

Dec. 6, 1938.

K. E. TERRY

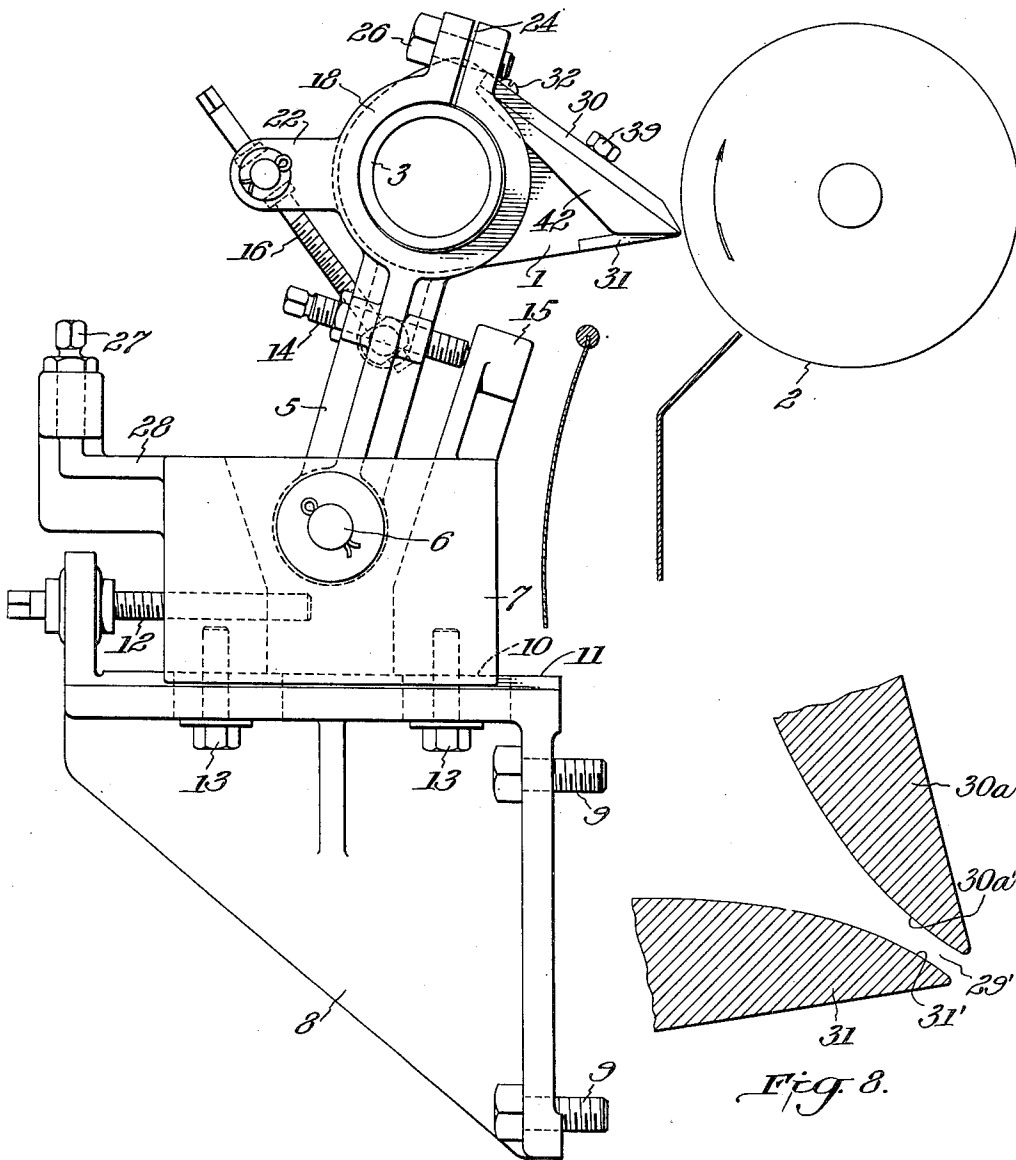
2,139,628

AIR DOCTOR

Filed May 6, 1936

3 Sheets-Sheet 1

Fig. 1.



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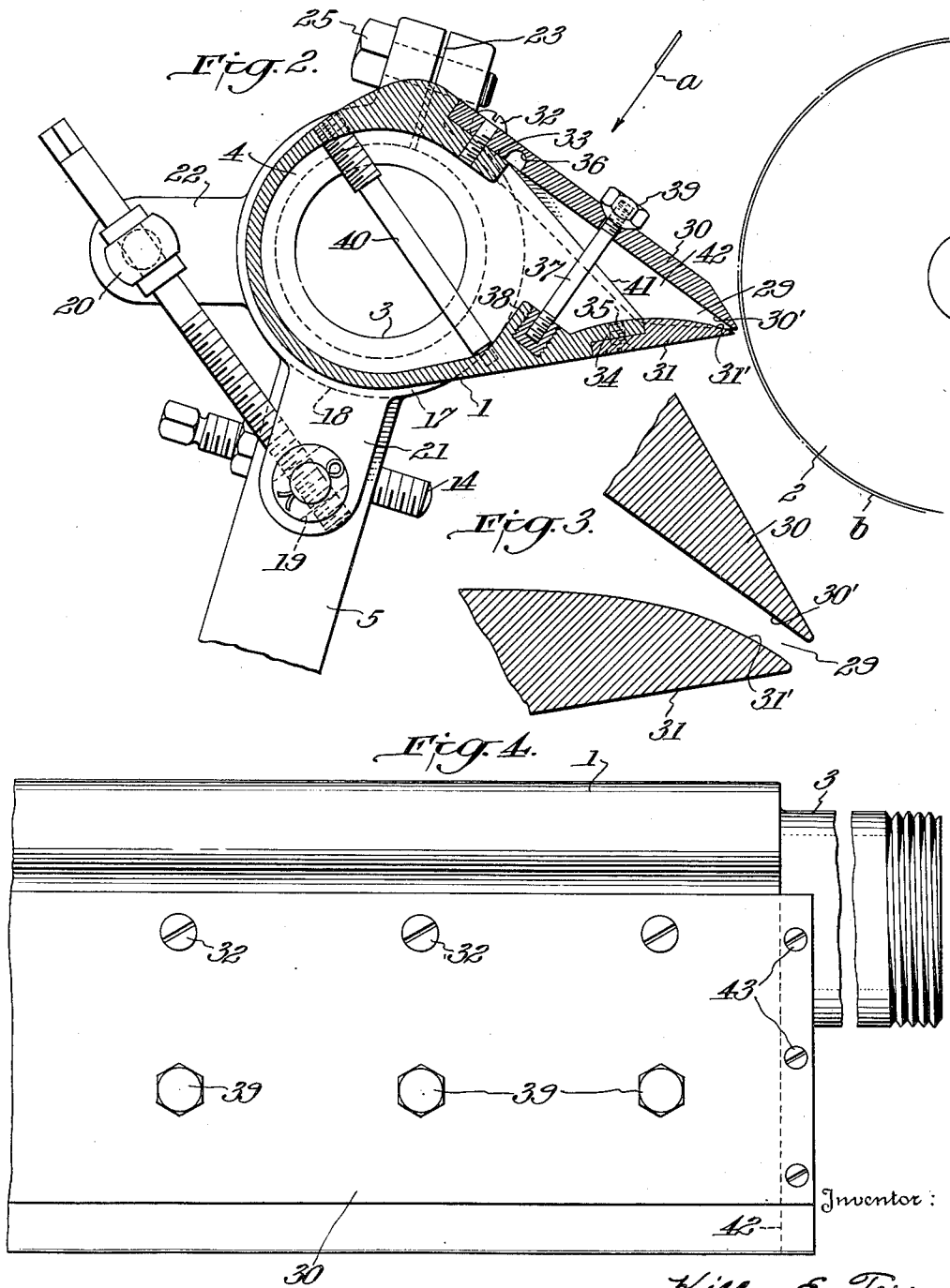
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3 Sheets-Sheet 2



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Fig. 5.

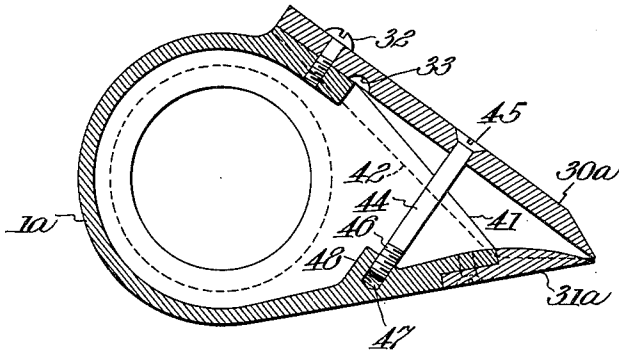


Fig. 6.

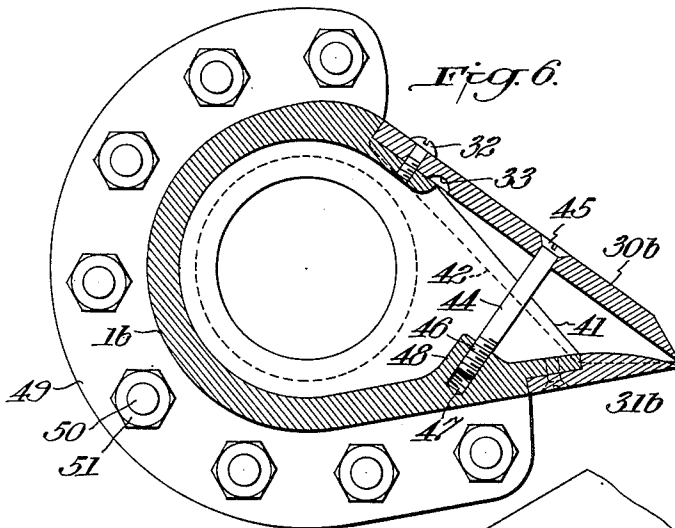
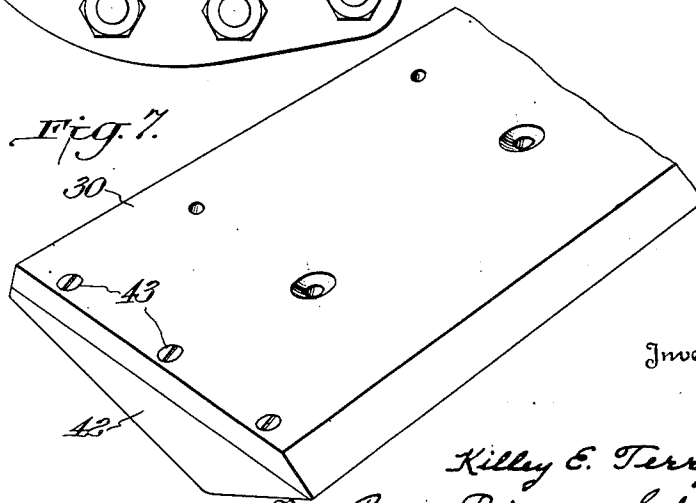


Fig. 7.



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UNITED STATES PATENT OFFICE

2,139,628

AIR DOCTOR

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Application May 6, 1936, Serial No. 78,235

11 Claims. (Cl. 91—18)

The present invention relates to apparatus adapted to deliver a relatively thin, elongated, jet or stream of fluid, e. g., a gaseous fluid such as air, and is concerned more particularly with an improved form of nozzle capable of delivering a relatively thin, elongated, sheet or ribbon of air (or other gas) of relatively non-divergent form. The structure of the present invention finds application in or connection with coating machines wherein a fluid coating, applied in continuous manner to a moving surface, is evened off and smoothed. Accordingly, in the following the invention will be described with particular reference to its application to a paper coating machine.

In paper coating machines, whether of the type in which the fluid coating material is received by an applicator roll, smoothed and evened thereon, and then transferred to the moving paper, or of the type in which the fluid coating material is applied directly to the paper and smoothed and evened thereon, it is customary to provide some mechanical means, such as a doctor, in scraper or roll form, for regulating the thickness of the coating. It has been customary, also, to provide scrapers, rolls or brushes for properly distributing, and smoothing or evening, the coating material just subsequent to its application to the surface. Various types of devices have been provided for these purposes, mainly of the mechanical forms just referred to, but such devices with which I am familiar have inherent disadvantages: thus, they are or may be subject to rapid wear, and their replacement, repair and readjustment entail an expense out of all proportion to their period of usefulness. Again, they are or may be relatively inflexible with respect to the width of the article being coated.

Proposals have been made to employ an "air doctor" in lieu of a mechanical scraper or of a doctor roll, and such "air doctor" has actually been employed in smoothing fluid coatings on moving webs of paper. However, the prior "air doctors" known to me had certain disadvantages. Thus, it was found that in certain prior art constructions, the nozzle operating at a pressure of 3 to 6 lbs. per square inch gauge, the air density of the issuing air stream was less than that of the ambient air. Also, the conditions were such that the air density varied along the stream or jet from the orifice outwardly. Moreover, the nozzle design did not insure an air stream flowing in a straight line but rather gave rise to a divergent stream. In some instances, vibratory motion of the orifice lips was induced.

An object of the present invention is the provision of an improved apparatus of the kind above described, which is free from the objections aforesaid. A further object of invention is the provision of a nozzle yielding an air stream flowing in a straight line without tending to diverge or converge, which stream shall be free from pressure, or density, variations along its length from the orifice outwards, in which nozzle no vibratory motion of the orifice lips will be induced. Other objects of invention will be apparent from a consideration of the following disclosure.

It has been found that the shape of the stream, delivered by the nozzle, is in general dependent in part upon the shape of the lower throat and orifice of the nozzle and upon the pressure of the emergent stream, and that the particular shape of the plenum chamber is of minor importance so long as it is made sufficiently large. Where the throat is well rounded so that the pressure change is gradual, and the pressure of the emerged stream is equal to the pressure of the ambient air, a straight-line stream of air results. But where the pressure of the emergent stream is higher than that of the ambient air, a special orifice must be used to obtain a straight-line stream free from variations.

The nozzle of the present invention comprises a relatively large plenum chamber one side of which, in effect, is materially elongated and flattened to define a throat portion of progressively decreasing cross-sectional area terminating in complementary lips forming a slit, or slot, orifice. Both lips may provide curves convex to each other; thus, both lips may have elliptical cross-sections. Except in particularly exacting cases, commercially good results are obtained where one of the lips provides a plane surface while the other provides a curve convex to the opposed plane surface: in such case, at least a portion of the throat wall adjacent the curved lip preferably is curved to conform to the curve of the latter. The latter construction is simpler to make and to adjust. The plenum chamber, throat and lips are substantially coextensive and rectilinear. A plurality of means are provided for warping a wall of the throat portion towards the other wall, whereby to vary the width of the orifice between the lips and to control and maintain the uniformity of the opening along the nozzle. Also there are provided means for pivotally supporting the nozzle, means for adjusting the angularity of the nozzle with respect to said supporting means, means for determining

the extent of pivotal motion of said supporting means, and means for varying the location of the supported nozzle on a base.

In the accompanying drawings illustrating the invention, in the several figures of which like parts are similarly designated,

Fig. 1 is a side elevation, with parts in partial section, of mechanism embodying the invention, the same being shown in proper operative relation to a coating applicator roll;

Fig. 2 is an enlarged fragmentary sectional elevation of parts of the apparatus illustrated in Fig. 1, the nozzle being shown in cross-section;

Fig. 3 is a greatly enlarged view illustrating one form and arrangement of the co-operating lips which provide the elongated orifice of the nozzle through which the jet of air is emitted;

Fig. 4 is a sectional plan view of a portion of the apparatus illustrated in Fig. 2, viewed in the direction of the arrow *a*, Fig. 2;

Figs. 5 and 6 illustrate modifications of the plenum chamber and nozzle of the invention;

Fig. 7 is a fragmentary perspective view of the adjustable plate means of the nozzle, and

Fig. 8 is a greatly enlarged view illustrating a modified form and arrangement of the cooperating lips shown in Fig. 3.

Referring particularly to Figs. 1, 2, 4 and 7, it will be seen that the apparatus illustrated therein includes a plenum chamber formed by a casing 1, preferably provided as an aluminum or other operable metal casting of an axial length sufficient to span the applicator roll 2 or the sheet or other article to be coated, such as the sheet of paper illustrated by *b*, Fig. 2, depending upon the process of coating being practiced. The casing 1 is provided at each end with a tubular sleeve or extension 3, these extensions serving not only as a means for introduction of air into the plenum chamber 4, but also as trunnions upon which the casing may be adjustably carried in complementary arms 5 pivoted at 6 in similar slides 7 mounted upon brackets 8, which latter may be secured, as by cap screws 9, to appropriate parts of the frame of the coating machine.

Complemental guides 10 and ways 11 on the slides and brackets, respectively, and adjusting screws 12 and clamping screws 13, provide for suitable adjustment of the slides 7 with respect to the brackets, and by these means it is possible to advance and retract the casing 1 relatively to the roll 2.

In addition to the adjustment of the casing 1 just referred to, angular adjustment of the nozzle, hereinafter to be particularly described, with respect to the periphery of the roll 2, or other surface in like position, may be accomplished by means of adjusting screws 14 carried by the arms 5 and bearing against stops 15 carried by the slides 7, and by adjusting screws 16 which provide for relative rotative movement between collars 17 clamped to the trunnion extensions 3 and collars 18 forming parts of the arms 5, these adjusting screws 16 cooperating with swivel members 19 and 20 carried by ears 21 and 22 extending radially from the collars 17 and 18, respectively. The collars 17 and 18 are both split, as indicated at 23 and 24, respectively, and may be clamped upon the trunnion sleeves 3 by means of screws 25 and 26, respectively. Thus, when appropriate angular rotative adjustment of the casing 1 has been made by adjustment of the adjusting screws 16, the casing may be clamped in such adjusted position by tightening the screws 25 and 26. Obviously, the collars 17 nor-

mally remain tightly clamped upon the trunnion sleeves 3 so as to impart rotative angular adjusting movement to the casing 1, and the trunnion sleeves are capable of turning relatively freely in the collars 18 which form parts of the arms 5. However, greater latitude of adjustment may be obtained by adjusting the casing 1 with respect to the collars 17, and this is made possible by virtue of the clamped frictional connection of the collars 17 with the trunnion sleeves 3.

When in operative position, as shown in Figs. 1 and 2, the assembly of the casing 1 on the arms 5 is supported upon the pivots 6 by contact of the adjusting screw 14 with the stops 15. It will be apparent, however, that the casing 1 may be swung away from the roll 2 upon the pivots 6, and when thus swung may be supported by adjustable stop screws 27 carried in offstanding brackets 28 on the slides 7, the screws 27 being so positioned as to contact with the collars 17.

Referring now particularly to the form of the casing 1 illustrated in Fig. 2, it will be appreciated that throughout its length the plenum chamber 4 is of relatively large size for the reception of relatively low pressure air (say, up to six pounds per square inch pressure) admitted through the trunnion sleeves 3, but that the effective area of the chamber is reduced through the nozzle as the orifice 29 is approached, whereby the velocity of the emitted air jet is very greatly increased over that of the air entering the plenum chamber.

As hereinbefore mentioned, one feature of the invention resides in the provision of means whereby the elongated jet of air may be given a substantially non-divergent character, thus enhancing its efficiency and enlarging its sphere of utility. To this end, the nozzle includes cooperating elements comprising plates 30 and 31, the inner surfaces of which, particularly that of the plate 31, present contours of predetermined character to provide lips for the orifice 29 of such shape as to ensure the emission of an elongated jet of air having the desired characteristics, as will be referred to later in more detail.

The plate 30 is secured by a plurality of screws 32 upon a seat 33 preferably forming a part of the casting of the casing, and the plate 31 is similarly secured upon an appropriate similarly formed seat 34 of the casing casting, by means of a plurality of screws 35. The plate 31 is preferably of rigid form and the means by which it is secured to the casing 1 are such as to maintain it in predetermined fixed relation with respect thereto.

The plate 30, however, preferably is adapted to be warped throughout the axial length of the nozzle so that appropriate adjustment of the orifice slit may be obtained, as desired. This warping of the plate 30 is facilitated by providing it with a weakening groove 36 adjacent to its point of attachment to the casing 1, and a plurality of stud bolts 37 secured in lugs 38 fixed in the casing 1 receive ball-seated adjusting nuts 39 whereby an adjusting leverage may be exerted upon the plate 30 to warp it upon the groove 36 as a pivot. In the preferred form of orifice adjustment means shown in Fig. 2, the stud bolts 37 extend through plate 30 by way of opening of slightly greater diameter than that of the bolts, whereby the relationship of the plate to the bolts may be varied somewhat with binding of the bolts, and without springing of the plate. The adjusting nuts 39 are ball-seated in complementary recesses in plate 30, whereby to

provide substantial air-tight engagement between the nuts and the plate regardless of slight tilting of the bolts and nuts.

As will be apparent from the showing of Fig. 4, the bolts 37 and nuts 39 are arranged at intervals throughout the width of the plate 30, and hence the warping effect of adjustment of these nuts 39 upon the plate 30 may be varied throughout its width to appropriately and uniformly vary the slit forming the nozzle orifice.

The casing 1 is preferably made as an aluminum casting as stated, the advantages of the use of such metal being obvious. The plates 30 and 31, however, are preferably made of phosphor bronze. Inasmuch as the strain incident to adjustment of the nozzle 29 by means of the nuts 39 is transmitted from one point of the casing 1 to another point thereof relatively remote therefrom, it may be advisable to interpose a plurality of strut screws 40 so arranged as to most effectively counteract and absorb the strains referred to.

At will be apparent, particularly from an inspection of Fig. 2, the end walls of the casing 1 terminate in diagonally extending edges 41, thus leaving between the lip of the plate 31 and the plate 30 triangular or V-shaped openings, and these openings are closed by appropriately shaped guards 42 secured by screws 43, or otherwise, to overhanging portions of the plate 30 (see Fig. 7), the guards 42 being thus positioned against the ends of the casing 1 and preferably in sliding engagement with respect thereto to accommodate movement imparted to the plate 30 by adjustment of the nuts 39.

Referring now to Fig. 3, wherein the lips of the plates 30 and 31 are shown upon a greatly enlarged scale to illustrate the particular complementary facial characteristics by which the desired form of nozzle and orifice thereof are provided, it will be seen that the lip 30' of the plate 30 is preferably formed as a plane surface, whereas the lip 31' of the plate 31 is a segment of a curve which preferably forms a part of an ellipse. The cooperating influence of lips having these facial characteristics, in combination with a relatively large plenum chamber and the communicating throat hereinbefore described, have been found, in practice, to produce, through the slit-like or slot-like orifice of the nozzle, a stream or jet of air of non-divergent character and of a suitable velocity, dependent upon the pressure of the air entering the plenum chamber, to provide a "pneumatic knife" effect capable of accomplishing desirable results, e. g., the desired action upon fluid coating materials against which it is projected. The proper angular adjustment of the nozzle with respect to the roll or surface against which the air jet is projected may be obtained by the adjusting mechanism hereinbefore described.

Instead of the combination of plane and convex lips as is illustrated in Fig. 3 the combination shown in Fig. 8 may be employed. In the latter figure, plate 30a substantially duplicates plate 31 in lip configuration, the orifice 29' being defined by the two curved lip surfaces 31' and 30a'. This construction makes possible the provision of an air stream or jet of non-divergent character.

In the modified form of the invention illustrated in Fig. 5, the plenum chamber of the casing 1a and the arrangement of the plates 30a and 31a providing the jet nozzle are substantially similar to those just described, and have similar

characteristics of influence upon the current of air. However, the means for warping the plate 30a is simplified in that instead of using stud bolts and adjusting nuts, adjusting screws 44 having their heads 45 bearing against the outer face of the plate 30a and their screw-threaded ends 46 cooperating with complementally screw-threaded sockets 47 in bosses 48 of the casing 1a are employed.

As thus far described, the casing 1 is provided as a single integral casting of appropriate dimensions as to diameter and axial length. In the modification of the invention illustrated in Fig. 6, however, the casing 1 is shown as made up of a plurality of sections 1b of appropriate length, each section being provided with integral bolting flanges 49 by which any number of the sections may be joined by means of appropriate bolts 50 and nuts 51 to produce a casing of desired appropriate length for the particular installation in which it is employed. The characteristics of the casing and of the planes 30b and 31b whereby an appropriate plenum chamber and jet nozzle are formed, are substantially the same as those hereinbefore described, and may take either the form illustrated in Fig. 5, or in Figs. 1 and 2, so far as details are concerned. Regardless of the number of portions constituting casing 1, I intend that each of the plates 30b and 31b shall be unitary; also, that in all modifications of the apparatus, each of said plates (30b or 30 or 30a, and 31b or 31 or 31a) shall be unitary and substantially coextensive with the plenum chamber, and shall have substantially constant cross-sectional form.

As will be apparent, the effective length of the orifice of the nozzle of the present invention may be made shorter than the maximum by closing a portion or portions thereof. This may be effected by, for instance, fitting a sheet of material, of the thickness corresponding to the desired orifice width, between the lips of the nozzle, thereby closing off that portion or those portions of the orifice through which it is desired no air shall pass.

For further explanation, reference is had to the following illustrative data: An "air doctor" the plenum chamber of which has a diameter of 4 inches has an orifice slit of 0.025 inch. For the first 0.015 inch back of the orifice the lips are plane and parallel; thereafter the curved lip diverges from the plane lip through a continuous and regular convex curve, so that at 0.25 inch from the actual orifice the divergence between the lips amounts to 0.10 inch, and progressively increases thereafter through the throat portion of approximately 4 inches extent until the throat wall merges with that of the plenum chamber. This "air doctor" delivers a non-divergent stream at 960 ft./sec., using air at about 10 pounds pressure throttled to control pressure at the orifice at from 2 to 6 pounds. It is adjusted to deliver the stream at an acute angle with respect to the tangent of the opposed surface carrying a fluid coating, the angle varying between about 40° and about 65° (preferably, about 41.5° in the case of an opposed 8 inch diameter applicator roll), the angle depending upon the linear speed of the opposed surface, the viscosity of the fluid coating, the desired weight of coating retained on the opposed surface, the velocity of the "air doctor" stream, and other variables. I have found that by use of this "air doctor" paper coatings which, with reciprocating brush smoothing devices, could not be run at a speed faster

than about 300 linear feet per minute, can be run at two or more times that speed, with no wave effect or other unevenness of the coating.

I claim:

5 1. An air doctor, adapted for use in a coating machine, for producing a thin, elongated, high-velocity substantially non-divergent stream of gaseous fluid, comprising an elongated plenum chamber of relatively large cross-sectional area, 10 converging walls defining a throat portion communicating with said plenum chamber which throat walls terminate in spaced complemental lips forming a discharge orifice, the outer edges of said lips being straight and parallel and co- 15 extensive with said throat portion and said plenum chamber, one of said lips providing a curved surface convex to the other lip, and said throat portion being relatively short in a direction normal to the major axis of the plenum chamber and having its walls rapidly approaching each other in the direction of the orifice whereby greatly to increase the momentum of a gaseous fluid moving under pressure from said plenum chamber to said orifice.

25 2. An air doctor, adapted for use in a coating machine, for producing a thin, transversely elongated, high-velocity, substantially non-divergent stream of gaseous fluid, comprising an elongated plenum chamber of relatively large cross-sectional area, a throat portion co-extensive with said plenum chamber, and spaced lip portions providing a discharge orifice, the outer edges of said lip portions being straight and parallel and co- 30 extensive with said throat portion, one of said lip portions providing a curved surface which is convex to the opposed lip surface and is a segment of a curve forming a part of an ellipse.

3. An air doctor, adapted for use in a coating machine, for producing a thin, transversely 40 elongated, high-velocity, substantially non-divergent stream of gaseous fluid, comprising an elongated plenum chamber of relatively large cross-sectional area, a throat portion co-extensive with said plenum chamber, and spaced lip portions providing a discharge orifice, the outer edges of said lip portions being straight and parallel and co-extensive with said throat portion, one of said lip portions providing a curved surface which is 45 convex to the opposed lip surface and is a segment of a curve forming a part of an ellipse, which convex curvature continues backwardly along a substantial part of the adjacent throat wall, the other lip portion providing a plane surface.

55 4. An air doctor, adapted for use in a coating machine, for producing a thin, transversely elongated, high-velocity, substantially non-divergent stream of gaseous fluid, comprising an elongated plenum chamber of relatively large cross-sectional area, a throat portion co-extensive with said plenum chamber, and spaced lip portions providing a discharge orifice, the outer edges of said lip portions being straight and parallel and co- 60 extensive with said throat portion, each of said lip portions providing a curved surface which is convex to the opposed lip surface and is a segment of a curve forming a part of an ellipse, the convex curvatures of said lip portions continuing backwardly along a substantial part of the adjacent walls.

70 5. An air doctor as defined in claim 1, characterized in that the confronting surfaces of the lips, immediately adjacent the outer edges thereof which define the discharge orifice, are straight plane and parallel for a distance, rearwardly from

said edges, which is not greater than the distance between said edges, said plane surfaces merging into the surfaces of the respective lips.

6. An air doctor as defined in claim 2, characterized in that the throat portion is defined 5 by walls communicating with the plenum chamber, and in that a plurality of means for warping the throat walls toward each other are provided at spaced intervals along the length of the air doctor whereby to determine the width, and to 10 control the uniformity of opening, of the discharge orifice.

7. An air doctor as defined in claim 1, characterized in that a plurality of means for warping the throat walls toward each other are provided 15 at spaced intervals along the length of the nozzle, whereby to determine the width and control the uniformity of opening of the orifice.

8. An air doctor as defined in claim 3, characterized in that an elongated, substantially 20 straight, cross-sectionally unitary member defines the plenum chamber and at least part of the curved side of the throat, in that a unitary member having one plane surface defines the plane surfaced lip and its adjacent throat portion, and 25 in that the lip portion providing the curved surface includes a detachable section secured to said throat portion and having its curved surface merging into that of the adjacent throat portion.

9. An air doctor apparatus, adapted for use in 30 a coating machine, for producing a thin elongated high velocity substantially non-divergent stream of air, comprising a relatively large casing defining a relatively large plenum chamber, walls defining a throat portion coextensive with 35 and communicating with said casing and terminating in spaced lips defining a discharge orifice, the outer edges of said lips being substantially straight parallel and coextensive with said throat portion, one lip and one throat wall presenting a plane surface and the other lip and other throat 40 wall providing a curved surface constituting a segment of an ellipse which, with relation to the opposed plane surface, is convex from the orifice backwardly towards the plenum chamber, trunnions carried at the ends of the plenum chamber casing at least one of said trunnions being hollow and communicating with the interior of the casing, and means providing bearing supports for said trunnions.

10. An air doctor apparatus, adapted for use 50 in a coating machine, for producing a thin elongated high velocity substantially non-divergent stream of air, comprising a relatively large casing defining a relatively large plenum chamber, walls defining a throat portion coextensive with 55 and communicating with said casing and terminating in spaced lips defining a discharge orifice, the outer edges of said lips being substantially straight parallel and coextensive with said throat portion, one lip and one throat wall presenting a plane surface and the other lip and other throat wall providing a curved surface constituting a segment of an ellipse which with relation to the 60 opposed plane surface, is convex from the slit orifice backwardly towards the plenum chamber, trunnions carried at the ends of the plenum chamber casing at least one of said trunnions being hollow and communicating with the interior of the casing, horizontally adjustable base 70 members, and means for pivotally supporting the trunnions above said base members.

11. An air doctor apparatus, adapted for use in a coating machine, for producing a thin elongated high velocity substantially non-divergent 75

stream of air, comprising a relatively large casing defining a relatively large plenum chamber, walls defining a throat portion coextensive with and communicating with said casing and terminating in spaced lips defining a discharge orifice, the outer edges of said lips being substantially straight parallel and coextensive with said throat portion, one lip and one throat wall presenting a plane surface and the other lip and other throat wall providing a curved surface constituting a segment of an ellipse which, with relation to the opposed plane surface, is convex

from the slit orifice backwardly towards the plenum chamber, trunnions carried at the ends of the plenum chamber casing at least one of said trunnions being hollow and communicating with the interior of the casing, adjustable base members and a pair of supporting arms pivotally mounted thereon, means for clamping the casing trunnions in said supporting arms, and means for adjusting the angularity of said casing with respect to said supporting arms.

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