by removable threaded fastening means.

3. An air knife according to claim 1 wherein said chamber is cylindrical.

4. An air knife according to claim 1 wherein the closed ends are plates provided with lateral support means.

5. An air knife according to claim 1 wherein a closed end is provided with an inlet passage for air.

6. An air knife according to claim 1 wherein the adjusting bolts have shanks of small cross section between the larger threaded ends.

7. An air knife according to claim 1 wherein the lip members are curved on their inner surfaces as they approach the orifice.

8. A coating apparatus comprising

- (1) a web-guiding roll,
- (2) a coating device adjacent said roll for applying a fluid coating to a web guided by said roll and
- (3) adjacent said coating apparatus, an air knife defined in claim 1 disposed so that the air jet issuing from the orifice will impinge on the applied coating and smooth it.

References Cited by the Examiner

UNITED STATES PATENTS

1,899,449	2/1933	Wallsten.
1,980,923	11/1934	Lebel.
2,139,628	12/1938	Terry.
2,366,926	1/1945	Melton.
2,415,644	2/1947	Leonhard et al. ---- 118—63 X
2,766,720	10/1956	Muller et al.
3,063,868	11/1962	Brandtsma et al.

FOREIGN PATENTS

953,034 11/1956 Germany.

MORRIS KAPLAN, *Primary Examiner.*