Aug. 20, 1935. M. L. WOODRUFF 2,012,115

METHOD OF AND APPARATUS FOR DRYING A CONTINUOUS WEB

Filed Feb. 17, 1932 4 Sheets-Sheet 1

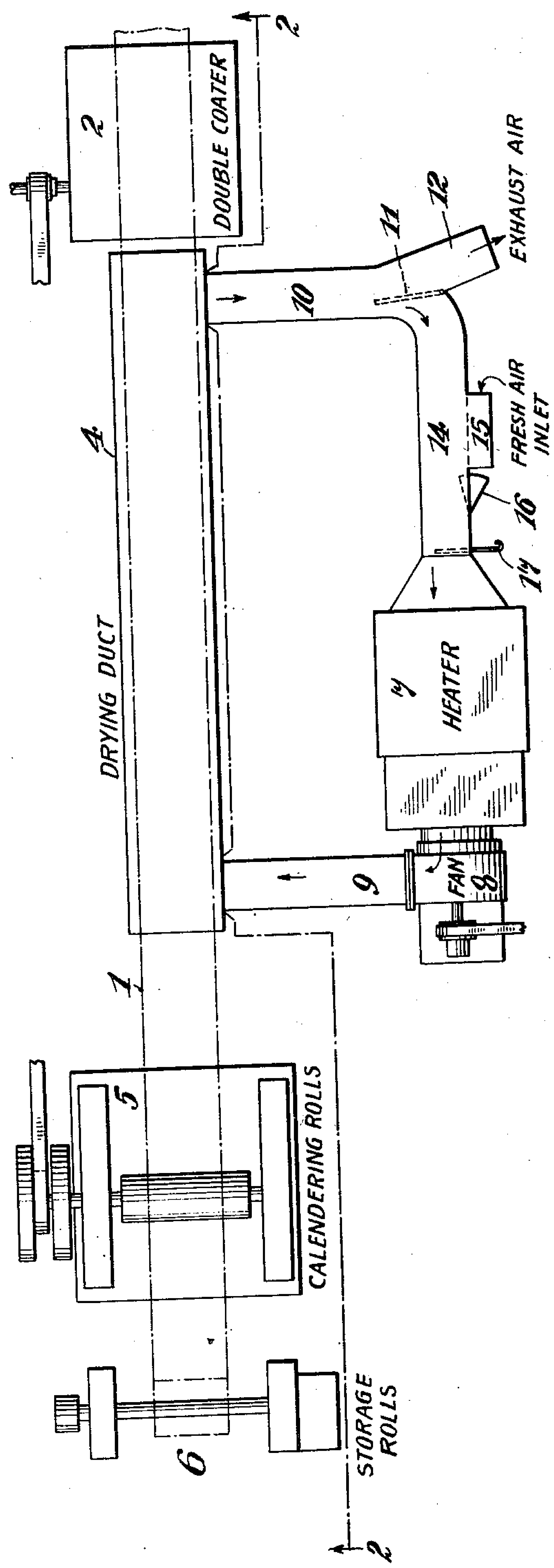

Fig. 1.

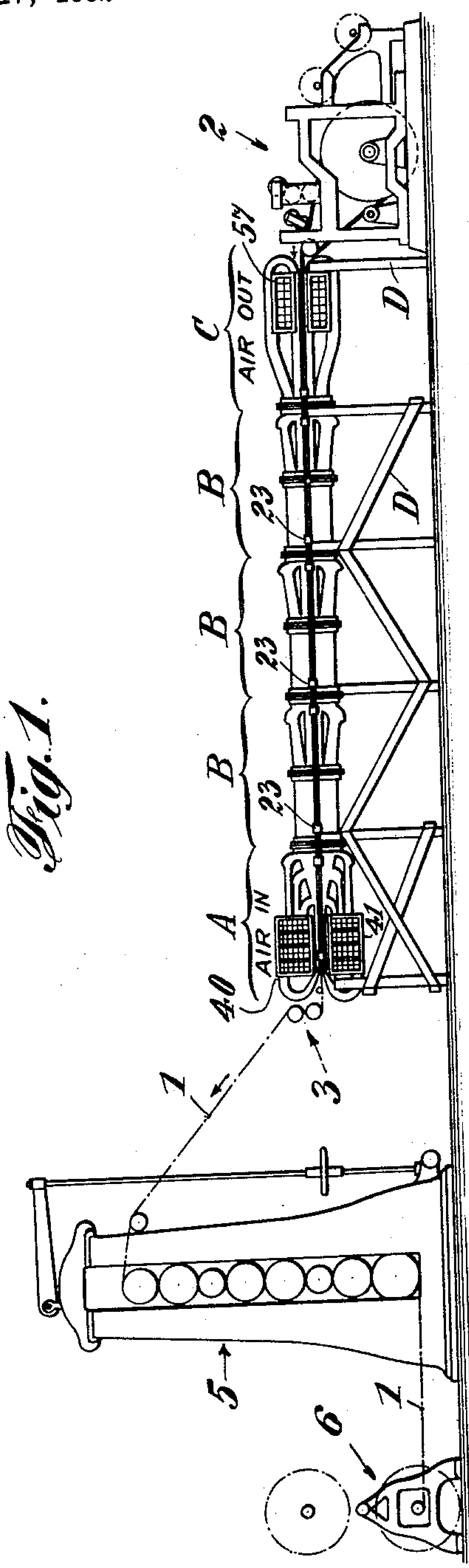

Fig. 2.

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Filed Feb. 17, 1932 4 Sheets-Sheet 2

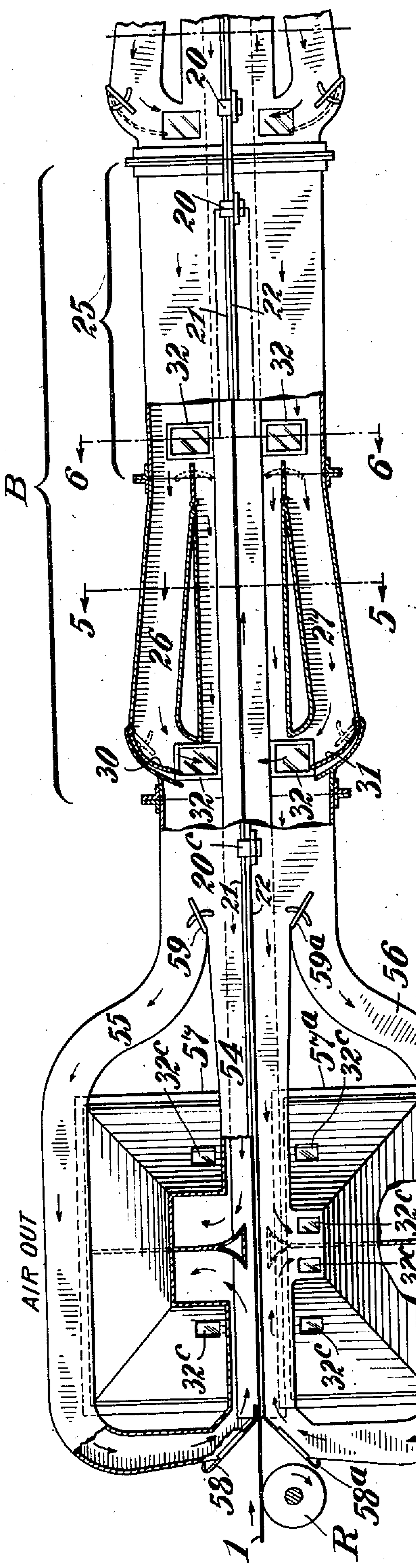

Fig. 3.

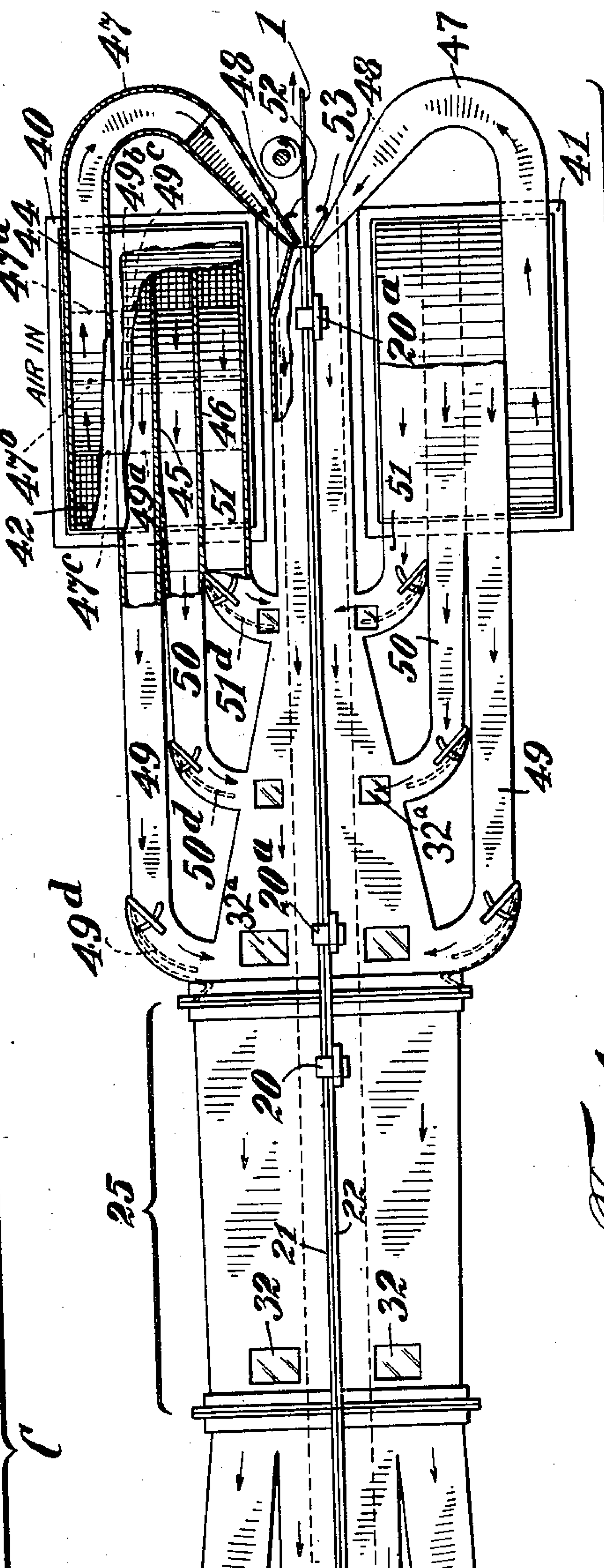

Fig. 4.

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METHOD OF AND APPARATUS FOR DRYING A CONTINUOUS WEB

Filed Feb. 17, 1932 4 Sheets-Sheet 3

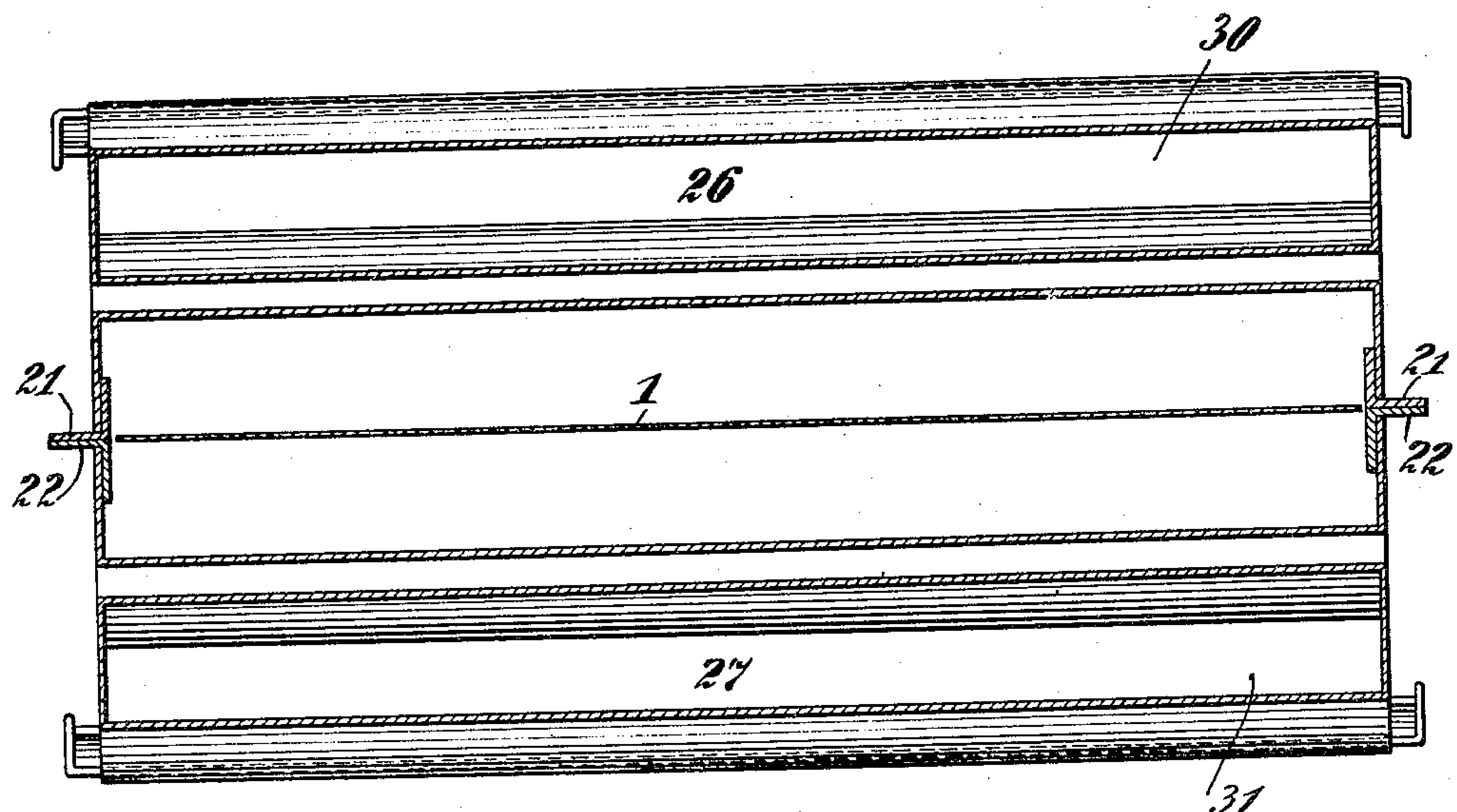

Fig. 5.

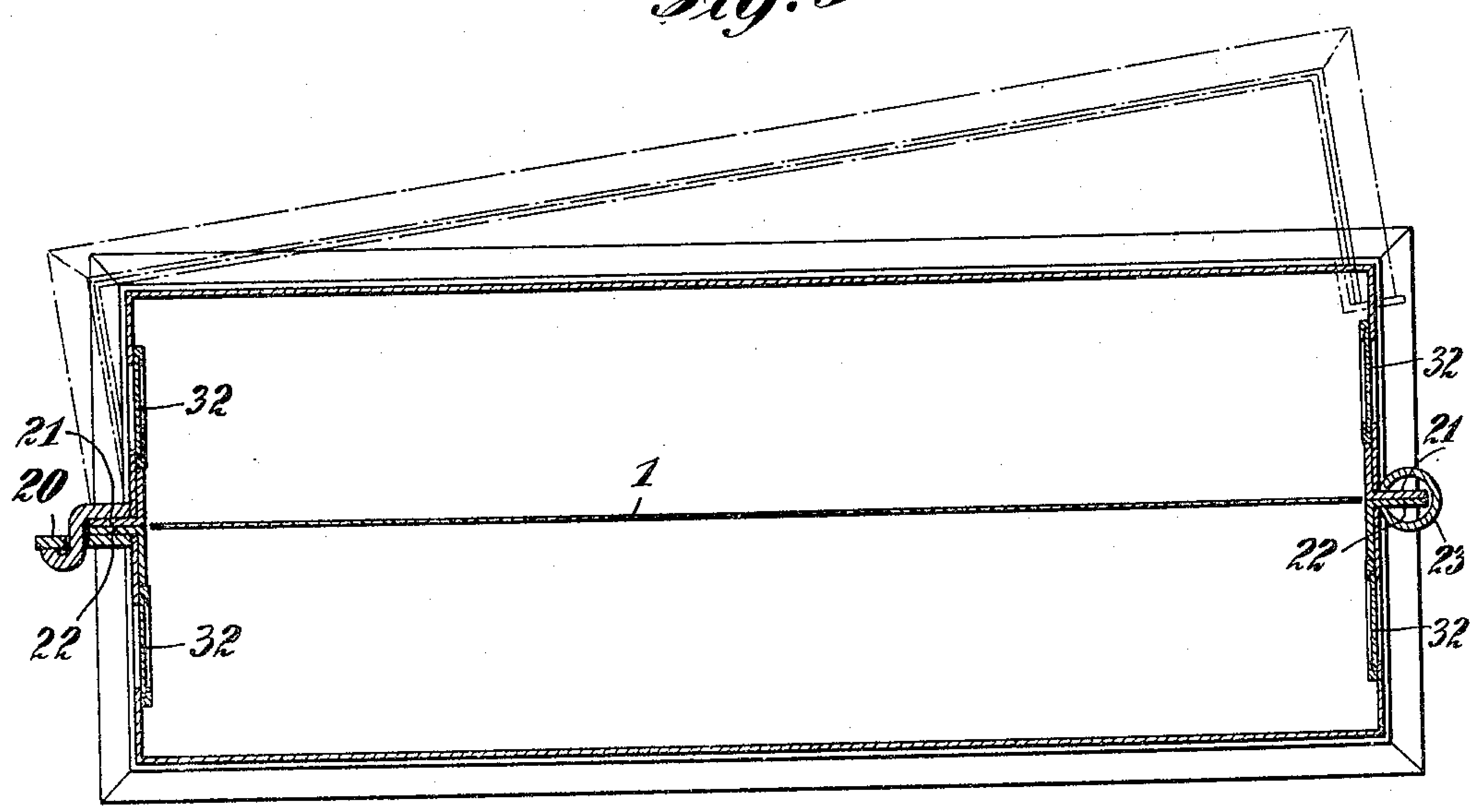

Fig. 6.

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METHOD OF AND APPARATUS FOR DRYING A CONTINUOUS WEB

Filed Feb. 17, 1932 4 Sheets-Sheet 4

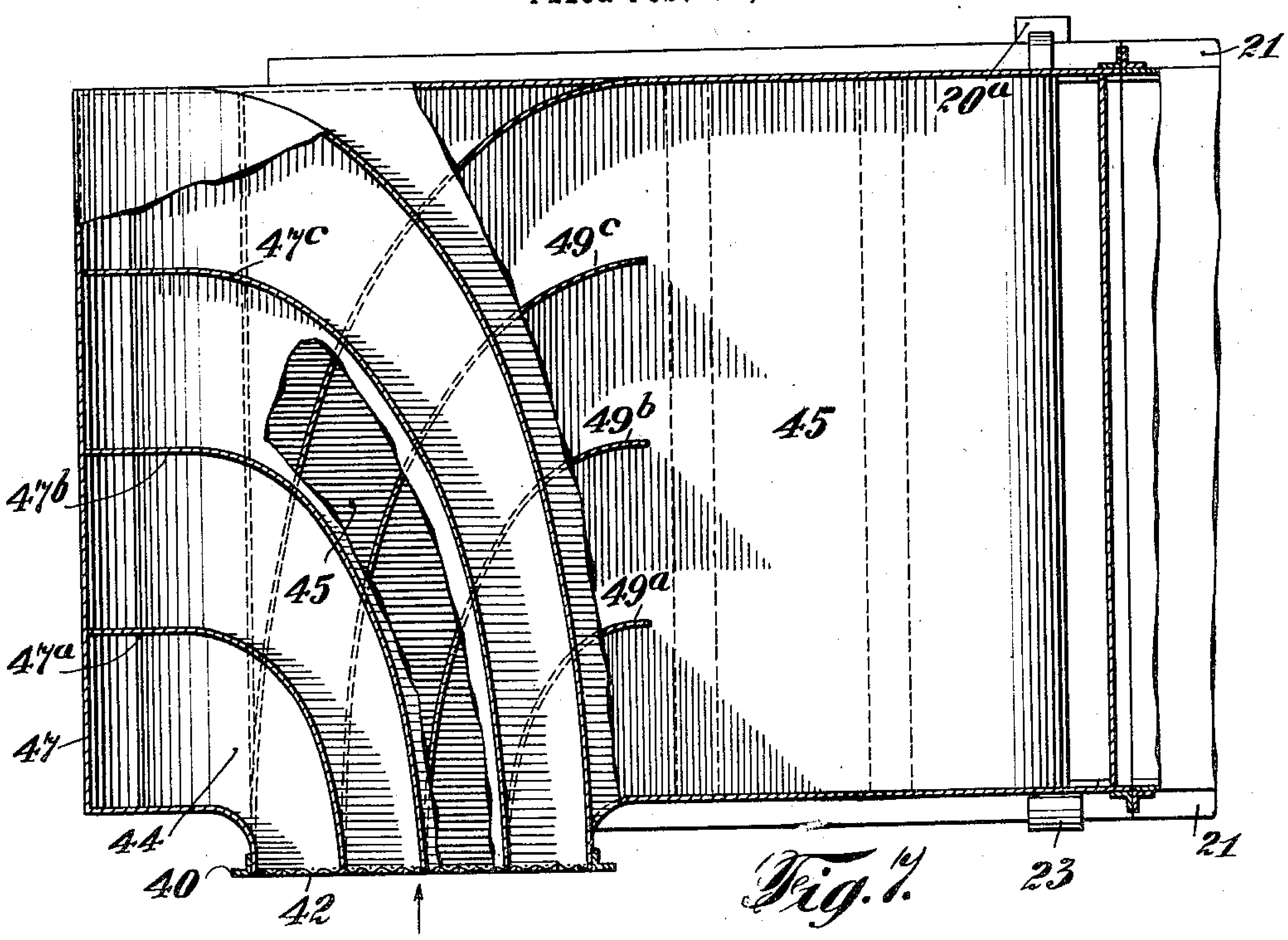

Fig. 7.

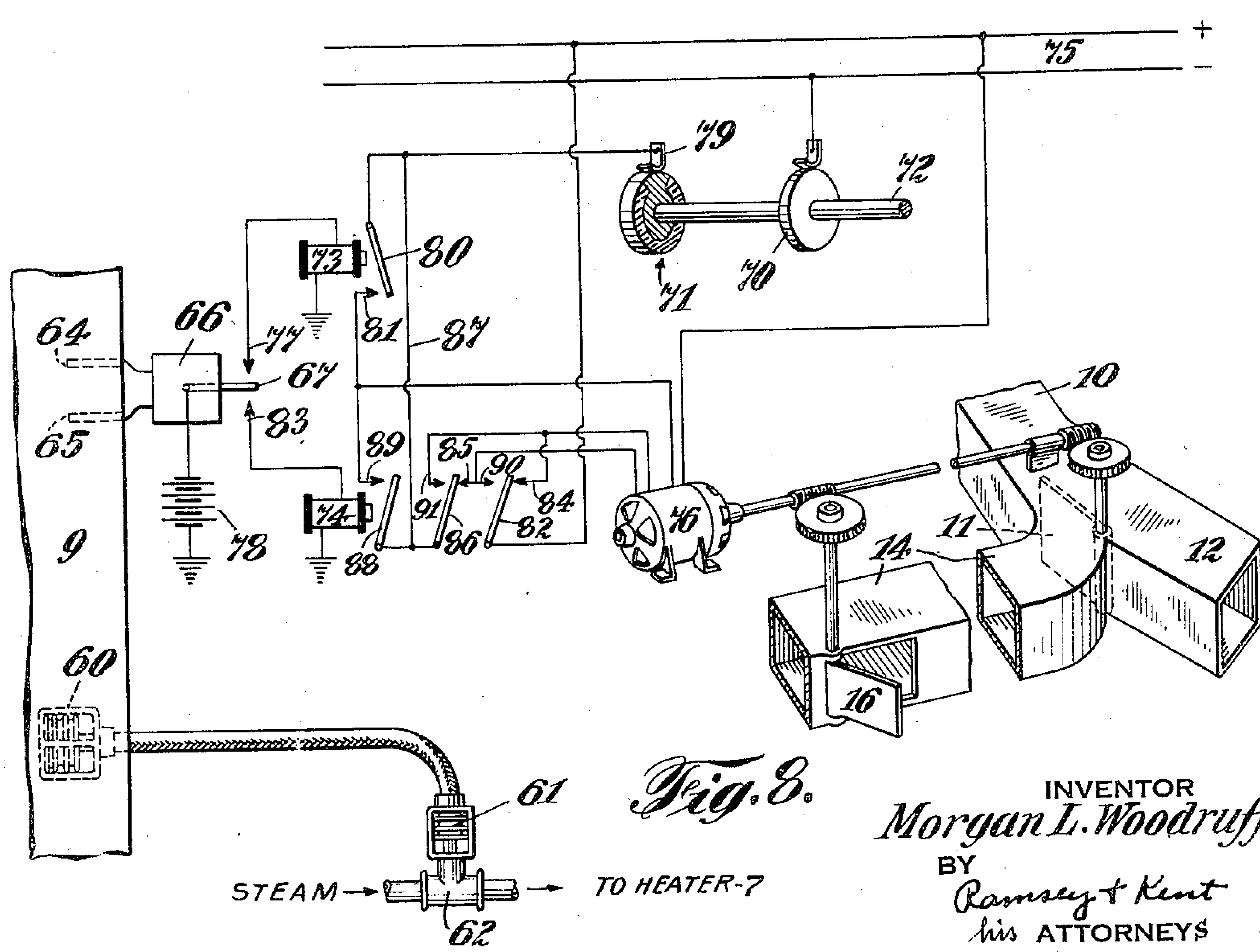

Fig. 8.

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Patented Aug. 20, 1935

UNITED STATES PATENT OFFICE

2,012,115

METHOD OF AND APPARATUS FOR DRYING A CONTINUOUS WEB

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Application February 17, 1932, Serial No. 593,440

12 Claims. (Cl. 34—48)

This invention relates inter alia to the manufacture of coated paper, and one of the salient phases of the invention resides in a method of and apparatus for drying a continuous web. The web drying phase of the invention is particularly applicable to the drying of a web of paper that has been coated on both surfaces, but other webs may be dried by the same method and with the same apparatus.

In the manufacture of coated paper, it is customary to coat one or both surfaces of the paper with a wet solution or mixture containing, among other ingredients, water, casein, finely ground clay, and pigment. Such coating mixtures are well known in the paper manufacturing art and are usually referred to as the "color". The drying of coated paper has long presented a serious commercial problem, because (a) after the coating is applied and smoothed out, the wet paper cannot be allowed to contact with rolls or other supporting devices, and (b) the nature of the coating used is such that the application of high drying temperatures to it burns the casein and ruins the product.

For many years the festoon system has been used in actual practice for the drying of coated paper. In festoon drying the web of paper leaving the coating machine is passed for a distance over a drying table from which issue jets of heated air that float the web and partially dry the coating. The drying efficiency of the drying table is so low that the web cannot be floated for the distance which would be required for complete drying. However, the drying table dries the coating sufficiently to permit the paper to be handled gingerly, and then it is draped in festoons over a series of slowly moving bars on which it is slowly carried through a drying room.

Festoon drying is obviously slow and cumbersome, and it requires a great deal of space for the drying operation. The festooned paper cannot be moved rapidly and air cannot be rapidly circulated through the drying room, because it would swing the loops of paper and bring them in contact with one another. Attempts have been made to speed up the drying and reduce the space required for the drying equipment by passing the web longitudinally through a duct through which a blast of air is passed. Although numerous duct type driers have been designed, none has proved entirely satisfactory in actual commercial practice; and hence the old festoon system is the one that is actually used today in the commercial production of coated paper.

The dried coated paper is wavy, and it has a dull finish. Accordingly the paper must be calendered to flatten it out and to give it a glossy finish. This means reeling the paper and transporting the reels to the calendering rolls. The paper cannot be fed directly to calendering rolls because they have to operate at high sped (in order to effectively calender) and festoon driers can only handle the paper at relatively low speed.

For proper calendering it is very important that the moisture content of the paper be just right. If the paper is too wet, it discolors; and if it is too dry the finish produced is poor. No satisfactory means has been devised for determining the correct moisture content. An experienced operator judges it by running his hand over the web as it goes to the calendering roll. With the drying systems now in commercial use the moisture content of the dried paper is usually not correct for calendering, and in many instances the paper has to be steamed as it is passed from the reel to the calendering rolls.

A general object of the present invention is to provide a method of (and/or apparatus for) coating, drying and calendering paper by continuous operations, without intermediate reeling of the paper.

Other objects are to provide improved control in the drying of webs or the like; and specifically to provide for proper control of the moisture content of paper being calendered.

More specific objects of the invention are (a) to provide a commercially practicable method of (and/or apparatus for) drying continuous webs at considerably higher speeds than is possible with the festoon system, (b) to provide a commercially practicable web drying apparatus which economizes in space as compared to present commercial practice; and (c) to provide a method of (and/or apparatus for) drying a continuous web at high speed and low cost as compared to present commercial practice.

Figure 1 of the drawings shows diagrammatically a plan lay-out of the apparatus.

Figure 2 shows more or less diagrammatically a side elevation taken approximately on line 2—2 of Figure 1.

Figure 3 is a fragmentary side elevation (partially in section) showing the end of the drying duct at which the web enters and the drying air leaves the duct. The view is taken looking from the side opposite to that shown in Figure 2.

Figure 4 is a fragmentary side elevation (partially in section) corresponding to Figure 3, but showing the opposite end of the drying duct, i. e., the end at which the web leaves and the drying air enters the duct.

Figure 5 is a vertical section through the drying duct, taken on line 5—5 of Figure 3.

Figure 6 is a vertical section through the drying duct, taken on line 6—6 of Figure 3.

Figure 7 is a detail plan view (partially in section) showing the air receiving end of the drying duct and the passages for distributing the drying air as it enters the drying duct.

Figure 8 shows diagrammatically control apparatus for automatically regulating the temperature and humidity of the drying air.

General arrangement of the apparatus

Reference will first be had to Figures 1 and 2. A continuously moving web of paper **1** is coated on both sides by a coater **2**, which may be of any known type suitable for high speed operation. The web leaves the coater and passes directly to a drying duct **4**, where it is dried under controlled conditions to leave it with the correct moisture content desired for subsequent operations, e. g., calendering. From the drying duct the paper passes over tension rolls **3**, and then to calendering rolls **5**, after which it is wound upon storage rolls **6**. Air heated by a steam heater **7** (of any suitable and known construction) is driven by a fan **8** through a conduit **9** that delivers the heated air to one end of the drying duct **4**, preferably the end at which the paper leaves. The air moves longitudinally through the drying duct and leaves it at the opposite end through a conduit **10**. Under control of an adjustable damper **11**, part of the air may be exhausted through conduit **12** to an exhaust stack, and the remainder of the air may be recirculated through conduit **14** to the heater **7**, where it is reheated and again passed through the drying duct **4**.

Fresh air to compensate for the air exhausted through conduit **12** may be admitted to conduit **14** by any suitable means. The means shown comprises a tunnel **15** open at both ends and attached to the outside of conduit **14**. Adjacent the down stream end of tunnel **15** there is an opening in the side of conduit **14** at which there is pivoted a scoop-shaped inlet damper **16**. Under the suction created by fan **8** and the air moving through conduit **14**, fresh air is drawn through tunnel **15**, and thence through the opening controlled by damper **16**, to the interior of conduit **14**. Damper **16** is adjustable to various positions to thereby vary the amount of fresh air admitted to conduit **14**.

Fan **8** may be suitably driven by a variable speed drive to thereby regulate the speed of the air driven through conduit **9** and the drying duct **4**, but further regulation of the air speed may be provided by means of a slide damper **17**, which may be operated to close off conduit **14** to any desired extent.

The drying duct as a whole

Referring to Figures 2, 3, and 4, it will be seen that the drying duct comprises an "air-in" section A, main drying sections B, B, B, and an "air-out" section C. It will, of course, be understood that the air is admitted to the drying duct at section A and leaves the drying duct at section C. The main drying sections B are all alike and any desired number of such sections B may be employed. The number of sections required depends upon various factors, such as the speed of the web, the nature of the web, the drying temperature and air velocity which can be employed, and the amount of moisture to be extracted from the web. The sections A, B, and C are, of course, connected together to form a continuous duct, and the entire duct may be supported by any suitable supporting structure D. The duct sections may each be fabricated in any suitable manner as by building them up from sheet iron suitably cut and welded; and the various duct sections may be assembled into one duct in any suitable manner as by bolting, riveting, or welding.

Main drying sections of drying duct

The construction of the duct sections B is clearly shown in Figures 3, 4, 5, and 6. Each of these sections is symmetrical about a horizontal median plane, and the two halves are hinged together at **20** so that each section (and the whole duct) can be opened up after the manner of a book. The upper and lower halves are respectively provided with contacting longitudinally extending flanges **21** and **22**, over which spring clamp members **23** may be forced to hold the duct closed.

In Figures 3 and 4, the web of paper **1** is moving to the right, and both above and beneath it layers of air are moving to the left. After passing through straight portion **25** of each duct section B, portions of the upper and lower layers of air are split off and flow through by-passes **26** and **27**, respectively. These by-passes **26** and **27** return the split off portions of the air to the main line of flow by impinging them substantially perpendicularly against the surface of the paper as indicated in Figure 3. Preferably the duct is so designed that its total cross sectional area at all points along its length is at least approximately a constant. Thus at section line 5—5 (Figure 3) the sum of the cross sectional areas of by-pass **26**, the main passage adjacent the paper, and by-pass **27**, is equal to the cross sectional area of the duct at section line 6—6.

It is apparent that the air stream impinging against the paper from by-pass **26** will tend to force the web downwardly, whereas the air stream impinging from the by-pass **27** will tend to force the web upwardly. Hence, the web **1** can be supported centrally of the duct by properly correlating the forces of the opposing air blasts. Dampers **30** and **31**, which extend transversely of the duct and are operable from the outside of the duct, may be manipulated to produce nozzle effects with locally increased velocity at the discharge ends of by-passes **26** and **27**. Thus the forces of the opposing air blasts can be correlated as necessary to give the web the proper resultant support. Any number of windows **32** may be provided through which the web may be observed.

Air-in section of drying duct

The conduit **9** is coupled to section A of the drying duct by a Y-shaped fitting to thereby deliver approximately half of the air above the web **1** and the remainder of the air below the web **1**. Section A is so constructed as to smoothly direct the incoming air and apply a layer of it to each surface of the moving web. The handling of the air by section A involves subdivision of the air streams and directing the subdivisions in such manner as to support the web, get the air gracefully moving longitudinally of the drying duct in the desired direction, and permit a large volume of air to be delivered to the drying duct without creating local pressure areas of a magnitude to cause unsatisfactory operation by whipping or deflecting the paper. The construction of the air-in end of the drying duct is best shown in Figures 4 and 7.

One leg of the Y-shaped fitting of conduit **9** (Figure 1) is coupled to a flange **40**, and the other leg is coupled to a flange **41**. The air delivery system for the top half of the drying duct is symmetrical with respect to the air delivery system for the bottom half of the duct, and hence only the top half will be described in detail, but corresponding reference characters are applied to the bottom half. The two halves of the section are hinged together at **20a**, so that by uncoupling the connection to flange **40**, the section may be opened with the rest of the duct.

The incoming air first passes through a screen **42** and is then divided into four horizontal superimposed layers by partitions **44**, **45**, and **46**. The first layer of air is fed through curved conduit **47** to an elongated nozzle **48** positioned transversely adjacent the paper web **1** so that as the web is about to leave the duct a fish-tail blast of air is delivered against the surface of the paper and inwardly of the drying duct. The second layer of air is passed through a conduit **49** and delivered substantially perpendicularly against the surface of the web some distance before the web leaves the duct. The third layer of air is delivered through a conduit **50** and impinged against the surface of the web at a point closer to the exit of the paper from the duct. The last layer of air is delivered through a conduit **51** and impinged against the surface of the web at a point still closer to the exit of the web from the duct.

Generally speaking, conduits **47**, **49**, **50** and **51** are of rectangular cross section and have a width a little greater than the width of the web of paper **1**. Since the web of paper may be several feet wide, it is desirable that there be uniform lateral distribution of the air within each of the conduits **47**, **49**, **50** and **51**. This is provided for by curved vertical deflectors in the entrance portion of each of the conduits **47**, **49**, **50** and **51**. The curved vertical deflectors of conduits **47** and **49** are best shown in Figure 7, which is a plan view of the air-in end of the drying duct. In conduit **47** there are deflectors **47a**, **47b**, and **47c**; and in conduit **49** there are deflectors **49a**, **49b**, and **49c**. There are similar deflectors in conduits **50** and **51**, and they are indicated in dotted lines in Fig. 4.

The discharge ends of conduits **49**, **50**, and **51** are preferably provided with transverse control dampers **49d**, **50d**, and **51d**, respectively. Any desired number of windows **32a** may be provided for observation of the web. Transversely extending slides **52** and **53** are movable toward and from the web to regulate the width of the exit slit through which the web leaves the duct.

It will be apparent that the entering air is so subdivided and controlled that a large volume of air can be smoothly and gracefully delivered to the duct without creating local pressure areas of a magnitude to whip the paper. Also the admission of the air is in opposed streams which support the paper. The jets from upper and lower conduits **47** are such as to insure air flow through the drying duct in the desired direction and to minimize air leakage through the slit where the web leaves the duct.

Air-out section of the drying duct

This section of the duct is best shown in Fig. 3. It also is made in upper and lower halves which are symmetrical about a median horizontal plane and are hinged together at **20c**. Also any suitable number of observation windows **32c** may be provided.

The oncoming stream of air is divided into three portions, one continuing on into center passage **54**, and the other two passing through by-passes **55** and **56**, respectively. By-passes **55** and **56**, discharge the air in a backward direction against the surface of the web, thus minimizing air leakage at the slit where the web enters the duct. Also the discharge from by-passes **55** and **56** meets the current through center passage **54**, thereby locally neutralizing the longitudinal flow in the duct and facilitating the discharge of the air laterally into discharge conduit **10** (Fig. 1).

Discharge conduit **10** is coupled by a Y-shaped fitting (not shown) to flanges **57** and **57a**. The volume of air which is flowing laterally of the drying duct to discharge conduit **10** cumulatively increases as we progress transversely of the drying duct toward discharge conduit **10**. Accordingly, this portion of duct section c is pyramidal in shape, with the base of the pyramid adjacent the plane of flanges **57** and **57a**.

The web may pass to the drying duct directly from burnishing roll R of the coater **2** (Fig. 1). This roll smooths the wet coating. It may be of a smooth brass roll so driven that its periphery moves in the direction of movement of web **1**, but at a very much higher linear speed than web **1**. The height of the slit through which the web enters the drying duct may be varied by adjustable slides **58** and **58a**. The flow through by-passes **55** and **56** may be regulated by adjustable dampers **59** and **59a**.

Temperature and humidity control of the drying air

As previously explained in connection with Fig. 1, at least a portion of the drying air is recirculated and passed through the drying duct more than once. Two advantages of this are (*a*) the same air can pick up additional moisture on a second passage through the drying duct, and by reusing the air less fresh air has to be heated, and thus heat is saved; and (*b*) since the recirculated air is moisture laden, it can be mixed with fresh air in such proportion as to control as desired the humidity of the air delivered to the drying duct. By proper humidity control of the drying air, together with proper coordination of the temperature and volume of the drying air and the speed at which the web **1** is moved, the moisture content of the dried (but not dehydrated) paper can be kept just right for future operations, e. g. calendering.

Means for automatically controlling the temperature and humidity of the air delivered to the drying duct are shown in Fig. 8. Within the duct **9** there is positioned a volatile liquid thermostat **60** connected to actuate a sylphon bellows **61** and through it control a valve **62** that regulates the admission of steam to heater **7** (Fig. 1). Thermostat **60**, and suitable valves to be actuated by it are well known and may be purchased on the open market.

Also within the conduit **9** are bulbs **64** and **65** each containing a volatile fluid. One of these bulbs is kept wet by suitable means such as a wick, and thus the two bulbs act as wet and dry bulb thermostats. The wet and dry bulbs **64** and **65** are connected to mechanism **66**, which responds to the difference in pressures (corresponding to wet and dry bulb temperatures) to thereby actuate tongue 67 in response to changes in the relative humidity of the air flowing through conduit 9 to the drying duct. The bulbs 64 and 65 and the mechanism 66 for actuating the tongue 67 are disclosed in U. S. patent to Roesch 1,429,973, issued September 26, 1922; and this apparatus is adjustable to cause it to regulate for different desired values of relative humidity.

Under the control of tongue 67, damper 16 (which controls the admission of fresh air) and damper 11 (which controls the recirculation) are automatically actuated to regulate the humidity of the air delivered to the drying duct through conduit 9. The control apparatus include slip ring 70 and make-and-break 71, both carried by shaft 72, which is continuously rotated by any suitable means. Under the control of relays 73 and 74, connection is made as required from power line 75 to motor 76 to effect the movement of dampers 11 and 16.

Assume that the humidity of the air in conduit 9 is higher than the value which the apparatus is set to maintain. Tongue 67 will move upwardly, engaging contact 77 and completing a circuit from battery 78 through the winding of the relay 73, thereby causing the relay to pick up. When the conducting sector of make-and-break 71 engages brush 79, circuit will be completed from the negative side of power line 75, slip ring 70, shaft 72, brush 79, relay armature 80, contact 81, armature of motor 76, and then to the positive side of power line 75. The field of the motor (D. C. shunt motor) is energized from the positive side of line 75, relay armature 82, contact 84, through the field of the motor to contact 85, relay armature 86, conductor 87, brush 79, conducting segments of make-and-break 71, shaft 72, and slip ring 70 to the negative side of the power line 75. This causes the motor 76 to rotate and give an increment of movement to dampers 11 and 16 in such direction as to further open damper 16 and move damper 11 to divert more of the outcoming air to the exhaust stack 12. Thus the amount of moisture laden air returned to the drying duct will be diminished and the amount of fresh air will be correspondingly increased, thereby reducing the humidity of the drying air delivered to the drying duct.

Make-and-break 71, the speed of motor 76, and the gearing to dampers 11 and 16 are so designed and correlated that a suitable increment of movement will be given to the dampers 11 and 16 while the conducting segment of make-and-break 71 is in contact with brush 79. No further movement of dampers 11 and 16 can take place until the conducting segment of make-and-break 71 again contacts with brush 79, and thus a suitable time interval is provided to give the apparatus a chance to respond to the change in damper positions. If the humidity is still too high when the conducting segment of make-and-break 71 again contacts with brush 79, tongue 67 will still be in engagement with contact 77 and hence a second similar increment of movement will be given to dampers 11 and 16. Thus adjustment of the dampers continues step-by-step until the humidity has reached the value for which the apparatus is set to regulate. Then tongue 67 will move to neutral position and no further movement of the dampers 11 and 16 will take place until the humidity again varies from the desired value.

Assume that the humidity of the air passing through conduit 9 is less than the value for which the apparatus is set to regulate. Tongue 67 then moves downwardly, engaging contact 83. This completes a circuit from battery 78, through contact 83, to the winding of relay 74, causing this relay to pick up. When the conducting sector of make-and-break 71 engages brush 79, circuit is completed (in the same direction as before) to the armature of motor 76 as follows: negative side of line 75, slip ring 70, shaft 72, brush 79, conductor 87, relay armature 88, contact 89, armature of motor 76, and then to the positive side of power line 75. Circuit is also completed from power line 75 to the field of motor 76, but the polarity of the connection is reversed, so as to cause the motor 76 to rotate in the opposite direction. The circuit through the field of motor 76 is from the positive side of power line 75, relay armature 82, contact 90, field winding of motor 76, contact 91, relay armature 86, conductor 87, brush 79, shaft 72, slip ring 70, to the negative side of power line 75. Thus, the motor 76 is energized to give a suitable increment of movement to each of dampers 11 and 16, damper 16 being moved toward closed position, and damper 11 being moved to divert less of the moisture laden air to the exhaust stack 12. Accordingly the humidity of the air delivered to conduit 9 is increased. If the humidity is still too low when the conducting sector of make-and-break 71 again contacts with brush 79, a further similar increment of movement will be given to dampers 16 and 11, to further increase the humidity. When the humidity reaches the correct value, tongue 67 will move to neutral position and dampers 11 and 16 will remain stationary.

It will be apparent that under the control of wet and dry bulbs 64 and 65, the dampers 11 and 16 are automatically manipulated to maintain the humidity at the given value which the apparatus is set to regulate. In some instances it may be sufficient to actuate only one of dampers 11 and 16 automatically instead of actuating both of the dampers. Motor 76 should, of course, be of the proper speed to give a sufficiently small increment of movement to the dampers at each energization of the motor. If a sufficiently low speed motor is not available, it can, of course, be geared down as required.

Air temperature and velocity

The rate of evaporation rises rapidly with increase of temperature of the drying air, but in the past it has not been possible to use high temperature drying air, because of burning of the casein in the coating. Experience has shown that with the drying systems previously used, the highest suitable temperature for the drying air is about 140° Fahrenheit. Also the rate of evaporation rises rapidly with increase of the air velocity (provided the air is actually in contact with the paper) but with the festoon system of drying, high air speed is impossible, as has been previously explained. With the duct type driers suggested in the prior art, whipping of the paper and inadequate support of the paper precluded the circulating of the drying air at high speed. Furthermore, high air speed in the previously suggested duct type driers would be largely ineffective, because in those driers such a small portion of the air makes adequate contact with the paper.

I have found that the casein or coating material is able to withstand high temperature air for a very brief time. Therefore, if the drying can be completed in this brief time, high temperature drying air can be used. By the method and apparatus disclosed, I am able to so support the paper that a large volume of drying air can be employed, which with the repeated impinging of the drying air against the surface of the web, speeds up the drying to a point permitting the use of high temperature drying air. Thus, I am able by this method to take advantage of the increased rate of evaporation of high temperature air without burning the coating. I preferably use drying air at a temperature in excess of 225 degrees Fahrenheit, and an air speed in excess of 2000 feet per minute, relative to the paper. Somewhat lower temperatures and air speeds may also be used to advantage. Preferably, however, the air speed is kept above 1500 feet per minute, relative to the paper. I have also obtained satisfactory results with temperatures up to 300 degrees Fahrenheit, and air speeds up to 3000 feet per minute, relative to the paper.

It is obvious that the method and apparatus may be used for drying other webs than webs of coated paper, though the invention is particularly adapted to drying paper coated on both sides. Drying mediums other than air may be employed, but air is usually the most readily available medium, and hence it has been specifically referred to. Of course, the method disclosed may be practiced by a variety of different forms of apparatus; and many changes may be made in applicant's apparatus without departing from the invention. Accordingly, the disclosure is merely illustrative in compliance with the patent statutes and is not to be considered as limiting the scope of the invention.

Having thus described my invention what I claim is:

1. The method of drying a continuous web which comprises continuously moving the web longitudinally of itself, applying a main layer of fluid drying medium to each surface of the web and moving the layers relative to the web and longitudinally thereof, repeatedly splitting off portions off each drying layer which are not in contact with the web and forming such split-off portions into separate streams, and repeatedly impinging such separate streams against the surface of the web and thereby returning them to the main drying layers.

2. The method of drying a continuous web which comprises continuously moving the web longitudinally of itself, applying a main layer of fluid drying medium to each surface of the web and moving the layers longitudinally of the web in the direction opposite to the web movement, repeatedly splitting off portions of each drying layer which are not in contact with the web and forming such split-off portions into separate streams, and repeatedly impinging such separate streams against the surface of the web and thereby returning them to the main layers.

3. The method of supporting a web in a duct which comprises forcing a blast of gas longitudinally through the duct, removing portions of the gas from the duct proper at at least one position along the duct, and returning the removed portions to the duct proper and impinging them against the web.

4. The method of keeping a web out of contact with a duct which comprises forcing a blast of gas longitudinally through the duct on opposite sides of the web; at at least one point along the duct, removing portions of the gas on opposite sides of the web from the duct proper by directing them gradually away from the direction of travel in the duct; and returning the removed portions to the duct proper and impinging them at a sharp angle against opposite sides of the web.

5. The method of keeping a web out of contact with a duct which comprises forcing a blast of gas longitudinally through the duct on opposite sides of the web; at a plurality of points along the duct, removing portions of the gas on opposite sides of the web from the duct proper by directing them gradually away from the direction of travel in the duct; and returning the removed portions to the duct proper and impinging them at a sharp angle against opposite sides of the web.

6. Drying apparatus comprising an elongated duct; means to force a fluid longitudinally through the duct from end to end thereof; and at least one pair of opposed by-passes extending longitudinally of the duct, said by-passes being effective to withdraw fluid from the duct, convey it longitudinally of the duct and return it thereto farther downstream in opposed streams.

7. Drying apparatus comprising an elongated duct; means to force a fluid longitudinally through the duct from end to end thereof; at least one pair of opposed by-passes extending longitudinally of the duct, said by-passes being effective to withdraw fluid from the duct, convey it longitudinally of the duct and return it thereto farther downstream in opposed streams; and means to control the flow through the by-passes.

8. In a drying duct; a fluid exit section at one end of the duct comprising by-passes extending longitudinally of the duct, said by-passes being effective to withdraw fluid from the duct before it reaches the end of the duct and return it longitudinally to the duct at its end; and means to discharge fluid laterally from the duct.

9. Drying apparatus comprising an elongated duct; means to force a fluid longitudinally through the duct from end to end thereof; at least one pair of opposed by-passes extending longitudinally of the duct, said by-passes being effective to withdraw fluid from the duct, convey it longitudinally of the duct and return it thereto in opposed streams; and control dampers adjacent the discharge ends of said by-passes.

10. The method of drying a web of coated paper which comprises heating a fluid drying medium to a temperature in excess of 200 degrees Fahrenheit, moving a main stream of the drying medium at such temperature in contact with and longitudinally of the web at a speed relative to the web of over 1800 feet per minute, repeatedly splitting off portions from the main stream and forming such split-off portions into separate streams, and then impinging such separate streams against the web and thereby returning them to the main stream.

11. The method of drying a web of paper having on its surface a wet coating containing organic material which comprises heating a fluid drying medium to a temperature in excess of 200 degrees Fahrenheit and under 501 degrees Fahrenheit, moving a stream of the medium at such temperature in contact with the web at a speed relative to the web of over 1800 feet per minute and under 5001 feet per minute, and removing the paper from the influence of the heated drying medium as soon as the desired dryness of the paper has been attained.

12. The method of drying a web of paper hav-