Nov. 1, 1966 T. F. MULLANEY 3,281,952

APPARATUS AND METHOD FOR PRODUCING CREPE PAPER AND THE LIKE

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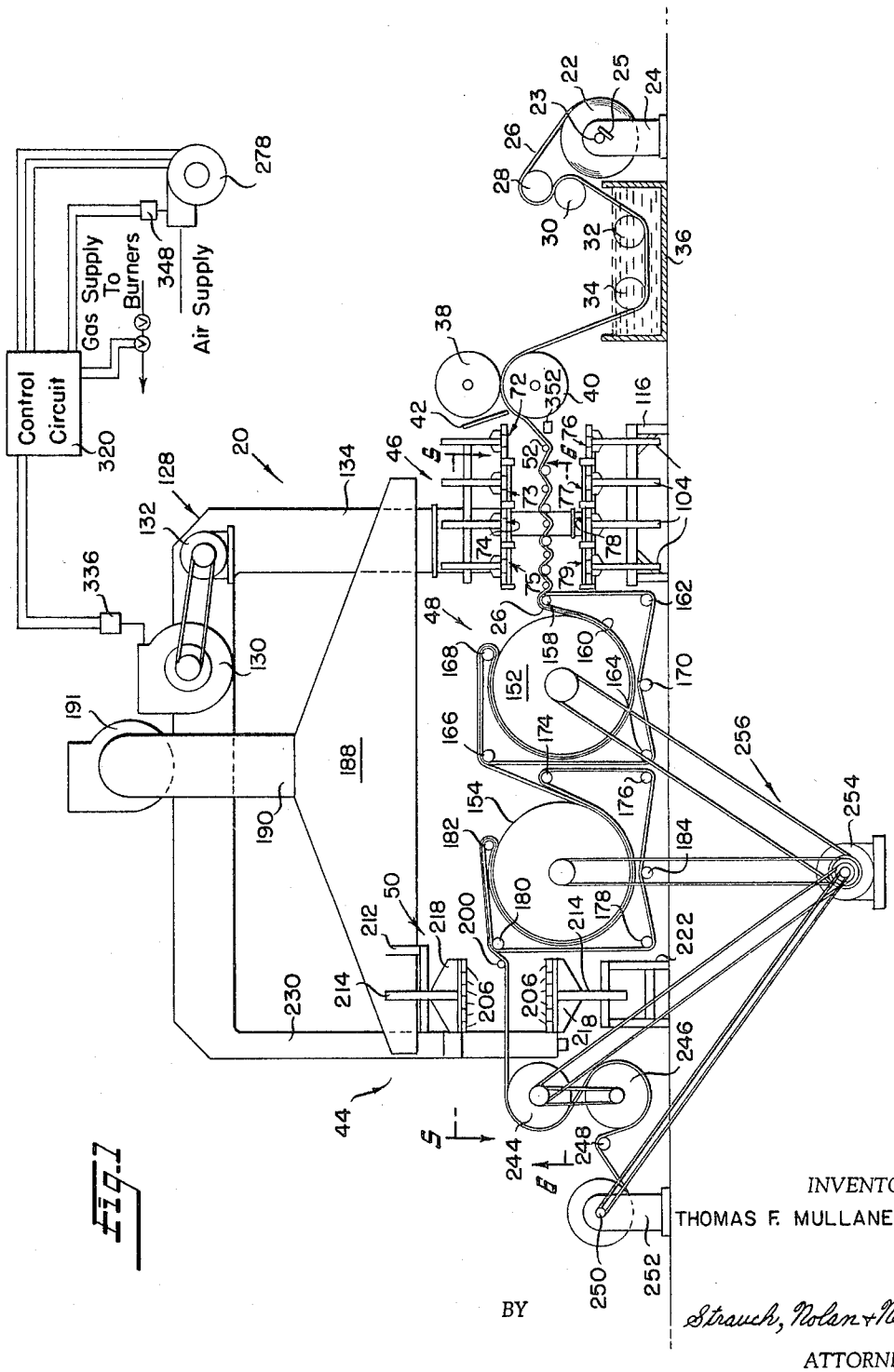


Fig. 1

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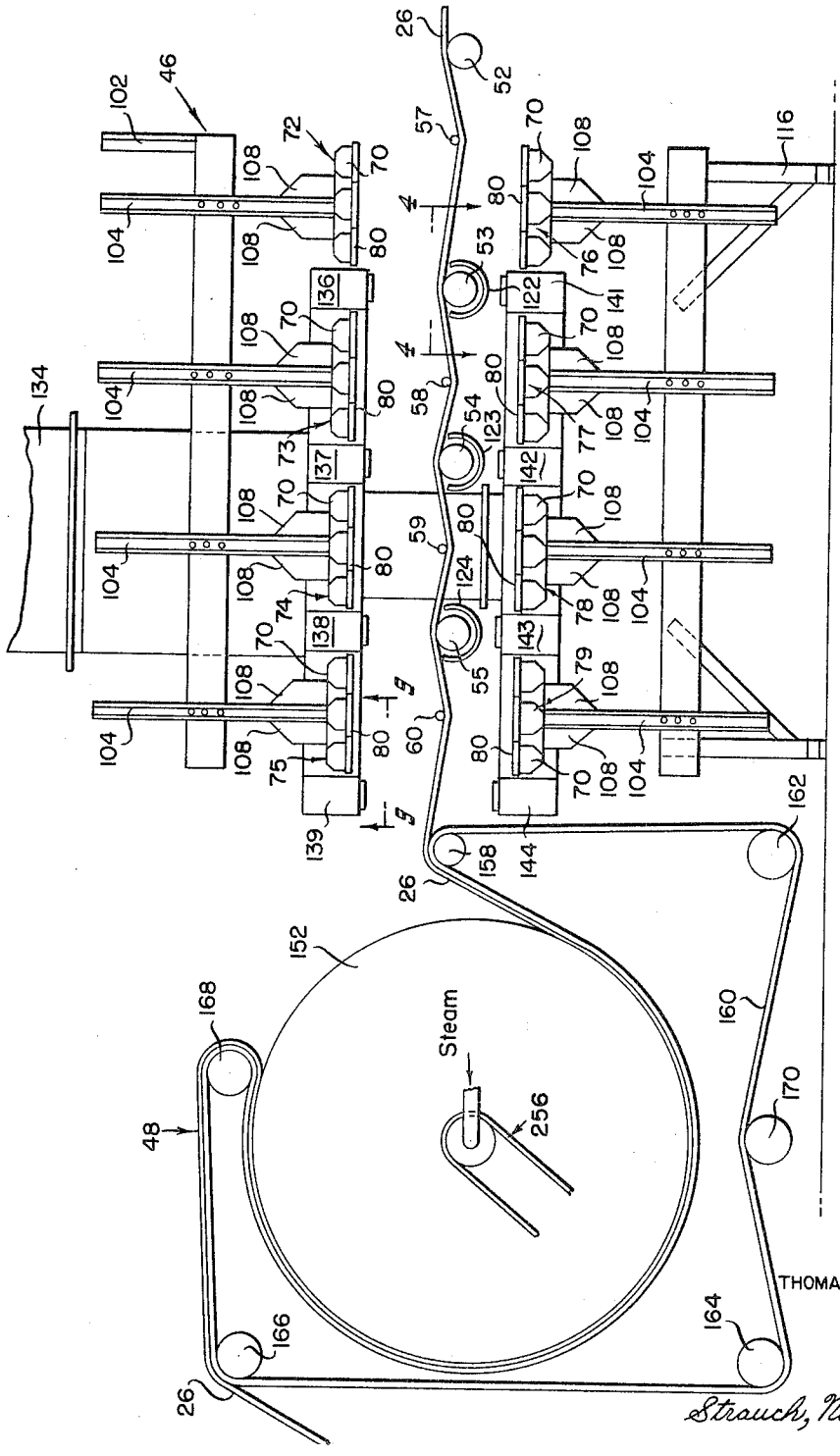


Fig. 2

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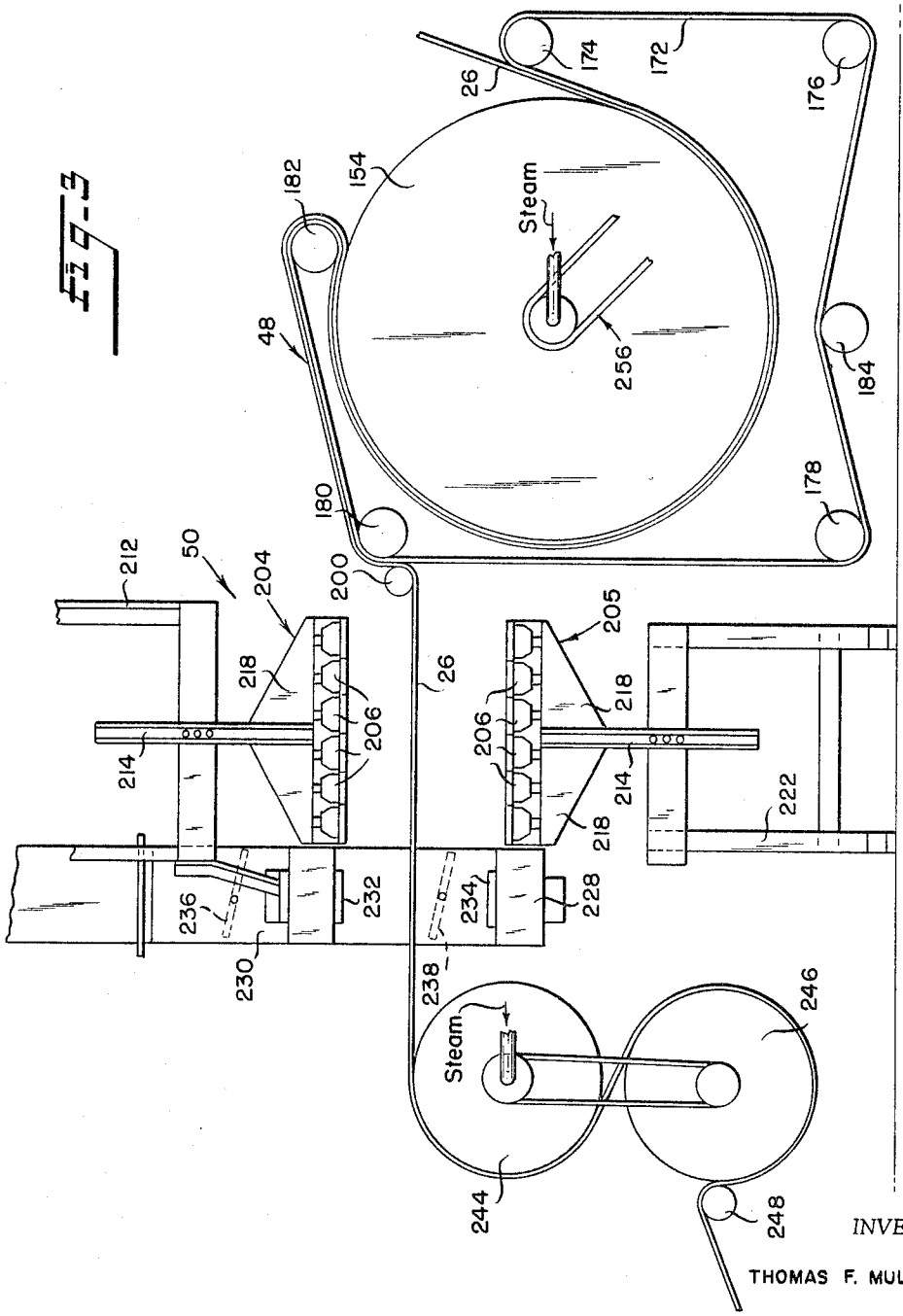
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Fig. 3



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3,281,952

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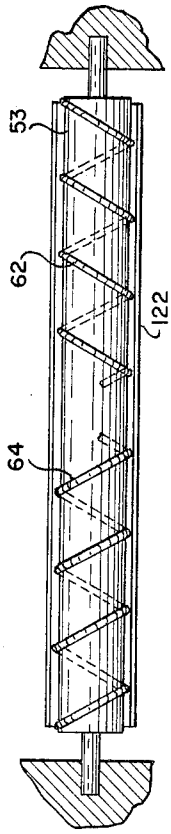


Fig. 4

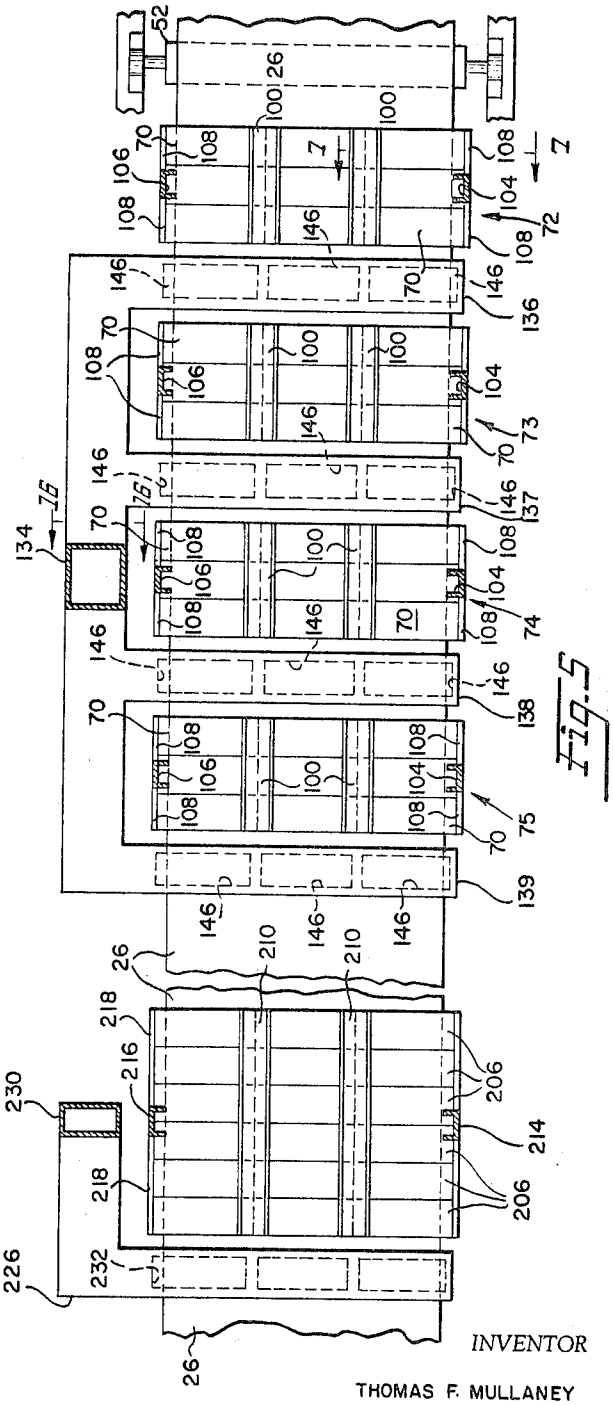


Fig. 5

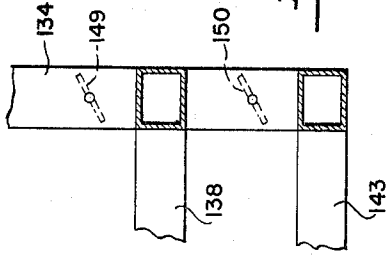


Fig. 16

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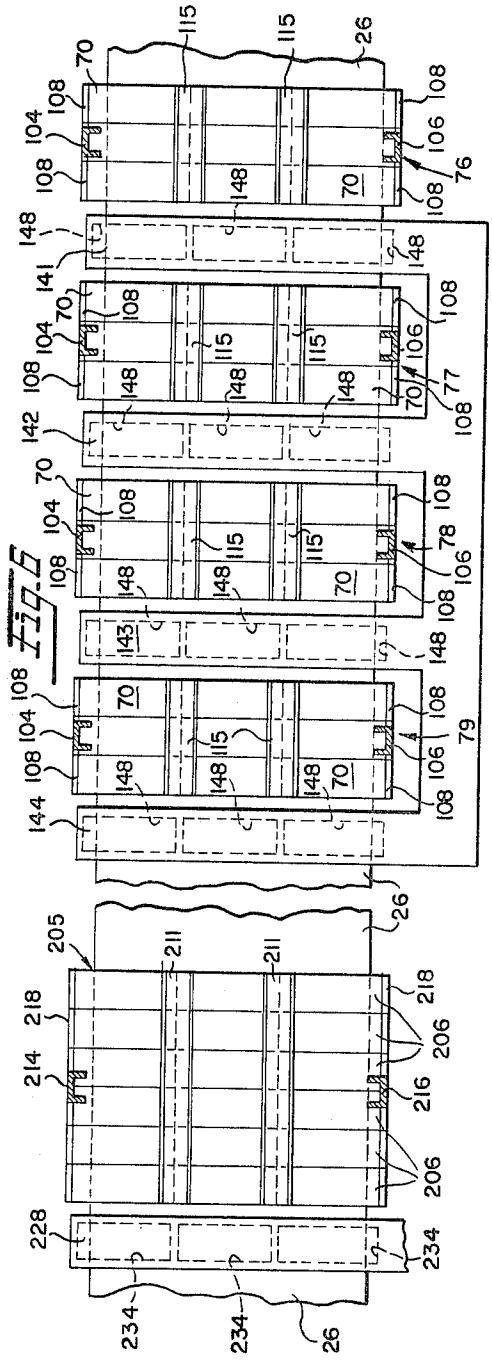


Fig. 6

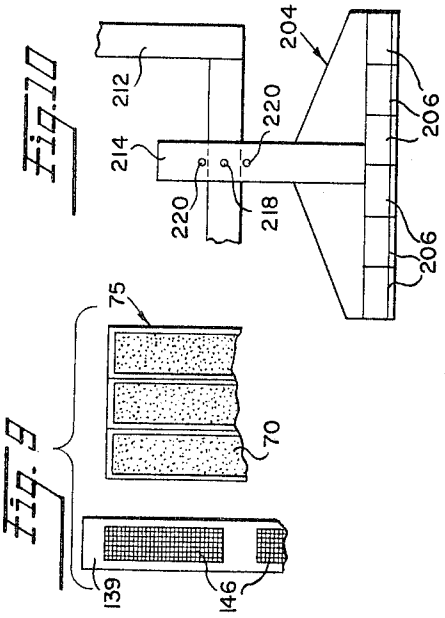
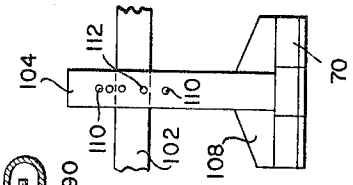


Fig. 10

Fig. 9



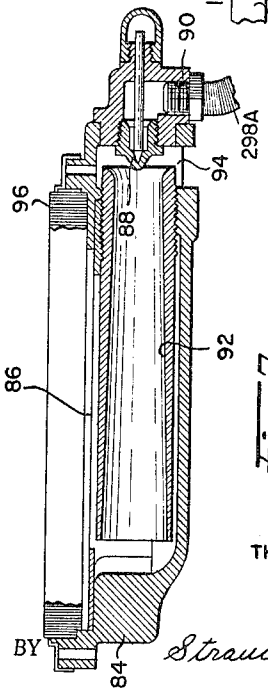


Fig. 8

Fig. 7

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APPARATUS AND METHOD FOR PRODUCING CREPE PAPER AND THE LIKE

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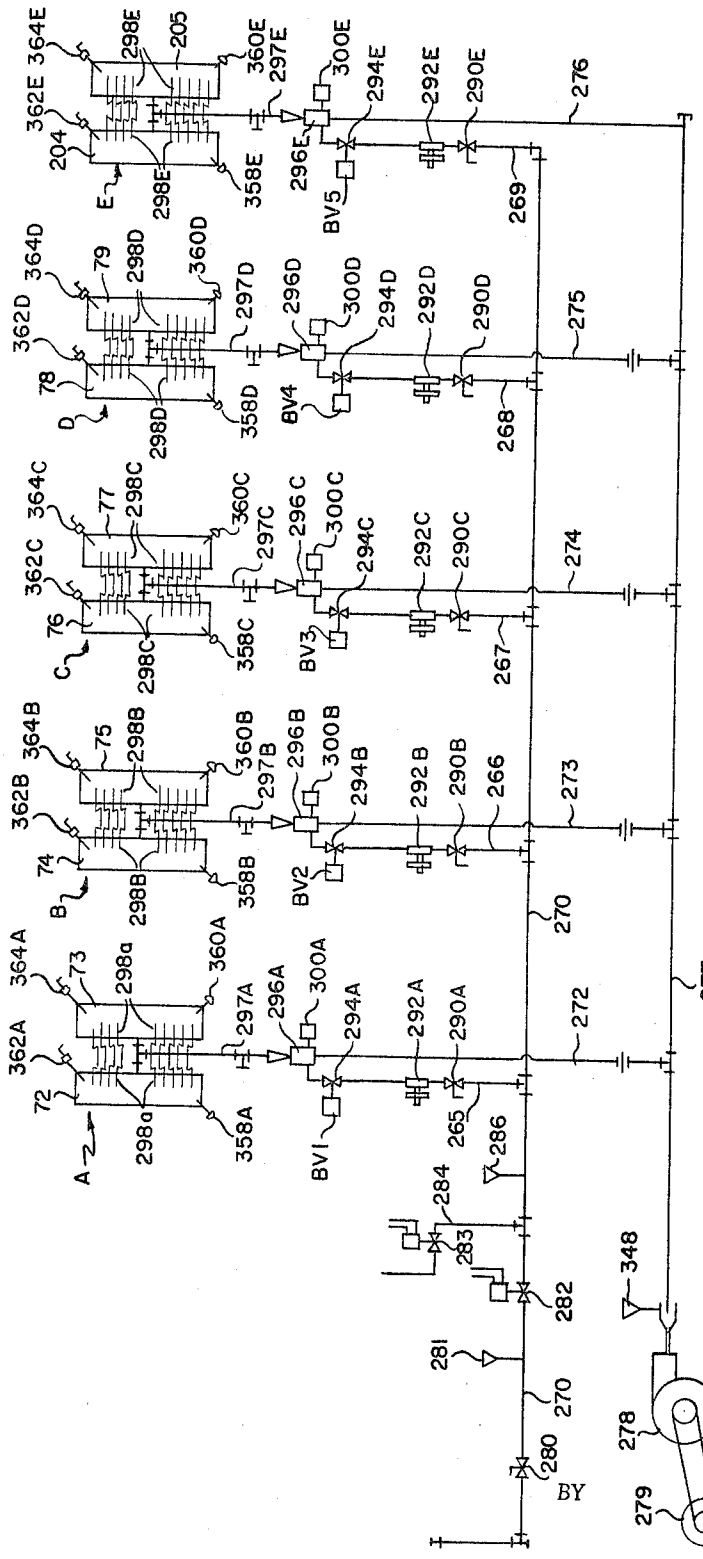


FIG. 11

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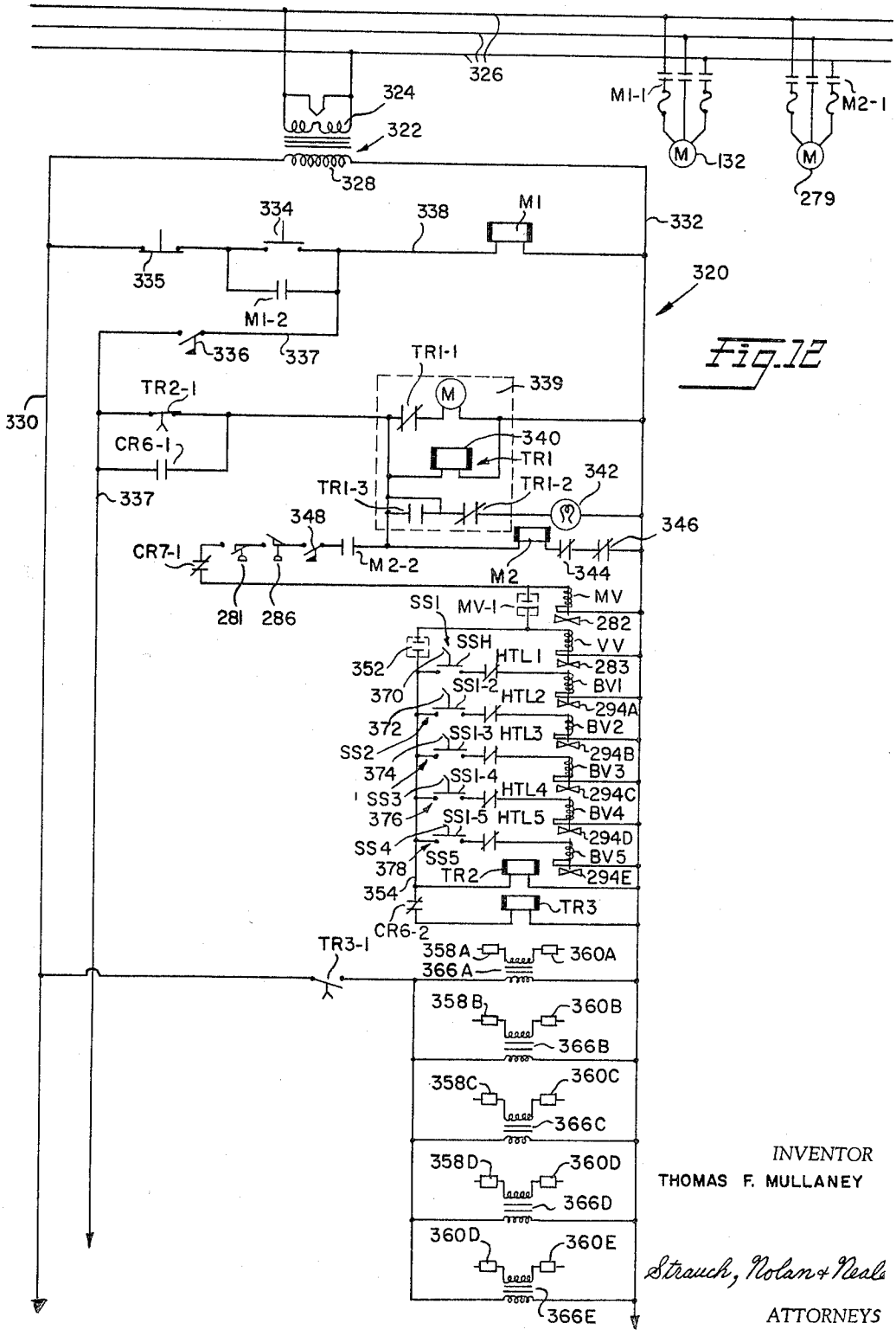


Fig. 12

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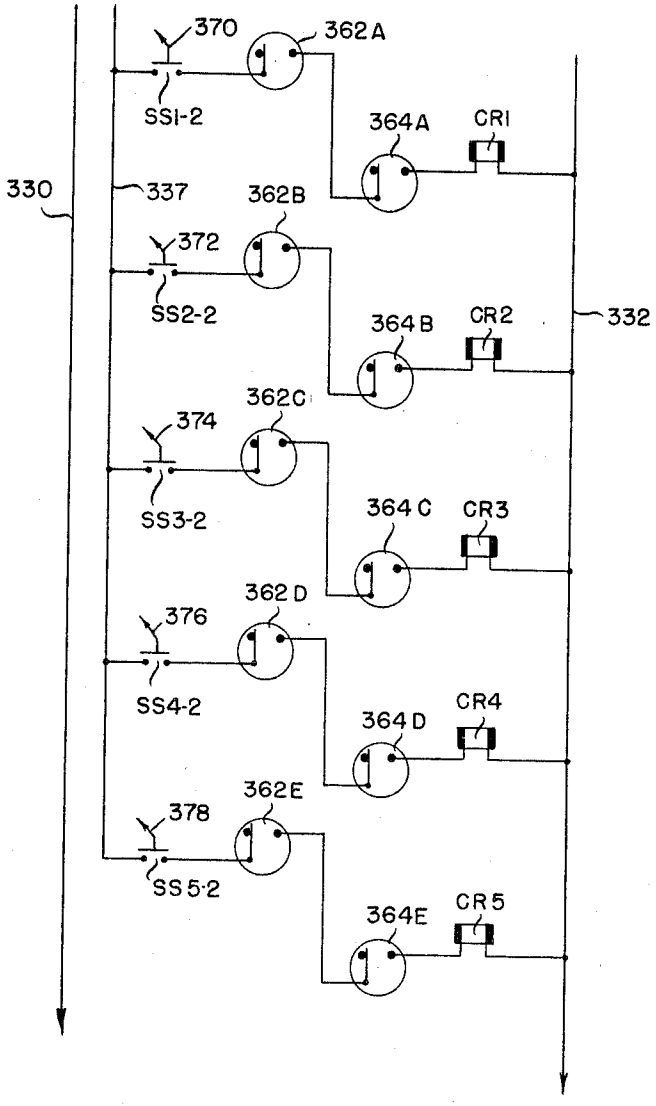


Fig. 13

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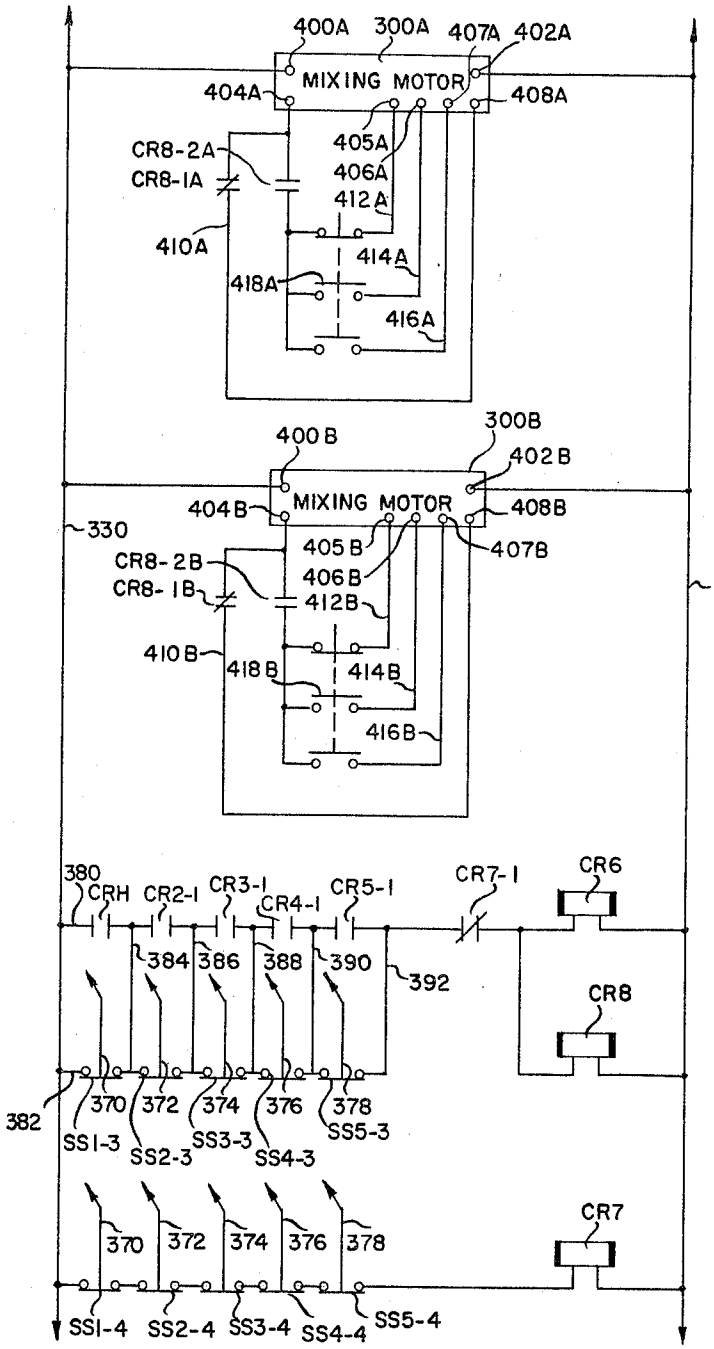


Fig. 14

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APPARATUS AND METHOD FOR PRODUCING CREPE PAPER AND THE LIKE

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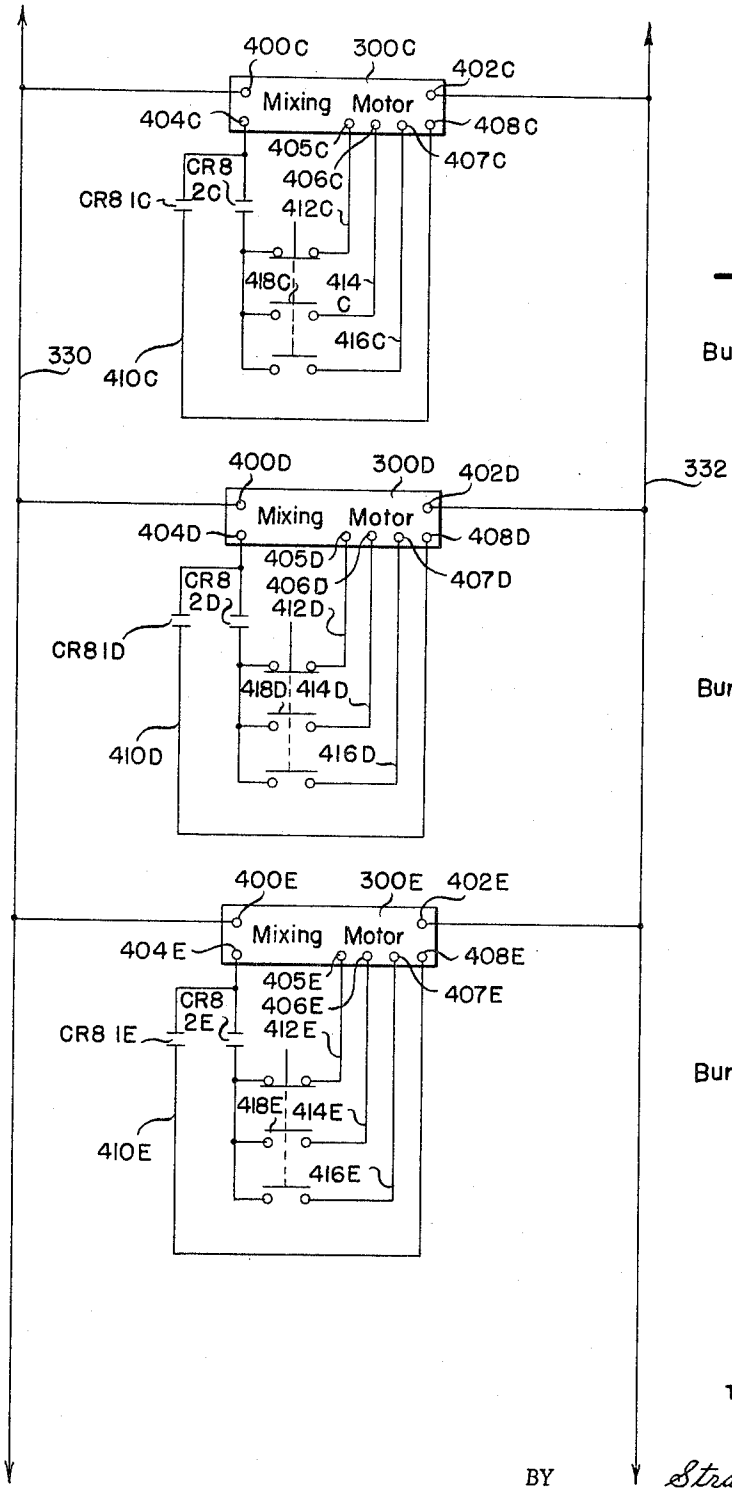


Fig. 15

Burner Zone C

Burner Zone D

Burner Zone E

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United States Patent Office 3,281,952
Patented Nov. 1, 1966

3,281,952

APPARATUS AND METHOD FOR PRODUCING CREPE PAPER AND THE LIKE

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Filed Aug. 9, 1963, Ser. No. 301,137
33 Claims. (Cl. 34—41)

The present invention relates to a paper conversion process and apparatus, and more particularly to an apparatus and method for producing crepe paper from such materials as kraft paper.

Conventionally, paper is creped by soaking a continuous strip of paper stock in warm water, passing the soaked paper strip over a roll and under a doctor blade to crinkle the wet paper, and then drying and stretching the wet crinkled strip to remove at least 95 percent of the moisture.

Machines for producing crepe paper, and particularly for drying and stretching the crinkled wet paper web, are required to handle many different kinds of paper of varying plys, weights, and widths. In addition, the drying and stretching apparatus must be capable of evaporating large amounts of water from the wet paper strip. Kraft paper, for example, which is often used to make crepe paper, has a dry weight of 90 pounds per 3,000 square feet which when wet may contain 53 pounds water that must be removed to produce an acceptable product. Paper used in the production of crepe paper may also be treated with wax, or it may be laminated by providing a layer of asphalt or plastic resin between two paper layers.

Prior to this invention, the moisture-ladened paper was dried and stretched by running it successively over a plurality of hollow steam-heated drums. The removal of moisture by this conventional apparatus is so slow that the production of the final product cannot be carried on at linear velocities greater than 30 feet per minute, and even at this relatively slow speed, the final moisture content is apt to be so high as to produce a product of inferior quality. For example, when asphalt laminated paper is dried on the conventional steam-heated drums, the asphalt objectionably bleeds through the paper in many spots. Also, excessive undesirable wrinkles are frequently produced.

Another factor impairing the quality of the paper product dried and stretched by conventional heated drum equipment is the poor strength of the wet paper web which prohibits the application of sufficient tension to pull the paper tautly into intimate contact wih the heated drum periphery, if tearing or rupture of the wet sheet is to be avoided. As a result, there is poor heat transfer contact between the paper and the heated drum, and the paper cannot be stretched sufficiently to prevent the formation of wrinkles.

It is, accordingly, the primary object of the present invention to provide a novel high speed, relatively low cost method and apparatus for increasing the rate at which crepe paper and the like may be produced without impairing the quality of the final product.

Briefly, the foregoing object of the present invention is accomplished by first subjecting the wet paper web to radiant heat from gas-fired infrared burners to drive off much of the moisture. The partially dried paper is then passed over a plurality of heated drums which stretch and further dry the paper web. After the paper is passed over the heated drums, it is subjected to a further infrared heat treatment by gas-fired infrared burners to reduce the moisture content close to a predetermined desired amount which is tolerably small enough to avoid impairment of the quality of the crepe paper but yet which

is large enough to prevent the paper from becoming brittle. Finally, the paper is passed over a heated drum to adjust the moisture content to the above-mentioned desired amount. By passing the paper successively through these operations, the rate of production can be increased three to five times in comparison with prior methods and apparatus, and particularly in comparison with prior methods utilizing only heated drum equipment.

A further object of the present invention is to provide a novel low cost paper strip drying and stretching apparatus that is automatically controlled, safe and inexpensive to operate, easy to service, and readily adjustable to handle a variety of different types of paper.

Still another object of the present invention is to provide a novel apparatus for producing crepe paper which has a long service life, which requires minimum upkeep, and which occupies minimum floor space.

Another object of the present invention is to provide a burner equipped drying apparatus with a novel control system which automatically cycles the burners from starting to running condition each time the unit is started and which once adjusted for a given operation will provide the desired operating condition each time the unit is restarted after shut down.

Still another object of the present invention is to provide a novel paper drying apparatus with means for permitting adjustment of the heat supply at various seriate zones, and to permit sensitive, independent regulation at each zone.

Further objects of the invention will become apparent as the description proceeds in connection with the appended claims and the annexed drawings wherein:

FIGURE 1 is a partially diagrammatic elevation of a high-speed crepe paper producing apparatus constructed according to the principles of the present invention;

FIGURE 2 is an enlarged fragmentary elevation of the right-hand portion of the drying and stretching apparatus illustrated in FIGURE 1;

FIGURE 3 is an enlarged fragmentary elevation of the left-hand portion of the drying and stretching apparatus illustrated in FIGURE 1;

FIGURE 4 is a section taken substantially along lines 4—4 of FIGURE 2 and illustrating details of one of the paper support rollers over which the paper rides as it is conveyed through the drying and stretching apparatus illustrated in FIGURE 2;

FIGURE 5 is a section taken substantially along lines 5—5 of FIGURE 1;

FIGURE 6 is a section taken substantially along lines 6—6 of FIGURE 1;

FIGURE 7 is a section taken substantially along lines 7—7 of FIGURE 2 and illustrating details of one of the burners contained in the drying and stretching apparatus;

FIGURE 8 is an enlarged fragmentary elevation illustrating the adustable support for one of the burner banks illustrated in FIG. 2;

FIGURE 9 is a section taken substantially along lines 9—9 of FIGURE 2 and illustrating the screened inlet openings to the exhaust duct system for removing moisture evaporated by the burner banks in the drying and stretching aparatus;

FIGURE 10 is an enlarged fragmentary elevation illustrating the adjustable support for one of the burner banks shown in FIGURE 3;

FIGURE 11 is a diagrammatic view of the gas and air burner supply piping and controls for furnishing a combustible mixture of air and gas to the burners illustrated in FIGURES 2 and 3;

FIGURES 12–15 illustrate an electrical circuit diagram for the apparatus shown in the previous figures, with the portions of the circuit illustrated in FIGURES 13–15

being continuations of the circuitry shown in FIGURES 12 and 13; and

FIGURE 16 is a section taken substantially along lines 16—16 of FIGURE 5.

Referring now to the drawings, and more particularly to FIGURE 1, the apparatus for producing crepe paper and incorporating the principles of the present invention is generally designated by the reference numeral **20**. A roll of paper **22** to be processed is mounted on a shaft **23** supported on a suitable unwind stand **24** and equipped with a standard tension brake **25**. Roll **22** is unwound from stand **24** and is fed as a continuous strip **26** between two adjacent rotatably-mounted rolls **28** and **30** where it may receive preliminary treatment such as coating with wax if desired.

With continued reference to FIGURE 1, strip **26** which may be between 30 inches and 64 inches in width, then is passed under two rolls **32** and **34** in a hot water tank **36** where the paper is soaked with water, generally absorbing as much as half of its own dry weight. The soaked paper strip leaving water tank **36** is passed between two rotatably-mounted, parallel flattening rolls **38** and **40** which preferably extend at right angles to the movement of strip **26** and which press the strip flat. Strip **26** then is successively passed under a conventional doctor blade **42** and through a stretching and drying unit **44** of apparatus **20**. Doctor blade **42** is located adjacent to rolls **38** and **40** and crinkles the wet paper passing between the rolls to provide a creped effect in the usual manner.

In accordance with the present invention, unit **44** consists essentially of three seriate sections: an initial infrared heating section **46**, an intermediate heating and stretching section **48**, and a final infrared heating section **50**. The crinkled wet paper strip, as shown in FIGURES 1 and 2, is conveyed generally horizontally through section **46**, riding on top of a series of parallel spaced apart rotatable support rolls **52, 53, 54** and **55** and under smaller diametered guide rods **57, 58, 59** and **60** to keep strip **26** taut so that it firmly engages the upper peripheral portion of rolls **52–55**. Rolls **52–55** and rods **57–60** are alternately spaced preferably at right angles to the direction of movement of strip **26**.

As best shown in FIGURE 4, each of the rolls **52–55** is provided with a pair of coils **62** and **64** which are respectively wound around the roll in the form of helixes starting from a central or medial region on the roll and extending to opposite ends of the roll. Coils **62** and **64** engage paper strip **26** and are respectively wound in opposite directions as shown so that as each roll **52–55** is rotated in the direction of the arrow shown in FIGURE 4, each half of strip **26** will be transversely dragged by coils **62** and **64** toward opposite ends of each of the rolls **52–55** with the result that the paper strip will be pulled flat across its entire width.

Referring now to FIGURES 2, 5 and 6 heating section **46** comprises a plurality of infrared gas-fired burners **70** divided equally into eight banks **72, 73, 74, 75, 76, 77, 78** and **79**. Each bank **72–79** preferably contains nine infrared burners arranged in three coextensive side-by-side horizontal rows having three burners each and extending at right angles to the movement of strip **26** through heating section **46**. The burners in each row are advantageously in end-to-end abutting relationship as best shown in FIGURE 5 so that each bank **72–79** provides a substantial continuous and rectangular radiating surface facing paper strip **26** and indicated by the reference character **80**.

Banks **72–75**, as best shown in FIGURES 2, are uniformly horizontally spaced apart vertically above paper strip **26** and span the entire width of the strip. Banks **76–79** are spaced vertically below strip **26** and vertically align with banks **72–75** respectively to form a heating channel **82** through strip **26** is horizontally conveyed.

Each of the burners **70** is preferably of the type described in United States Letters Patent No. 2,775,294 issued December 25, 1956, to Gunther Schwank, and, as shown in FIGURE 7, essentially comprises a burner casing **84** defining a mixing chamber **86**. A fuel gas nozzle **88** supported by casing **84** and having an inlet **90** discharges a jet stream of fuel into a mixing tube **92** and draws in primary air through opening **94**. The air and fuel gas are mixed in chamber **86**, and the mixture passes through a perforated ceramic burner plate **96** fixed to casing **84**. Incandescent combustion takes place on the outer surface of plate **96**. Preferably, burners **70** have a maximum output of 12,000 B.t.u. per hour and are 2¼ inches wide by 22 inches long.

As best shown in FIGURE 2, the burning surface of each burner plate **96** faces the wet crinkled paper strip **26** and is substantially parallel to the movement of the paper strip through channel **82**. The burners **70** in each bank **72–75** have their radiating surfaces contained in a common plane and are rigidly fixed together at their abutting ends by structural members generally indicated at **100** in FIGURE 5.

Each of the burner banks **72–75**, as shown in FIGURES 2, 5 and 8, is independently supported for vertical adjustment from a rigid overhead framework **102**. Burner bank **72** is supported by a pair of vertical channel members **104** and **106** which are fixed to the end burners in bank **72** by gussets **108**. Each of the members **104** and **106**, as best shown in FIGURE 8, is provided with a series of vertically spaced apart adjustment holes **110** and is supported from framework **102** by a pin **112** which extends through a selected one of the holes **110**. The pins **112** for channel members **104** and **106** may be removed permitting burner bank **72** to be vertically displaced to a desired distance from paper strip **26** and then inserted into the proper hole **110** for retaining burner bank **72** in place.

The structure for adjustably supporting burner banks **73–75** from framework **102** is the same as that just described for bank **72**, like reference numerals being employed to identify like parts.

Referring to FIGURES 2 and 6, the burners in each bank **76–79** below the wet crinkled strip **26** are rigidly fixed as a unit by suitable structural members **115**. Each of the banks **76–79**, similar to banks **72–75**, are mounted for independent vertical adjustment on a rigid floor-mounted framework **116**. The structure supporting banks **76–79** on framework **116** is the same as the channel member and pin structure described for the upper banks **72–75** and, to this extent, like reference characters have been employed to designate like parts. Thus, by independently adjusting the vertical distance between the heat radiating surfaces of each burner bank **72–79** and paper strip **26**, the amount of moisture evaporated by each burner bank can be independently controlled to provide an effective zoned removal of moisture.

With continuing reference to FIGURE 2, roll **52** is mounted at the inlet end to channel **82**, and rolls **53–55** are disposed within channel **82** horizontally between vertically aligned pairs of burner banks **72–79**. The portions of paper strip **26** horizontally spanning rolls **52–55** are thus vertically exposed on both sides of burners **70** in banks **72–79**. Curved heat deflecting shields **122, 123** and **124** extending partially around rolls **53–55**, respectively, protect these rolls from the radiant heat emitted by burners **70**. Shields **122–124** are of identical construction and each terminate to provide an upwardly facing mouth exposing the upper periphery of rolls **53–55** for engagement by paper strip **26** as it passes through channel **82**.

With reference to FIGURES 1, 2, 5 and 6, moisture evaporated by the infrared radiation in heating section **46** is carried away by a ventilating system **128** comprising a high velocity exhaust fan **130** driven by a motor **132**. The inlet side of fan **130** is connected by a main exhaust duct **134** to four parallel uniformly spaced apart branch ducts **136, 137, 138** and **139** located vertically above the wet paper strip **26** and to four parallel uniform-

ly spaced apart branch ducts **141**, **142**, **143** and **144** located vertically below strip **26**.

As viewed from FIGURE 2, branch ducts **136–139** are respectively located horizontally to the left of burner banks **72–75** so that duct **136** is between burner banks **72** and **73**, duct **137** is between burner banks **73** and **74**, duct **138** is between burner banks **74** and **75**, and duct **139** is at the outlet of channel **82**. Ducts **136–139** preferably extend at right angles to the movement of strip **26** and are each provided with screened inlet openings **146** (FIGURE 9) and extending across strip **26**, and preferably contained in a common horizontal plane.

Branch ducts **141–144** are respectively disposed vertically below ducts **136–139** and to the left of burner banks **76–79**, respectively, so that duct **141** is between banks **76** and **77**, duct **142** is between banks **77** and **78**, and duct **143** is between banks **78** and **79**. Ducts **141–144** extend at right angles to the movement of paper strip **26** and have screened inlet openings **148** (FIGURE 6) facing and extending across the underside of strip **26**. Thus, both sides of strip **26** passing through channel **82** are subjected to a series of alternate radiant heating and high velocity air exhaust zones.

Dampers **149** and **150** (FIGURE 16) contained in duct **134** are adjustable to control the amount of air moved through branch ducts **136–139** and **141–144**.

By heating the paper strip **26** with burners **70**, the molecules of water evaporate from the surface of strip **26**, forming a dry boundary layer in each side of the wet paper and a vaporous barrier layer adjacent the opposite sides of the strip. As the drying process continues, the molecules of liquid migrate through the dry boundary layer and escape from the wet paper strip into the adjacent barrier layer. As the concentration of molecules in the barrier layer increases, these molecules tend to diffuse back to the lower concentrated dry boundary layer in the paper.

With the present invention, this vaporous barrier layer is continously removed by operation of fan **130** in ventilating system **128** thereby promoting the rapid escape of the water molecules from the dry boundary layers on both sides of the paper strip.

With the alternate arrangement of burner banks and exhaust branch ducts, the concentration of water molecules in the vapor barrier being exhausted remains relatively low. Thus, rapid migration of water molecules from the paper strip is promoted to improve the evaporation rate of the drying apparatus.

The partially dried crinkled paper strip **26** leaving heating section **46** is then passed through heating section **48** which comprises, as best shown in FIGURES 1–3, a pair of side-by-side hollow, steam-heated drums **152** and **154** rotatably mounted about parallel spaced apart axes contained in a common plane and extending at right angles to the direction of movement of strip **26**. Drums **152** and **154** may be of any conventional construction for drying paper and are internally heated by steam at a pressure preferably within the range of 35–40 pounds per square inch.

Strip **26** entering heating section **48** passes over a roller **158** and is wrapped around approximately three-quarters of the periphery of drum **152** by an endless belt **160** which is made of porous, heat resistant fabric and which is about ⅜ inch thick. Belt **160** passes around roller **158**, under a pair of bottom rollers **162** and **164**, over an upper roller **166** and around a top roller **168**. Roller **158** is disposed at the entrance to heating section **48** approximately midway between the top and bottom of drum **152**. Rollers **162** and **164** are spaced on opposite sides of and below drum **152**. Roller **166** is spaced vertically above roller **164** and also above the level of drum **152**. Roller **168** is mounted vertically over drum **152** and cooperates with roller **158** to wrap the portion of belt **160** extending therebetween around the periphery of drum **152** in the manner shown. A belt tensioning roller **170** over which belt **160** passes, is mounted vertically below drum **152** approximately midway between rollers **162** and **164**.

As shown best in FIGURES 1 and 2, the portion of paper strip **26** passing between rollers **158** and **168** is pressed firmly and intimately against the periphery of drum **152** by belt **160** which absorbs the moisture from strip **26** and permits it to evaporate into the surrounding atmosphere.

After the wet paper strip leaves the periphery of drum **152**, it passes around roller **168** and over roller **166**. The paper strip leaving roller **166** is then wrapped around approximately three-quarters of the periphery of drum **154** by another belt **172** also made of ⅜ inch thick, porous, heat resistant material. Belt **172** passes around a series of rollers **174**, **176**, **178**, **180**, **182** and **184** which are correspondingly positioned in the same manner as rollers **158**, **162**, **164**, **166**, **168** and **170** respectively. Similar to the function of belt **160**, belt **172** firmly presses strip **26** against the periphery of drum **154** and absorbs the moisture from strip **26**. The moisture absorbed by belts **160** and **172** evaporates and is exhausted, as shown in FIGURE 1, through an overhead hood **188** connected by an exhaust duct **190** to a motor driven exhaust fan **191**. Fan **191** removes moisture from the immediate vicinity of drums **152** and **154** and also removes that moisture not removed by exhaust fan **130**.

With continued reference to FIGURE 2, the portion of strip **26** leaving the periphery of drum **154** passes around roller **182**, over roller **180**, under a tensioning guide roller **200**, and enters heating section **50**. Heating section **50**, as best shown in FIGURES 3 and 5, comprises upper and lower banks **204** and **205** of infrared gas-fired burners **206** which are preferably of the same construction as burners **70**. Burners **206** in bank **204** are arranged in six parallel abutting side-by-side rows each containing three burners in abutting end-to-end relationship. The radiating surfaces of burners **206** in bank **204** face strip **26** passing through heating section **50** and are preferably all contained in a common horizontal plane extending parallel to the path of movement of strip **26**. An equal number of burners in bank **205** are arranged in the same manner as and vertically below the burners in bank **204**. The radiating surfaces of burners **206** in bank **205** facing the underside of strip **26** preferably are contained in a common plane extending parallel to the radiating surfaces of the burners in bank **204**. The burners in banks **204** and **205** thus cooperate to form a heating channel **208** through which strip **26** horizontally passes.

With reference now to FIGURES 3, 5 and 6, burners **206** in bank **204** are secured together as a unit by means of suitable structural members indicated at **210** in FIGURE 5. Similarly, the burners in bank **205** are unitarily secured together by structural members **211**.

Bank **204** is mounted for vertical adjustment from a rigid overhead framework **212** by parallel upstanding channel members **214** and **216** which are fixed to the burners at the end of the six rows by rigid plates indicated at **218**. Each of the channel members **214** and **216** is adjustably mounted for vertical displacement by a pin **218** (FIGURE 10) which extends through a selected one of a series of vertically spaced apart adjustment holes **220** formed in the channel web. By this structure, the pins **218** for channel members **214** and **216** may be removed permitting burner bank **204** to be vertically displaced to a desired distance from strip **26** passing through heating section **50** and then inserted into the proper hole for retaining the burner bank at the selected distance from the paper strip. A like support structure adjustably supports burner bank **204** on a rigid floor-mounted framework **222**, and to this extent, like parts are identified by like reference numerals. With this structure, it is clear that burner banks **204** and **205** are independently vertically adjustable to desired distances from strip **26** to heat the paper strip to effect the evaporation of a desired amount of moisture.

With continuing reference to FIGURES 3, 5 and 6, the portion of strip **26** leaving the heating zone provided by burner banks **204** and **205** passes horizontally between two vertically spaced apart horizontally extending air exhaust branch ducts **226** and **228** which are connected by a main duct **230** to the inlet side of fan **130**. Branch ducts **226** and **230** extend at right angles to the movement of strip **26** and are respectively provided with screened inlet openings **232** and **234** equidistantly spaced apart from and facing opposite sides of strip **26** and preferably extending the entire width of the paper.

Dampers **236** and **238** (FIGURE 3) disposed in main duct **230** adjacent to the connections with branch ducts **226** and **228**, respectively, are individually adjustable to control the amount of air moved through each of the ducts **226** and **228**.

As best shown in FIGURE 1, strip **26** leaving heating section **50** passes over and partially around a hollow, steam-heated, rotatably-mounted cylinder **244** and then under and partially around an unheated rotatably-mounted cylinder **246** in an S-like configuration. Cylinder **244** is spaced vertically above cylinder **246**, and the axes of both cylinders **244** and **246** are parallel at right angles to the movement of strip **26**. The creped paper strip is pulled taut by the heated cylinder **244** to prevent the formation of wrinkles. Cylinder **244**, as will be explained in detail later on, completes the drying operation by reducing the moisture content in strip **26** to at least an amount which will not adversely affect the quality of the final product. The dried paper leaving cylinder **246** is passed over a roller **248** and then, to complete the operation, is wound into a roll on a shaft **250** which is rotatably mounted on a rewind stand **252**.

As shown in FIGURE 1, drums **152** and **154**, cylinders **244** and **246**, rollers **38** and **40**, and rewind shaft **250** may be drive connected to a motor **254** by suitable drive trains such as adjustable speed ratio belt and pulley drives indicated at **256**. The belt and pulley drives **256** are so adjusted that drum **154** will be rotated at a greater peripheral speed than drum **152**, and that cylinder **244** will be rotated at a peripheral speed at least equal to that of drum **154**. Advantageously, cylinder **246** and rewind shaft **250** are rotated at the same angular speed as cylinder **244**. The speed of drum **154** is made sufficiently greater than that of drum **152** to stretch strip **26** by an amount which is small enough to avoid tearing, but yet which is large enough to stretch the paper strip for eliminating wrinkles and to maintain the strip in intimate contact with the heated peripheries of the drums. Thus, strip **26**, during its passage through unit **44**, is stretched and kept taut and free of wrinkles.

Considering the processing of the paper with the apparatus just described, the burner banks **72–79**, **204** and **205** are initially vertically adjusted independently of each other to thus adjust the amount of heat supplied by each burner bank. The apparatus is then set in operation by igniting the burners and starting the various motors by controls to be described later on. The dry roll of unprocessed paper **22** on stand **24** is unwound, and as it passes around rolls **28** and **30**, it may be coated with wax or subjected to other preliminary treatment as desired. The paper strip **26** then is successively soaked with hot water by passing it through wetting tank **36**, flattened by passing it between rolls **38** and **40**, and crimped by the action of doctor blade **42**.

The wet crinkled paper strip then is conveyed through heating section **46** where it is heated by infrared radiation from burner banks **72–79** to cause much of the moisture to be evaporated and exhausted by fan **130**. The partially dried crinkled strip is then passed around drum **152** for smoothing and further heating to evaporate more moisture. After that, strip **26** is passed around drum **154** for smoothing, stretching and further heating to evaporate still more moisture. As paper strip **26** is carried around drums **152** and **154**, it is, in addition to being stretched, pressed between belts **160** and **172** and the peripheries of drums **152** and **154** causing additional moisture to be squeezed out and absorbed by belts **160** and **172**. In addition, the pressure applied by belts **160** and **172** irons paper strip **26** flat.

Then, strip **26** is conveyed through the second and final infrared heating section **50** for reducing the moisture content to close to the desired final amount which is large enough to prevent the paper from becoming brittle, but yet which is small enough to avoid impairment of the quality of the product. Final heating of strip **26** is accomplished by cylinder **244** which pulls the paper taut and which reduces the moisture content the desired tolerable amount which at least for single strip creped paper, laminated asphalt creped paper, and also laminated resin creped paper is preferably 5% and may be within the range of 5%–7%.

It has been found that if the moisture content in the creped paper product is lower than 5%, the paper will be objectionably brittle. If, on the other hand, the final moisture content in the paper is more than 7%, it has been found that the quality of the paper may be impaired. In particular a final moisture content of 7% in laminated creped paper objectionably promotes bleed through of the asphalt or resin.

With this process and apparatus of the present invention, the paper strip **26** can be fed through apparatus **20** and particularly through the drying and heating unit **44** at a linear velocity of 90 feet per minute, which amounts to less than ½ minute for a spot on strip **26** to travel through the apparatus.

According to the present invention, it has been found that it is necessary to apply heat and to remove moisture in the seriate series of steps just described to prevent paper strip **26** from being scorched or damaged, but yet insuring that the final moisture content is satisfactorily reduced to a tolerable desired amount of approximately 5 percent of the original content while carrying on the operation at such high speeds as mentioned above. The amount of water that must be evaporated in the process and apparatus of this invention depends, a great deal, on the properties of the material being processed. One of the more difficult papers to process is 90-pound kraft paper which, when soaked, will absorb 53 pounds of water per 3,000 square feet. Accordingly, if a five foot wide strip of this paper is run through apparatus **20** at 90 feet per minute and is dried to a final water content of 5 pounds per 3,000 square feet, the amount of water that must be evaporated is 432 pounds per hour. Also depending on the type of paper to be dried, the infrared wave length preferably should be 0.9–6 microns.

In the present embodiment, the maximum capacity of all the burners in banks **72–79** is 576,000 B.t.u. per hour, of which at least half, depending in one respect upon the vertical adjustment of the burner banks, will reach strip **26** and evaporate up to **262** pounds of water. The maximum heat input of burner banks **204** and **205**, being 432,000 B.t.u. per hour in this embodiment, will evaporate up to 196 pounds of water per hour. Hence, heating sections **46** and **50** together have sufficient heating capacity to evaporate as much as 458 pounds of water per hour. Since considerable water is also evaporated by the heated drums **152** and **154** in section **48**, ample capacity is available to permit a high speed operation.

However, heat alone, or even for that matter, infrared radiation alone, will not produce the desired speed and quality of crepe paper since the wet paper strip **26** must be stretched and ironed while being dried in the unique relation with the heating sections previously described in order to achieve a quality product at the high speed production rates attributable to this invention. In particular, it has been found, according to this invention, that the infrared heat must be applied at such stages with respect to the contact of paper strip **26** with drums **152** and **154** that just the right amount of moisture content is available

to allow the paper strip to be easily and quickly ironed, stretched and dried by squeezing it between belts 160 and 172 and the peripheries of drums 152 and 154 respectively. For example, in processing a 90-pound asphalt laminated kraft paper with the method and apparatus of this invention, about 48 percent of the water is removed in heating section 46, about 21 percent is removed in section 48, about 24 percent is removed in section 50, and about 2 percent is removed by the steam-heated cylinder 244, leaving 5 percent of the moisture in the paper. The last 2 percent of moisture is not removed by the infrared heating section 50 to prevent scorching of the paper by the radiant heat of the burners.

From the foregoing, it is clear that infrared heating section 46 removes approximately one-half of the moisture content in paper strip 26 and that appreciably less moisture is removed at each of the succeeding heating sections 48 and 50. It has been found that it is essential to remove approximately at least half of the moisture content before stretching the paper strip on steam heated drums 152 and 154 in order to prevent bleed through in laminated paper products. The exact amount of moisture removed at section 46 may run as high as 51 percent and even somewhat more, but if there is insufficient removal of moisture before stretching, bleed through is likely to occur particularly at the relatively high speeds at which the paper is processed in this invention.

Thus, by dividing the infrared burners into two heating sections, namely sections 46 and 50, which respectively furnish the proper amount of heat both before and after paper strip 26 contacts drums 152 and 154, the heat furnished by burner banks 72–79 in section 46 reduces the moisture content in strip 26 to the point where drums 152 and 154 and their respective belts 160 and 172 are most effective, while the heat furnished by section 50 evaporates as much of the remaining moisture as possible without scorching the paper strip.

Another advantage of using radiant energy to heat the wet paper strip 26 in heating section 46 is that the strength of the paper is increased by evaporating much of the moisture before it is ironed and stretched by drums 152 and 154. This increased strength permits the paper strip passing around drums 152 and 154 to be sufficiently stretched without tearing to eliminate objectionable wrinkles. The coils 62 and 64 on rolls 52–55 by pulling strip 26 taut across its width also check for formation of wrinkles and assure that the paper strip is flat across its width as it enters section 48.

In addition, application of infrared radiation particularly at the initial and final evaporation stages is more efficient than application of heat by conduction or covection. Thus, by subjecting paper strip 26 to infrared radiation at sections 46 and 50 which respectively include the initial and final evaporation stages, the drying rate is economically improved. Also, the particular arrangement of ducts in ventilating system 128 assures that the moisture is removed as fast as it leaves the paper. This prevents the occurrence of heavily concentrated vapor barriers which would retard the evaporation of water from the paper.

Since controlled evaporation and hence close regulation of heat is required to achieve a fast production rate of creped paper and the like, the burner banks 72–79, 204 and 205 are, according to the present invention, divided, as shown in FIGURES 1 and 11, into five separate control zones A, B, C, D and E to which fuel gas and air in controllable amounts are independently supplied. Burner banks 72 and 73 are in zone A, burner banks 74 and 75 are in zone B, burner banks 76 and 77 are in zone C, burner banks 78 and 79 are in zone D and burner banks 204 and 205 are in zone E. Branch pipelines 265, 266, 267, 268 and 269 connected in parallel to main supply line 270 deliver fuel gas to the burners in zones A, B, C, D and E, respectively. Similarly, branch pipelines 272, 273, 274, 275 and 276 connected in parallel to an air supply line 277 furnish air for mixture with the fuel gas at zones A, B, C, D, and E, respectively. A blower 278 driven by a motor 279 is connected to air line 277 to supply air preferably under a pressure of approximately 8 ounces per square inch gauge. Gas pressure in line 270 is approximately 1 p.s.i.g.

Serially disposed in gas line 270 upstream from the connection of branch lines 265–269 is a manual shut-off valve 280, a connection for a low pressure gas cut-off switch 281 and a solenoid operated shut-off valve 282. A vent valve 283 is contained in a pipeline 284 connected to gas line 270 between valve 282 and the connection of branch lines 265–269. A high pressure cut-off switch 286 is connected to gas line 270 between the connection of line 284 and branch line 265.

Since the gas and air supply connections and burner control equipment are alike for each of the zones A–E, this structure will be described only for zone A. Like parts in zones B–E are designated by like reference numerals suffixed by the letter of their respective zones.

Thus, with continued reference to FIGURE 11, branch line 265 contains a manual shut-off valve 290A and a pressure regulating valve 292A downstream of valve 290A. Downstream of pressure regulating valve 292A, branch line 265 contains a normally closed solenoid operated burner valve 294A.

With continuing reference to FIGURE 11, the gas and air branch lines 265 and 272 are connected to the inlet side of a mixer 296A. The outlet of mixer 296A is connected by a manifold 297A to eighteen flexible conduits 298A which are respectively connected one to each of the burner inlets 90 in the banks 72 and 73.

Mixers 296A–E may be of any suitable multi-ratio construction for mixing together the fuel gas and air supplies such as, for example, the commercially available Maxon MR mixers. In the present embodiment, mixers 296A–D are preferably rated at 475,000 B.t.u. per hour and mixer 296E is preferably rated at 830,000 B.t.u. per hour. As shown, mixers 296A–E are respectively driven by control motors 300A–E. Control motors 300A–E each are operative to cycle their respective mixers 296A–E between a starting mixture of gas and air adjusted to light readily, and a running mixture which may be adjusted to provide the desired heat output for optimum efficiency.

Referring now to FIGURES 12–14, a control circuit 320 for the burners in drying apparatus 20 is provided with a transformer 322 having a primary winding 324 connected across an alternating three-phase current source such as ordinary power mains indicated at 326. The secondary winding 328 of transformer 322 is connected between conductors 330 and 332 to supply operating power for circuit 320. A spring-loaded push button start switch 334 for starting the operation of the burners in drying apparatus 20 is connected between conductors 330 and 332 in series with a starting relay winding M1 which is energizable to close two sets of normally open contacts M1–1 and M1–2.

With continued reference to FIGURE 12, motor 132 for driving exhaust fan 130 is connected to power mains 326 through contacts M1–1. Energization of relay winding M1 by momentarily depressing switch 334 closes contacts M1–1 to start motor 132. Contacts M1–2, which are also closed by energizing relay winding M1, are in parallel with switch 334 to establish a holding circuit around switch 334 for maintaining relay winding M1 energized upon release of switch 334. This holding circuit may be traced from transformer secondary 328, through conductor 330, through a normally closed spring-loaded push button stop switch 335, through contacts M1–2, through relay winding M1, and through conductor 332 to the other side of control circuit transformer secondary 328.

When fan 130 reaches its operating speed, the resultant air pressure closes an air switch 336 contained in a conductor 337 in series with contact M1–2. Conductor 337

is also connected to a conductor 338 serially connecting switch 334 and winding M1. Closing of air switch 336 establishes parallel circuits through timer motor 339 and relay winding 340 of a timer relay TR1 and through a pilot lamp 342. Timer relay TR1 has two sets of normally closed time delay contacts TR1–1 and TR1–2 and one set of normally open time delay conntacts TR1–3. Contacts TR1–1 are serially connected between air switch 336 and motor 339 and contacts TR1–2 are connected between switch 336 and pilot lamp 342. Contacts TR1–3 are connected between switch 336 and one terminal of a combustion air blower motor starting winding M2 which has its other terminal connected to conductor 332 in parallel circuit relation with timer relay TR1.

With continued reference to FIGURE 12, the circuit for energizing motor 339 may be traced from conductor 330 at one side of transformer secondary 328, through contacts M1–2, through air switch 336, through that part of conductor 337 in which continuity has been established by closing switch 336, through a set of normally closed time delay contacts TR2–1, through normally closed contacts TR1–1, and through relay 339 to conductor 332 at the opposite side of transformer secondary 328. The circuit for energizing motor 340 may be traced from conductor 330, through contacts M1–2, through switch 336, through winding 340 which is connected around winding 339 and contacts TR1–1, to conductor 332 at the other side of transformer secondary 328. The circuit for energizing pilot lamp 342 may be traced also from conductor 330, through contacts M1–2, through switch 336, through contacts TR2–1, through normally closed contacts TR1–2, through lamp 342, to conductor 332.

After a predetermined time delay following energization of winding 339, conntacts TR1–1 and TR1–2 open and contacts TR1–3 close. This time delay is made sufficiently long to permit fan 130 to urge apparatus 20 of any objectionable accumulations of combustible mixtures that may be present. Opening contacts TR1–2 and TR1–1 respectively interrupts the circuit to pilot lamp 342, indicating the completion of the purging cycle, and de-energizes timer relay winding 339.

Contacts TR1–3 are held closed by energization of motor 340 to complete a circuit for energizing relay winding M2. This circuit may be traced from conductor 337, through normally closed contacts TR1–3, through winding M2, and through normally closed contacts overload contacts 344 and 346 to conductor 332. Energization of winding M2 closes normally open contacts M2–1 to complete a circuit for starting blower motor 279. Normally open contacts M2–2 connected in series with contacts TR1–3 are also closed by the energization of relay winding M2.

When blower 278 reaches its operating speed, the air pressure in air supply line closes an air switch 348 to establish a circuit for energizing a gas supply solenoid coil MV which opens gas valve 282 in gas line 270 permitting gas under pressure to flow through line 270 and into branch lines 265–269. This circuit for energizing solenoid MV may be traced from conductor 330, through stop switch 335, through contacts M1–2, through exhaust air switch 336, through contacts TR2–1, through contacts TR1–3, through contacts M2–2, through blower air switch 348, through high pressure gas switch 286 which is normally closed, through low pressure gas switch which is closed by the gas pressure in line 270, through a set of normally closed contacts CR7–1, and through solenoid MV to conductor 332.

With continued reference to FIGURE 12, solenoid MV has a set of normally open contacts MV–1 in series with a vent valve solenoid VV. Solenoid is connected in parallel with solenoid MV and is energizable to close vent valve 283. By energizing solenoid MV, contacts MV–1 will close completing a circuit to energize vent solenoid VV for closing vent valve 283. Thus, vent valve 283 will close when the main gas valve 282 is opened and, conversely, valve 283 will open when valve 282 is closed, permitting any leakage of gas to the downstream side of valve 282 to be purged to atmosphere when the drying apparatus is not in operation.

With continued reference to FIGURE 12, closing of contacts MV–1 and operation of motor 254 (FIGURE 1) to start movement of paper strip 26 through the apparatus places the system in condition for firing the burners in heating sections 46 and 50 by completing circuits to energize a flashing timer winding TR2 and an ignition timer relay winding TR3. Movement of paper strip 26 closes a normally open conventionally constructed conveyor interlock switch 352 which is contained in a conductor 354 connected between windings TR2 and TR3 and contacts MV–1. Switch 352 may have a movable contact element spring biased to open position, and engageable with a fixed contact element upon movement of strip 26.

The circuit for energizing winding TR2 may be traced from conductor 330, through stop switch 335, through contacts M1–2, through switch 336, through contacts TR2–1, through contacts TR1–3, through contacts M2–2, through switch 348 through high and low gas pressure switches 286 and 281, through contacts CR7–1 through contacts MV–1 and switch 352 which establish continuity in part of conductor 354, and through winding TR2 to conductor 332. Winding TR3 is connected through a set of normally closed contacts CR6–2 to conductor 354 in parallel and winding TR2, and is energizable by a circuit traceable from conductor 352 and through contacts CR6–2 to conductor 332.

With reference to FIGURES 11–13, the burner banks 72 and 73 in zone A are respectively provided with ignition spark plugs 358A and 360A and with flame detecting rods 362A and 364A. Flame detecting rods 362A and 364A are located remotely from their associated ignition spark plugs 358A and 360A in the manner shown. Similarly, zones B, C, D and E are respectively provided with ignition spark plugs 358B–E and 360B–E, and also with flame detecting rods 362B–E and 364B–E.

With continued reference to FIGURE 12, five ignition transformers, 366A, 366B, 366C, 366D and 366E for heating zones A, B, C, D and E are connected in parallel between conductors 330 and 332. The secondaries of transformers 366A–E are respectively connected to the two spark plugs at each heating zone. Winding TR3 closes a set of normally open contacts TR3–1 connected in series with transformers 366A–E between conductors 330 and 332 to energize the transformer secondaries for generating igniting sparks across the electrodes of plugs 358A–E and 360A–E. Contacts TR3–1 are held close for a predetermined duration sufficient for ignition and then are reopened. This will ignite the gas-air mixture flowing from any of the burners in zones A–E.

With reference to FIGURES 12–14, identically constructed manual on-off switch assemblies SS1, SS2, SS3, SS4 and SS5 are employed to respectively control flow of gas through branch lines 265–269 at burner zones A–E. Switch assembly SS1 comprises four on-off switches SS1–1 (FIGURE 12), SS1–2 (FIGURE 13), SS1–3 (FIGURE 14), and SS1–4 (FIGURE 14) ganged together for unitary actuation by a suitable linkage indicated at 370. Switches SS1–1 and SS1–2 are open when switches SS1–3 and SS1–4 are closed. Conversely, switches SS1–3 and SS1–4 will be open when switches SS1–2 and SS1–2 are closed.

The four switches in assembly SS2 are identified by the reference characters SS2–1, SS2–2, SS2–3 and SS2–4 and are ganged together for unitary actuation by a suitable linkage 372. The on-off switches in assembly SS3 are correspondingly identified by the reference characters SS3–1, SS3–2, SS3–3 and SS3–4 and are ganged for unitary actuation by a linkage 374. Similarly, the switches in assembly SS4 are identified by the reference characters

SS4–1, SS4–2, SS4–3 and SS4–4 and are ganged for unitary movement by linkage 376. In assembly SS5, the switches are designated by the reference characters SS5–1, SS5–2, SS5–3 and SS5–4 and are ganged for unitary actuation by a linkage 378. Actuation of the switches in the ganged assemblies SS2, SS3, SS4 and SS5 is the same as the actuation of correspondingly referenced switches in assembly SS1.

Referring to FIGURE 12, switches SS1–1, SS2–1, SS3–1, SS4–1 and SS5–1 are connected to conductor 354 in series with burner valve solenoid coils BV1, BV2, BV3, BV4 and BV5 respectively. By individually closing switches SS1–1, SS2–1, SS3–1, SS4–1 and SS5–1 parallel circuits are established respectively through normally closed high temperature limit switches HTL1, HTL2, HTL3, HTL4 and HTL5 to respectively energize solenoids BV1, BV2, BV3, BV4 and BV5. Energization of solenoids BV1–BV5 respectively open the burner branch line valves 294A–294E to admit fuel gas to mixers 296A–296E respectively, thus supplying combustible mixtures of air and gas to the burners in zones A–E. Selective operation of the infrared burners in zones A–E by actuating switch assemblies SS1–SS5 provides a wide heat supply range to meet different process conditions.

From FIGURE 12 it is clear that windings TR2 and TR3 together with burner solenoids BV1–BV5 will be simultaneously energized when continuity is established in conductor 354 by closing contacts MV–1 and switch 352. This requires that paper strip 26 is moving through the apparatus and that the main burner valve 282 is opened to supply gas to branch lines 265–269 before any of the branch line valves 294A–294E can be opened or igniting current can be induced in the secondaries of transformers 366A–366E. By closing contacts TR3–1 for a predetermined period, transformers 366A–366E are energized for igniting the fuel gas. When both of the flame rods 362A and 364A at zone A detect the presence of a flame, a circuit is established, as shown in FIGURE 13, for energizing a relay winding CR1. Similarly, when a flame is detected by the pairs of flame rods in zones B, C, D and E, circuits are completed to energize relay windings CR2, CR3, CR4 and CR5 respectively. The circuit for energizing winding CR1 may be traced from conductor 337 through switch SS1–2, through flame rod 362A, through flame rod 364A, and through winding CR1 to conductor 332. The energizing circuits for winding CR2, CR3, CR4 and CR5 are parallel and similar to the energizing circuit for winding CR1.

In the event any of the switches SS1–1, SS2–1, SS3–1, SS4–1 and SS5–1 are open, the corresponding switches SS1–2, SS2–2, SS3–2, SS4–2 and SS5–2 will also be open preventing circuits from being completed for energizing relay windings CR1, CR2, CR3, CR4 and CR5 respectively.

As shown in FIGURE 14, energization of windings CR1, CR2, CR3, CR4 and CR5 respectively close normally open contacts CR1–1, CR2–1, CR3–1, CR4–1 and CR5–1 all of which are series connected in a conductor 380 between conductors 330 and 332. Switches SS1–3, SS2–3, SS3–3, SS4–3 and SS5–3 are series connected in a conductor 382 between conductors 330 and 332 and are in parallel with contacts CR1–1, CR2–1, CR3–1, CR4–1 and CR5–1. Conductors 384, 386, 388, 390 and 392 connected between conductors 380 and 382 provide current paths around each of the contacts CR1–1, CR2–1, CR3–1, CR4–1 and CR5–1 in the event any of the switches SS1–2, SS2–2, SS3–2, SS4–2 and SS5–2 have been opened to prevent energization of relay windings CR1, CR2, CR3, CR4 and CR5 respectively.

Thus, when one or more of contacts CR1–1, CR2–1, CR3–1, CR4–1 and CR5–1 close, a circuit is established for energizing two relay windings CR6 and CR8 which are connected in parallel between conductors 330 and 332. If only switch SS1–2 is closed, for example, the circuit for energizing windings CR6 and CR8 may be traced from conductor 330 through contacts CR1–1, through conductor 384, through switches SS2–3, SS3–3, SS4–3 and SS5–3, through conductor 392, through a set of normally closed contacts CR7–1, and through windings CR6 and CR8 to conductor 332. Energization of relay winding CR6 closes a set of normally open contacts CR6–1 which establish a holding circuit around contacts TR2–1. Contacts TR2–1 are normally closed and are opened after a time delay of about 15 seconds by energization of timer TR2. Thus, if winding CR6 remains deenergized preventing contacts CR6–1 from closing, the opening of contacts TR2–1 will interrupt the circuits to motors 132 and 279 and to all of the valve actuating solenoids, thus shutting down the system. This condition will occur if none of the switches SS1–2, SS2–2, SS3–2, SS4–2 and SS5–2 are closed, or if the flame rods at any of the burner zones A–E fail to detect the presence of a flame.

Energization of winding CR6 opens the normally closed contacts CR6–2 which deenergizes relay TR3 to cause contacts TR3–1 to open and thereby interrupt the circuit to ignition transformers 366A–366E.

With continued reference to FIGURE 14, mixing motor 300A may be of any conventional construction and is advantageously the commercially available Barber-Coleman MF 489 motor having a pair of current supply terminals 400A and 402A, and winding terminals 404A, 405A, 406A, 407A and 408A. Terminals 400A and 402A are respectively connected to conductors 330 and 332 across transformer secondary 328. A conductor 410A connected between terminals 404A and 408A contains a normally closed set of contacts CR8–1A which are opened by energizing winding CR8. When contacts CR8–1A are closed establishing continuity in conductor 410A, motor 300A is so energized as to actuate mixer 296A for providing a rich starting fuel mixture to permit ready ignition of fuel at the burners.

With continued reference to FIGURE 14, conductors 412A, 414A and 416A are respectively connected at corresponding ends to terminals 405A, 406A and 407A respectively. The opposite ends of conductors 412A, 414A and 416A are connected through a set of normally open contacts CR8–2A to terminal 404A. A three position manual switch 418A connected in conductors 412A, 414A and 416A is actuatable, when contacts CR8–2A are closed, to selectively establish circuits to terminals 405A, 406A and 407A for varying the motor output between high, low and medium speeds. This permits three running outputs to vary the combustible fuel mixture as desired.

With the foregoing circuitry, it will be appreciated that contacts CR8–1A are closed and contacts CR8–2A are opened until the presence of a flame is detected at any of the burner zones A–E. Thus, until combustion is started, contacts CR8–1A keep motor 300A conditioned for providing a rich starting fuel mixture. When the presence of a flame is detected at any of the burner zones A–E, relay winding CR8 is energized in the manner previously explained to open contacts CR8–1A and to close contacts CR8–2A. This action conditions motor 300A to provide a less rich running fuel mixture.

The circuitry just described for motor 300A is the same for motors 300B, 300C, 300D and 300E, and to this extent, like reference numerals suffixed by the reference character corresponding to zones B–E have been used as shown in FIGURES 14 and 15.

With continued reference to FIGURE 14, a relay winding CR7 between conductors 330 and 332 is energizable by a circuit which is traceable from conductor 330, serially through switches SS1–4, SS2–4, SS3–4, SS4–4 and SS5–4, to conductor 332. Thus, when any of the switches SS1–4, SS2–4, SS3–4, SS4–4 and SS5–4 are opened, indicating that the corresponding switches SS1–1, SS2–1,

SS3–1, SS4–1 and SS5–1 are closed to permit energization of burner solenoids BV1–BV5 respectively, winding CR7 will remain deenergized. If, on the other hand, switches SS1–4, SS2–4, SS3–4, and SS5–4 are closed, winding CR7 is energized to open the normally closed contacts CR7–1 to shut down the system.

It will be appreciated that where a fine regulation of the combustible mixture is required, conventional proportioning motors providing an infinite output variation may be employed in place of motors 300A–300E. To this end, it is sometimes desirable to particularly replace motors 300A, 300B and 300E with control motors providing a choice of an infinite number of running outputs within a certain range. This would permit a more precise control of heat supplied at zones A, B and E to regulate more closely the amounts of moisture removed. Thus by fine moisture removal adjustments the rapid production rate and high quality previously discussed is more easily achieved.

In operation of the apparatus and control circuit just described, paper strip 26 is set in motion by starting motor 254, switches SS1–SS5 are actuated, and switch 334 is depressed to start the system. As a result of depressing switch 334, exhaust fan 130 is first started. After a predetermined delay permitting fan 130 to purge unit 44 of any accumulations of combustible mixtures, air blower 278 is started and the main burner solenoid operated valve 282 is opened in line 270. At this time, the normally open solenoid operated vent valve 283 will close. By energizing solenoid MV to open valve 282 and by moving strip 26, contacts MV–1 and switch 352 will be closed to permit energization of the branch line valve operating solenoids BV1–BV5.

Following energization of burner valve solenoids BV1–BV5 to open valves 294A–294E, transformers 366A–366E are energized to prepare the burners for ignition. The fuel gas flowing through valves 294A–294E enters mixers 296A–296E where it is mixed with incoming air supplied by blower 278. At start-up, motors 300A–300E are conditioned to provide a rich combustible mixture since relay winding CR8, as yet, has not been energized as previously explained. This rich combustible mixture is ignited at the burners by spark plugs 358A–358E and 360A–360E.

The presence of flame is then detected by flame rod detectors 362A–362E and 364A–364E. This action causes energization of relay windings CR1–CR5 to close contacts CR1–1, CR2–1, CR3–1, CR4–1 and CR5–1. By closing these contacts, relay windings CR6 and CR8 are energized. Energization of winding CR6 provides a holding circuit by closing contacts CR6–1 and deenergizes the ignition transformers 366A–366E by opening contacts CR6–2. Energization of winding CR8 opens contacts CR8–1A through CR8–1E and closes contacts CR8–2A through CR8–2E to cycle the mixing motors 300A–300E to provide a less rich, running, combustible mixture which may be adjusted as needed by actuation of the three-position switches 418A–418E. To shut down the system, stop switch 335 is depressed.

If the radiant surface at any of the burner zones A–E becomes too hot (more than 1575° F.), the corresponding limit switches HTL1–HTL5 will open to respectively deenergize the burner solenoids BV1–BV5 and close burner branch line valves 294A–294E.

With the foregoing control system, it will be appreciated that in addition to close regulation of the heat supplied by the infrared burners in zones A–E, any pair of the burner banks in zones A–E may be cut off as desired to meet process conditions and to prevent overheating of the paper strip 26 at any desired rate or cut off completely at selected zones. In addition, the control circuit cycles the system through the necessary steps to provide a safe starting operation. The entire circuit also cycles the air-gas mixers 296A–296E to provide a rich combustible mixture on start-up and a more economical mixture after the fuel has been ignited.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by United States Letters Patent is:

1. In an apparatus for processing a continuously moving wet paper strip,
   (a) means for stretching an intermediate portion of said paper strip by advancing a succeeding portion of said strip at a faster speed than a preceding portion thereof,
   (b) means for drying said strip along said intermediate portion simultaneously with the stretching thereof, and
   (c) means subjecting said strip to radiant heat to evaporate predetermined amounts of moisture in said intermediate portion before and after it is stretched.

2. In an apparatus for processing a continuously moving wet paper strip, means for simultaneously stretching and partially drying said paper strip, and means subjecting said strip to radiant heat to evaporate predetermined amounts of moisture in said strip before and after said strip is stretched, said means for simultaneously stretching and partially drying said paper strip comprising a plurality of internally heated drums, means for passing said paper strip successively around the respective peripheries of said heated drums, and means for rotating said drums at progressively increased speeds to impart movement to said strip and to stetch said strip.

3. An apparatus for drying and stretching a continuous wet paper strip comprising:
   (a) means providing first, second and third seriate drying zones,
   (b) means for continuously moving said paper strip successively through said first, second and third zones,
   (c) radiant energy heating means in said first zone for heating said paper strip with radiant energy to evaporate a substantial predetermined amount of moisture in said strip,
   (d) means including a plurality of internally heated drums in said second zone for stretching and further heating said paper strip to evaporate additional moisture, and
   (e) radiant energy heating means in said third zone for heating said paper strip with radiant energy to reduce the moisture content in said strip close to a predetermined tolerable amount.

4. The apparatus defined in claim 3 wherein said radiant heating means comprises a plurality of infrared burners mounted in separate banks to project radiant energy concomitantly towards both sides of said strip.

5. The apparatus defined in claim 4 comprising means for adjustably mounting each of said banks of burners to permit selective variation of the linear distance between said strip and the radiant faces of said burners.

6. The apparatus defined in claim 4 wherein said banks are divided into separate burner zones, and wherein means are provided for independently and selectively supplying fuel to each of said burner zones.

7. The apparatus defined in claim 6 comprising an interlock switch actuatable by movement of said strip, and means permitting the delivery of fuel to said burners only when said switch is actuated.

8. The apparatus defined in claim 4 comprising
   (a) means including an exhaust fan for continuously removing moisture-ladened air from the vicinity of said strip,

(b) means for supplying fuel to said burners, and
(c) means responsive to the operation of said fan to provide an air purging cycle before permitting the delivery of fuel to said burners.

9. The apparatus defined in claim 6 wherein said fuel supply means comprises
(a) means providing a fuel gas supply source,
(b) means providing a pressurized air supply source,
(c) mixing means connected to said gas and air sources for furnishing a combustible mixture of air and fuel gas to said burners in each of said burner zones,
(d) means including an exhaust fan operable to continuously remove air from the vicinity of said strip,
(e) and means permitting the supply of air and fuel gas to said mixing means only when said fan is operating.

10. An apparatus for drying and stretching a continuous wet creped paper strip comprising:
(a) means providing first, second, third and fourth seriate drying zones,
(b) means for continuously moving said paper strip successively through said first, second, third and fourth drying zones,
(c) first combustion type infrared generator means in said first zone for directing radiant energy towards both sides of said wet paper strip to evaporate a substantial predetermined amount of the moisture therein,
(d) means in said second zone for stretching, ironing and for further heating said strip to evaporate additional moisture,
(e) second combustion type infrared generator means in said third zone for directing radiant energy towards both sides of said paper strip to reduce the moisture content in said strip close to a desired predetermined amount,
(f) internally heated cylinder means in said fourth zone,
(g) means for passing said paper strip into intimate contact with the periphery of said cylinder means to reduce the moisture content in said strip at least to said predetermined amount; and
(h) control means for independently regulating the amounts of heat supplied by said first and second combustion type infrared generator means, whereby the amounts of moisture removed at said first and third zones are independently controlled.

11. The apparatus defined in claim 10 wherein said means in said second zone comprises:
(a) a plurality of internally heated drums,
(b) means including porous moisture absorbent belt means wrapping and tightly pressing said strip successively around the peripheries of said drums to facilitate transfer of heat to said strip and to iron said strip flat, and
(c) means for rotating a succeeding one of said drums at a faster speed than a preceding one of said drums to stretch said paper strip passing therebetween.

12. The apparatus defined in claim 10 wherein said first generator means comprises a plurality of infrared burners arranged in a plurality of banks on each side of said strip, means supplying fuel separately to each of said banks and means for independently controlling the supply of fuel to said banks and for independently adjusting the heat value of the fuel supplied to each bank.

13. The apparatus defined in claim 10 wherein said first and second combustion type infrared generator means are divided into a plurality of separate banks on each side of said strip, and means for individually adjusting the linear distance of each of said banks from said strip.

14. The apparatus defined in claim 12 comprising:
(a) ventilating means for exhausting moisture-ladened air from said first and third zones,
(b) said ventilating means comprising ducts having inlet openings extending at least between each adjacent pair of said banks on each side of said strip in said first zone to provide alternate heating and air exhaust regions extending transversely of the movement of said paper strip.

15. The apparatus defined in claim 13 comprising:
(a) ventilating means for exhausting moisture-ladened air from said first and third zones,
(b) said ventilating means comprises ducts disposed on both sides of said strip and having inlet openings in said third zone extending transversely of the movement of said strip and being disposed adjacent to the downstream side of each of said banks with respect to strip movement.

16. The apparatus defined in claim 13 wherein said banks in said first zone define a substantially horizontal channel through which said paper strip passes, and wherein rolls are provided in said channel to support said strip passing therethrough, and means on said rolls for transversely pulling said strip flat.

17. The apparatus defined in claim 16 wherein said means for pulling said strip flat comprises a pair of oppositely wound helical coils surrounding each of said rolls.

18. The apparatus defined in claim 16 wherein said banks in said first zone are mounted in vertically aligned pairs and wherein said support rolls are horizontally offset to extend between said vertically aligned pairs, each of said rolls being partially surrounded by a curved heat deflecting shield exposing only the upper peripheral portion of each roll for engagement with said paper strip.

19. In an apparatus for producing crepe paper and having means for soaking a continuous paper strip to be processed with water and for crinkling the soaked paper strip, the improvement comprising:
(a) means for continuously moving said wet crinkled paper strip successively through first, second, third and fourth drying zones,
(b) heating means in said first and third zones consisting only of infrared burners arranged in a plurality of banks transversely of said strip and on both sides thereof to project radiant energy at both sides of said strip to evaporate predetermined amounts of moisture,
(c) a plurality of internally heated rotatably mounted drums in said second zone,
(d) means for passing said paper strip successively around the peripheries of said drums and including porous, moisture-absorbent, heat-resistant roller-mounted endless belts pressing said paper strip tightly against the peripheries of said drums,
(e) means for rotating at least one succeeding drum at at faster speed than a preceding one of said drums to stretch said paper strip,
(f) an internally heated cylinder in said fourth zone,
(g) means for passing said strip partially around the periphery of said cylinder, and
(h) exhaust means for removing moisture-ladened air from said drying zones.

20. A process for drying a continuously moving wet paper strip comprising the steps of
(a) continuously stretching said strip by increasing the linear velocity of at least one succeeding portion of said strip relative to its direction of movement,
(b) heating the portion of said strip being stretched, and
(c) projecting radiant energy onto said paper strip before said strip is stretched to evaporate a predetermined amount of moisture.

21. A process for producing crepe paper comprising the steps of
(a) soaking a continuous paper strip to be processed in hot water,
(b) crimping the soaked paper strip,
(c) evaporating a predetermined part of the moisture in said strip solely by application of infrared heat,
(d) ironing and stretching the partially dried strip simultaneously with applying heat to said strip to evaporate additional moisture,

(e) removing most of the remaining moisture in said stretched and ironed strip by application of infrared heat, and finally

(f) reducing the moisture content in said strip to a predetermined amount by heating said strip by conduction.

22. The process defined in claim 21 comprising the step of pressing the soaked paper strip flat before it is crimped.

23. The process defined in claim 21 wherein the moisture removed by infrared heat prior to ironing and stretching amounts at least approximately to 50 percent of the total moisture contained in said strip.

24. The process defined in claim 23 wherein the application of infrared heat after the strip is ironed and stretched removes sufficient moisture to leave 7–9 percent of the total moisture content in the paper strip, and wherein approximately 20 percent of the total moisture content is removed while the strip is being ironed and stretched.

25. A process for producing crepe paper comprising the steps of

(a) imparting continuous movement to a paper strip to be processed,

(b) passing said paper strip through hot water to soak it,

(c) crimping the soaked paper strip to provide a creped effect,

(d) providing for first, second, third and fourth drying and processing seriate stations,

(e) passing said soaked, crimped paper strip successively through said first, second, third and fourth stations,

(f) heating said strip in said first station only with radiant energy to evaporate a predetermined part of the moisture in said strip and thereby leaving a predetermined amount of unevaporated moisture in said strip,

(g) stretching said strip as it passes through said second station,

(h) squeezing said strip passing through said second station between a moisture absorbent surface and a ridid heated surface to remove an additional proportion of moisture and to iron said strip flat.

(i) heating said strip at said third station only by radiant energy to reduce the moisture content in said strip close to a predetermined tolerable amount, and

(j) passing said strip over a rigid heated surface at said fourth station to heat said strip sufficiently for reducing the moisture content therein to said tolerable amount.

26. The process defined in claim 25 wherein said strip passing through said first station is pulled at opposite edges so that it is flat and taut across its width as it passes between said moisture absorbent surface and said heated surface at said second station.

27. The process defined in claim 25 wherein said strip is asphalt laminated paper and wherein the percentages of moisture respectively removed at said first, second, third and fourth stations are approximately 48 percent, 21 percent, 24 percent and 2 perecnt.

28. The apparatus defined in claim 2 wherein said radiant heating means comprises a plurality of infrared burners, the combination comprising:

(a) means providing separate fuel gas and pressurized air supply sources for said burners,

(b) mixing means connected to said sources for furnishing to said burners a combustible mixture of variable proportions of air and fuel gas,

(c) means for igniting the fuel at said burners, and

(d) means responsive to the presence of fire at said burners to automatically adjust the air-gas ratio of said mixture.

29. The apparatus defined in claim 28 comprising

(a) air exhaust means including a fan for removing air from the vicinity of said strip, and

(b) means including air actuated switch means permitting supply of fuel gas to said mixing means only when said fan is operating to exhaust air.

30. In an apparatus for drying and stretching a strip of soaked creped paper comprising:

(a) means for continuously conveying said soaked paper strip successively through first, second and third drying stations,

(b) a plurality of internally heated rotatably mounted drums at said second station,

(c) means for passing said paper strip around the peripheries of said drums,

(d) means for rotating at least one succeeding drum at a faster speed than a preceding one to stretch said paper strip,

(e) at least two infrared combustion type generators respectively providing first and second heating zones at said first station and disposed to project infrared energy towards opposite sides of said paper strip,

(f) at least two infrared combustion type generators providing a third heating zone at said third station and disposed to project radiant energy towards opposite sides of said paper strip,

(g) fuel supply means for the generators in each of said zones, and

(h) means for independently controlling the supply of fuel to the generators in each of said zones.

31. The apparatus defined in claim 30 comprising means for selectively adjusting the heat value of fuel supply for said heating zones independently of each other.

32. The apparatus defined in claim 30 comprising means for igniting fuel delivered to selected ones of said generators and automatic cut-off means for terminating flow of fuel to all of said generators upon failure of fuel to remain ignited at any of the selected ones of said generators.

33. A method for continuously drying and stretching a continuous web of wet paper comprising the steps of

(a) imparting continuous linear movement to said web,

(b) evaporating a predetermined amount of moisture in the moving web by applying radiant energy thereto, and

(c) subsequent to the application of said radiant energy, subjecting said moving web to further drying and to a stretching action by increasing the linear velocity of a succeeding portion of said web relative to its direction of travel.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,281,952 November 1, 1966

Thomas F. Mullaney

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 50, for "wih" read -- with --; column 3, line 68, for "FIGURES" read -- FIGURE --; column 11, line 36, for "urge" read -- purge --; column 12, line 29, for "and", first occurrence, read -- with --; column 18, line 49, for "at" read -- a --; column 19, line 42, for "ridid" read -- rigid --.

Signed and sealed this 1st day of August 1967.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents