United States Patent

Rodwin et al.

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[54] **SONIC DRYING OF WEBS**

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[30] **Foreign Application Priority Data**

July 7, 1969 Canada.....56,305

[52] **U.S. Cl.** **34/69,** 34/18, 34/155

[51] **Int. Cl.**.....**F26b 19/00**

[58] **Field of Search**.....34/23, 69, 155, 158, 18

[56] **References Cited**

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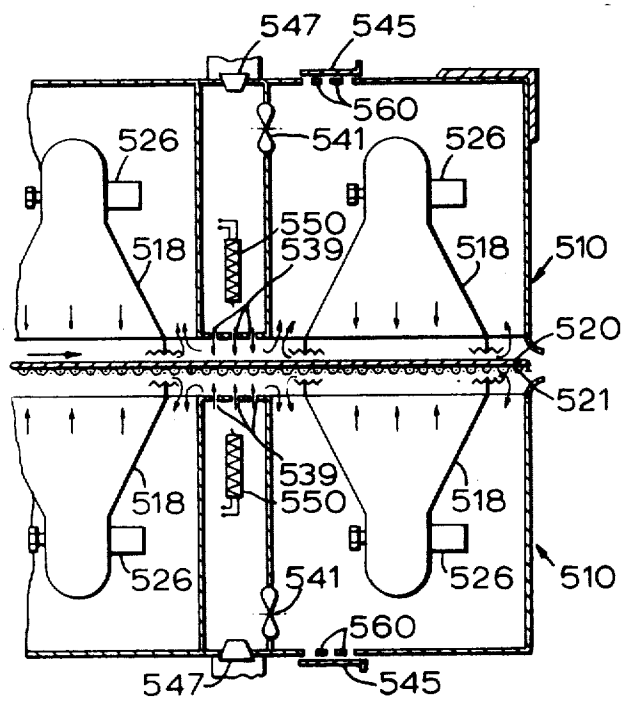
[57] **ABSTRACT**

A paper dryer is provided with a sonic drying section through which the web is passed and subjected to high intensity noise from grouped noise generators, usually air operated, to dislocate moisture from the web for enhanced drying rates.

4 Claims, 7 Drawing Figures



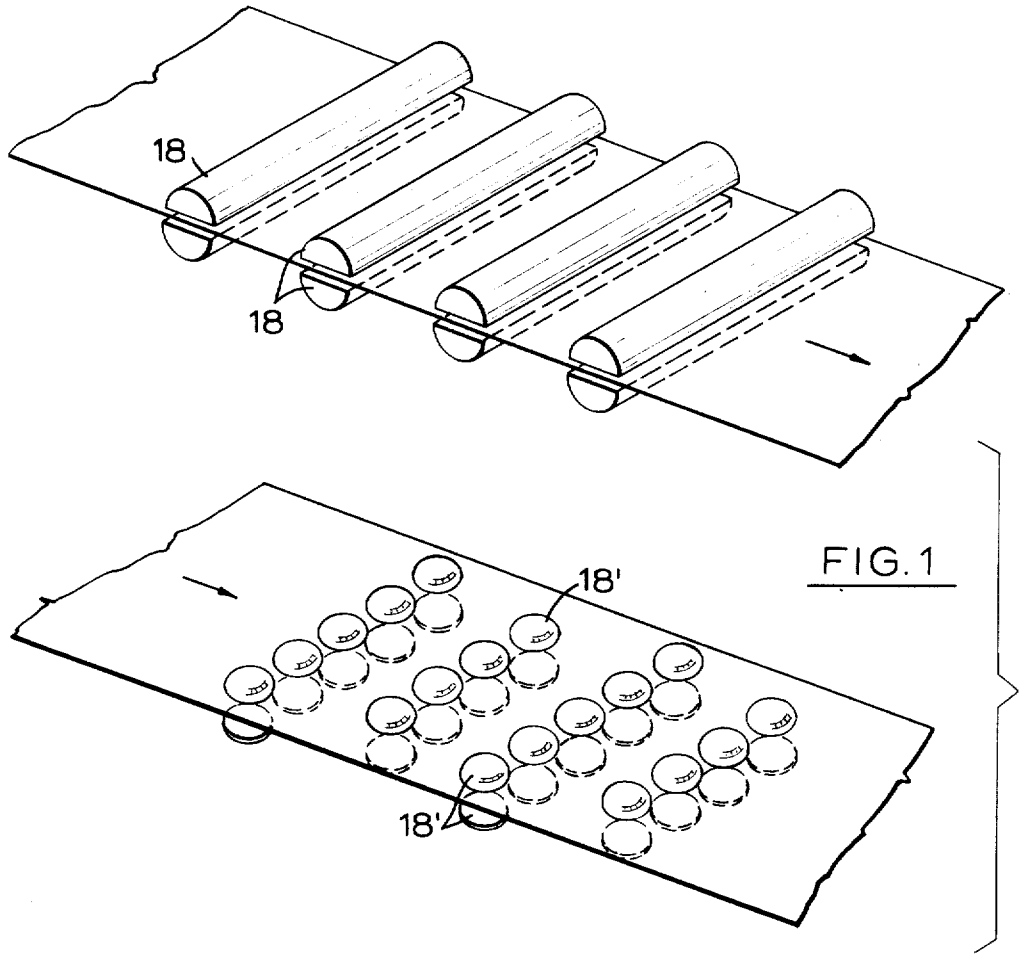


FIG. 1

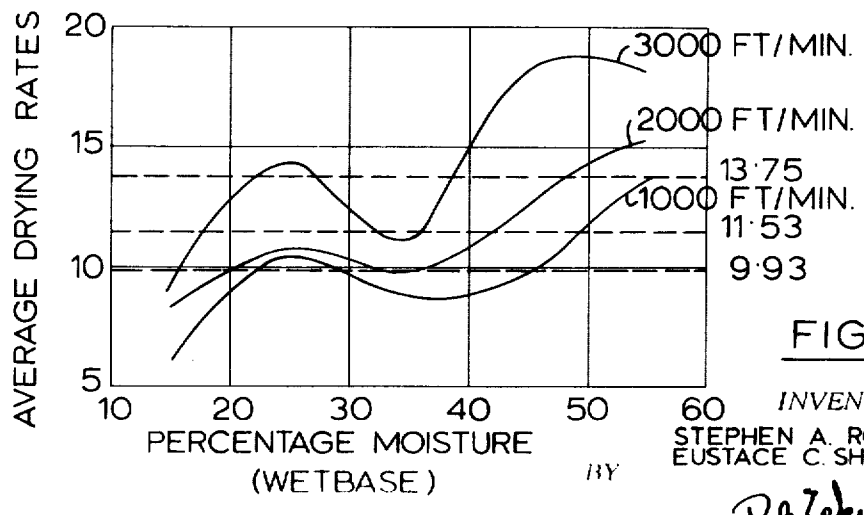


FIG. 7

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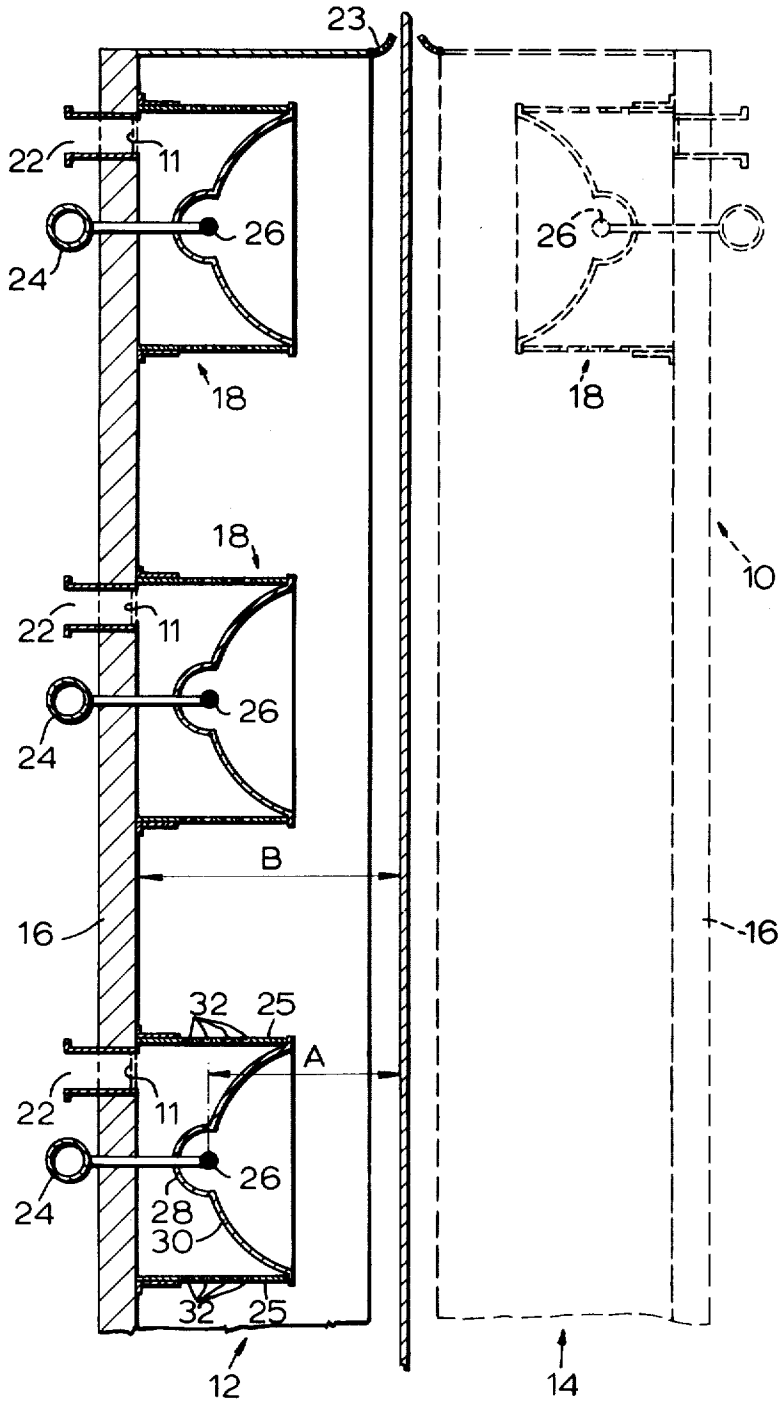

FIG. 2

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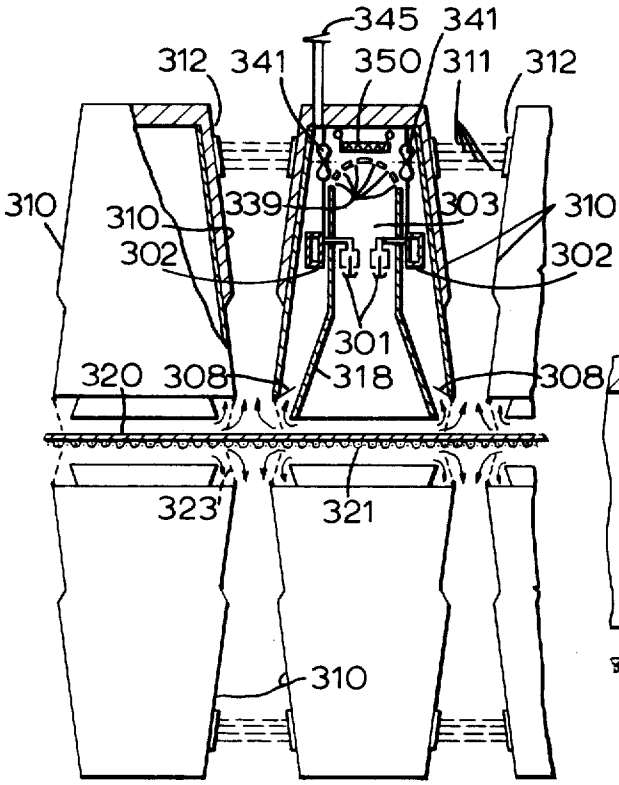

FIG. 3

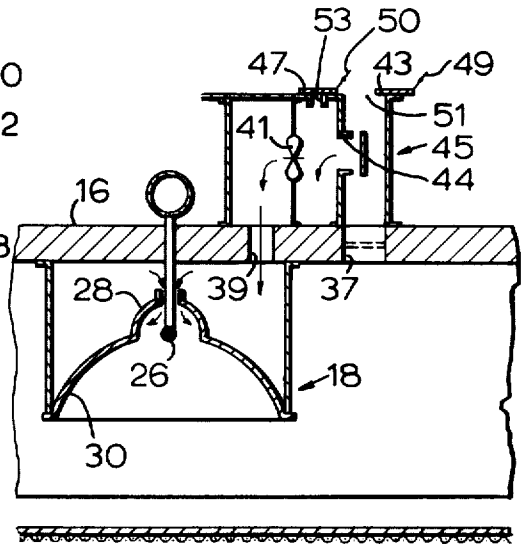

FIG. 4

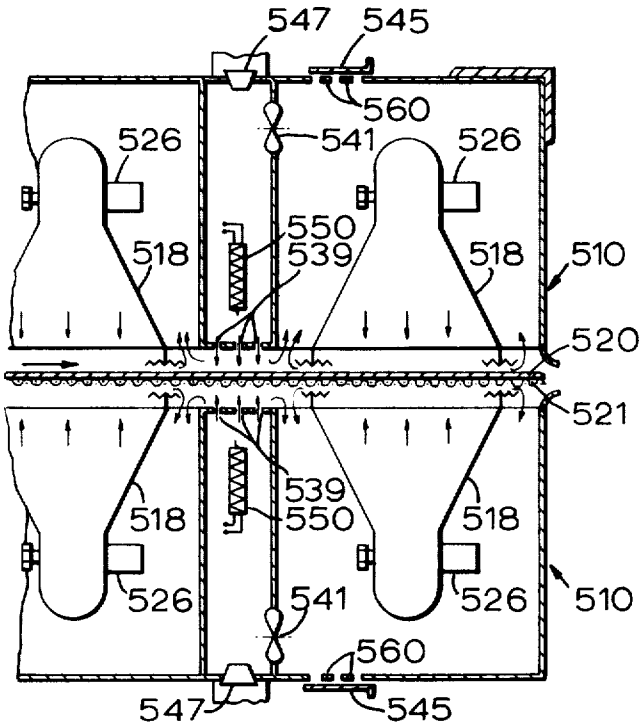

FIG. 5

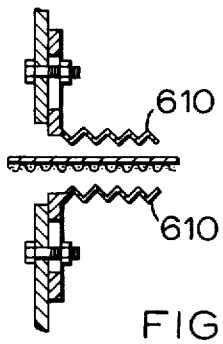

FIG. 6

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SONIC DRYING OF WEBS

This invention is directed to apparatus for dislocating moisture from a wet web using sonic generators.

In the pulp and paper industry a large portion of the cost of making paper arises from the need to dewater the pulp stock by the removal of the approximately 98 percent by weight water content of the stock. Conventionally, the removal by mechanical means of moisture from the web terminates at the end of the press section. From there on, further drying is usually achieved by more costly thermal drying, in the drier section. The present invention extends the use of mechanical removal of water throughout the drier section, with consequent economic benefit.

The present invention provides an apparatus for obtaining the mechanical dislocation of liquid within a web by the application of sonicly vibrating gaseous fluid thereto either alone or in combination with an impingement gas flow for the removal of the dislocated liquid. While such liquid is usually water, such is not necessarily the case, as other liquids in furnish are also known.

It has been found that the application of longitudinal sound waves to a web such as a felt or a paper web at appropriate levels of sound energy will promote transverse dislocation of liquid relative to the web.

In order to transport moisture from the surface or surface of the web, it is necessary to provide a gaseous or vapor flow against a surface or surfaces of the web. It has been found that by utilizing pressurized fluid medium such as air initially as the energizing source for a sound generator such as a stem jet whistle, and then passing the air from the whistle against the web, that the fluid can serve the dual function of whistle energization and the at least partial wiping and transportation of the released moisture mist away from the surface.

The raising of the temperature of the energizing fluid enhances sound energization. However, in the matter of transporting dislocated moisture from the web partially moist air, such as air issuing from the sound sources, after having picked up web moisture either as finely distributed mist or in vapor form, is effective as a moisture transporting agent, while also enhancing the sound field due to its characteristic of reducing sound attenuation, relative to a dry air sound field. Web moisture may be carried in mist droplet form by the air stream, being dispersed by the sound field into micro droplets as opposed to passage only in the vapor form for conventional heat drying processes, thus enhancing the economics of extraction in liquid form.

It has been further found that the effectiveness of the sound generators, such as stem jet whistles may be enhanced by the provision of suitable sound reflectors, thus improving considerably the efficiency of sound utilization.

The present invention may be utilized with stationary webs. However, in order to meet production requirements of rapid dewatering for moving webs such as in a paper machine, the present invention is utilized in relation to a moving web, in which high web passage speeds may be achieved. It will be understood that the effect of increased speed may enhance drying rates due to improved action of the sonic field in the web boundary. Hence this process is particularly suited for high speed machines.

A particular advantage afforded by the present invention relates to the adaptability thereof with existing paper drying machinery whereby the drying rates of the combined plant may be increased, thereby permitting the speed of the paper making machine to be correspondingly increased. In addition, owing to the general tendency of sonic drying to concentrate moisture at the web boundaries the effects of other subsequent surface drying processes are generally enhanced. In addition, the fact, that sonic drying does not result in such a large temperature drop as is normally experienced in conventional evaporative drying due to evaporative cooling, makes the achievement and maintenance of suitable web temperatures more economical.

In utilizing a sonic field having sound generators such as stem jet whistles, it is necessary that the sonic energy input to the paper web shall not exceed the approximate value of 10 watts per square centimeter as chemical decomposition or donolysis may start to occur at this energy level. Thus the use of a maximum of up to 169 decibels (db) may be regarded as quite safe, in providing a maximum of 8 watts/cm^2, as compared with the 10 watts/cm^2 which 170 decibels represents.

It has been found that the apparent inefficiency of a free open sound field is greatly improved when in web drying it is applied as a reflective field. Applied sound energy initially provides mechanical moisture dislocation, and subsequently a considerable portion of the generated sound energy is transformed into heat, hence supplying a staged energy transformation which benefits the overall drying process. Similarly, in providing uncooled compressed air as whistle energizing medium, the mechanical losses of the air compressor appear as a temperature rise in the whistle air to promote effective compressor and web drying efficiency while also enhancing whistle operation, if effectively utilized.

From psychometric charts, it is known that the requirement of energy for moisture removal from a web is diminished if the mean temperature of the air dyring the web is maintained as high as possible owing to favorable changes in It tension and viscosity which result. Ir has been found that the action of a sonic field in an air streal also favorably changes boundary surface tension and heat transfer coefficients to enhance drying, while also suitably conditioning the inside of the porous web structure. Thus higher temperature air has been found highly beneficial in promoting heat and mass transfer to improve drying rates.

The effective use of sound generators such as stem jet whistles in drying a moving paper web require the capability of exercising control over the web drying rate, both generally and locally. One characteristic of a sonic field is the advisability to locate the plane of the paper web substantially perpendicular to the sound wave generally at distances representing multiples of half the wave length from the sound source. In general, a change in air flow conditions at the whistle inlet leads to a change in frequency with a consequent change in wave length. For permanently set whistles this would probably reduce resonation, so that resonation air flow ranges have to be established and maintained. For this reason, it is not practical to permit substantial changes to the air flow rates for a particular whistle arrange-

ment, as the deviation of sonic conditions from the design point would not permit consistency in drying. In order to provide control of the rate of moisture removal with other than acoustic means, it is necessary to effect control over the additional moisture removal media, namely by controlling the wiping or impingement air flow within a predetermined range of mass flow, velocity and psychometric conditions.

Wiping or impingement air may be supplied in a variety of ways to afford control of drying rates. When air is used for actuating the sonic generator, it is generally possible and desirable to utilize resonated exhaust process air, with or without secondary air of low moisture content, by passing the air as a wiping fluid across the web surface. Low velocity air wiping may be achieved utilizing pressure build up in the sound field. The control of air escape from the sonic zone by suitable throttle means is then readily provided, to effect the desired control over moisture removal by variation of the wiping air flow rate. Alternative to the foregoing provision or additionally thereto, there may be provided air pressurizing means such as a fan or blower, for the direct supply of secondary air in bypass relation to the whistle. Such by-pass secondary air may be passed through the resonating field produced by the whistles. Local control by adjustment of wiping air flow permits the eradication of wet streaks in the web. Such bypass secondary air may be fresh air or recirculation air, or a mixture of fresh and recirculation air to provide desired psychometric conditions.

The operation of the sound generation means is enhanced by the provision of sound reflector means to direct the sound energy against the web and by reflection to return a considerable portion of energy to the source in re-energizing relation therewith. In addition, at the boundaries of the sonic drying zone, the provision of auxiliary sound reflectors to minimize the passage of sound energy from the zone enhances the sound intensity within the zone while reducing the provision of sound proofing necessary to reduce outside noise to practical working levels. The provision of perforated reflectors adjacent the web entry and exit locations permits the passage of air therepast in web wiping relation, while enhancing the performance of the sound chamber. The sonic energy absorption losses in reflectors is effectively returned to the process in the form of heat energy.

While theoretical considerations of the application of compressed air against a moving web, applied initially as sound energy in energizing a whistle might lead to the conclusion that efficient utilization will produce rather low air temperature, it has been found that the appearance of sonic losses as heat energy, from the effects previously discussed, maintain the air temperature at a preset level, of for instance 200° F. Thus high recovery of sound energy as useful heat enhances the overall process efficiency. While the described embodiments are directed to single and double sided impingement against a planar web, the utilization of the present invention with a dryer cylinder is also contemplated.

In obtaining the full benefits of sonic web drying, removal of moisture displaced to air adjacent the web surface is particularly important, so as to avoid re-wetting of the web. One very effective means for boundary moisture removal is the use of impingement air jets, as a form of air wiper.

The particular advantages obtained in utilizing sonic drying against both sides of a web is the improvement in drying rates and the balancing or manipulation of transverse forces acting upon the web. In the case of a symmetrical, balanced arrangement, the use of a support web or wire may on occasion be dispensed with.

In addition to the effectiveness of the foregoing disclosed drying process, it will be understood that particular advantages accrue in combining a short sonic dryer section with an existing conventional dryer, generally locating the sonic section at the inlet or wetter end in order to fully utilize the characteristic higher dislocation rates achieved with the wetter web. The improved overall performance of a so-modified dryer section permits up-rating of the speed of the complete paper machine in cases where the primary limitation to such up-rating has been dryer performance.

The subject process includes the supply of compressed air to the sound generators. The raising of the temperature of the supply air enhances both drying and whistle efficiency. To produce higher temperature supply air, the choice exists between heating of the already hot compressor output air by independent heating means or more effectively utilizing the compressor to produce the required exhaust temperature, by raising compressor inlet temperature slightly above ambient, providing intake air in the range of 90° F to 140° F at the compressor inlet. For most of the considered embodiments, the latter course is more economical in heat energy requirement, while capita cost is minimized.

Certain embodiments of the present invention are described, reference being had to the accompanying drawings wherein:

FIG. 1 shows two perspective sectional arrangements of embodiments of the subject invention showing the use of transverse trough-like sound generators, and individual sound reflectors, respectively;

FIG. 2 is a side sectional view showing a first embodiment having an unsupported web and using only primary or whistle air as the moisture transport medium;

FIG. 3 is a side sectional view showing a further embodiment having a resonant chamber receiving secondary air;

FIG. 4 is a further embodiment similar to that of FIG. 1, with secondary air circulation provision;

FIG. 5 is a view similar to FIG. 3 of a further embodiment;

FIG 6 is a sectional detail of an edge seal suitable for use with the sound chambers illustrated in FIGS. 2 – 5; and

FIG. 7 shows characteristic drying rate curves, and appears with FIG. 1.

Referring to FIG. 1, this illustrates the form of two alternative sound generator arrangements, the first showing trough-shaped reflectors 18 in series arrangement within a sound hood, each trough reflector having a plurality of stem jet whistles herein, while in the second arrangement is shown a plurality of whistles, each with an individual reflector 18' and mounted in staggered relation.

Referring to FIG. 2, this shows a vertical unsupported web run wherein the drier section 10 has a first sonic chamber 12, and an opposing sonic chamber 14, each chamber having a cap or cover 16 comprising

reverberation plates. Each chamber **12, 14** is provided with a plurality of sound generators **18** to propagate longitudinal sound waves against the web **20**. The chamber may be in horizontal or vertical arrangement, depending generally on the provision of web support netting and the symetry of incident energy, in relation to the grade of paper.

Each sound generator **18** comprises a trough-like reflector having a plurality of spaced whistles, such as a stem jet whistle **26** provided with air from a compressor by supply conduit means **24**, and mounted within sound reflecting means **28, 30** to concentrate both the longitudinal sound emission and sound reflection at the surface of the web **20**, the distance "A" representing very nearly a multiple of the whistle half wave length at desired operating conditions. The individual whistles **26** are spaced laterally in the reflecting means **28, 30** at substantially uniform distances having multiples of half wave length apart to minimize mutual interference. Intervening baffles may be used.

The reverberating cap or cover **16** defining a sonic chest also is located at a selected distance "B" from the web surface, equal to approximately a multiple of the whistle half wave length. In supplement to the reflecting surfaces **28, 30** and **16** the reflector plates **23** adjacent the web path also serve to retain sound energy within the section **10**. The alternative provision of individual whistles having circular individual reflectors of similar diametral section to that of the trough reflectors is also contemplated.

The sound generators **18** including supporting side walls **25** having apertures **32** extending therethrough and connecting with vents **22** in the cover **16** to permit the passage of air from the whistles in fluid wiping relation over the surface of web **20**, for exhaust to the hooded zone above the section **10**, by way of the apertures **22**, shown as having sound relfecting baffle means **11** therein to maintain a low sound level in the vicinity of the drier section.

In addition to the provision of trough end walls, the provision of intermediate separating walls between at least some of the adjacent whistles is contemplated.

In the embodiments of FIGS. **3, 4** and **5** the sound reflectors **31, 41** and **51** also are illustrated as extending for the width of the respective drier section **10**. The alternative use of individual circular reflectors shown in FIG. **1** shows a mutual staggered arrangement to provide distribution of sound field across the web.

The arrangement of FIG. **4** shows air circulator **45**, having an enclosure mounted on the cover **16** of the sonic chest with an air circulating fan **41** mounted therein. The apertures **37, 44** and **39** provide access for wiping air recirculating within the sonic chest of the drier section **10**, while the dampers **43** and **47** operating in conjunction with apertures **51** and **53** provide blending elation with hood air from outside the sonic chest for a desired combination of hood air and recirculation air in accordance with desired psychometric conditions. The setting of the dampers **43** and **47** is controlled by the levers **49** and **50**.

FIG. **5** shows a horizontal arrangement wherein a support wire mesh **521** carries the web **520** in supported relation between the opposed sound chests **510**. Each chest **510** contains one or more troughlike reflectors **518**, each reflector containing a plurality of stem whistles **526** in mutually spaced relation. The cross-sectional profile of the rough reflectors **518** differs from the parabolic form of FIGS. **1** and **4**. Primary air from the whistles **526**, together with secondary air passing downward through apertures **539**, serves to scour the boundary layer from off the web **520**. The secondary air is heated by heaters **550**, illustrated as being of the electrical resistance type. Fan means **541** provides circulation of the secondary air, while the adjustable dampers **545** control the inlet access of hood air and the adjustable dampers **547** control the portion of air passing from the fans **541** in recirculating relation over the surface of web **520** by regulating the portion of mixed primary and secondary air escaping to the hood. The maintenance of adequate ventilation is important in prevention of web rewetting by maintaining suitable psychometric conditions. The sound reflectors or baffles **560** reduce the escape of noise upwards into the hood space.

In the embodiment of FIG. **6** the wiping of the moist boundary layer containing dislocated moisture in mist-like or droplet form is facilitated by the provision of mechanical wiping members **610** serving both to assist in removal of moist air, to maintain the sound level within the hood by reflection of incident sound waves back into the space beneath the whistles, and to stabilize the running of the web. The members **610** are adjustably mounted to provide adjustable spacing from the web surface, with the off-coming gap on the downstream side of a sound generator being greater than the on-coming or upstream gap. The use of saw-toothed or levelled surface wipers is contemplated.

In the FIG. **3** embodiment a reverberating chamber **303** is provided. In addition to incoming whistle air from high pressure ducts **302** serving the whistles **301** shown mounted in mutual opposed staggered relation considered in the cross machine direction, secondary air is recirculated by fans **341** while heating means **350** impart additional heat to the secondary air. The sound and heat insulated cap structures **310** are provided with sound external hood **311** therebetween to minimize noise loss to the external hood space. Dampers **308** adjustably mounted at the respective cap edges permit control of secondary air recirculation though the fan means **341**. Non-resonating incoming hood air or fresh air is admitted by way of inlets **339**, while outward passage of moist air to the hood space takes place through the outlets **312**. The edge sound losses are minimized by provision of sound reflector plates **323**. The staggered opposed whistles **301** are mounted in a reverberating chamber **303** through which flows the incoming secondary air as circulated by the fans **341**. Control of psychometric conditions at the web surface by use of controlled secondary recirculation and make-up air and the recirculation by the fans **341** permits optimized drying. The provision of additional stem jet whistles in the reverberating chamber of at least one of the hoods **310** in excess of the usual requirement permits selective additional reverberating energization for wet streak control.

Referring to FIG. **7**, which shows the variation of drying rate with web dampness, having tree characteristic Curves representing three different web speeds, it will be seen that, with the exception of the range 25 percent to 35 percent wetness (wet base), the charac-

teristic drying rate curve has a positive gradient, so that in the majority of the wetness range there is a tendency to eliminate wet streaking.

A further and unobvious advantage afforded by the use of sonic drying is that, for a side range of web wetness the effective drying rate increases with the wetness of the web. Thus, for the range so affected, there is inherent tendency to control wet streaks.

What I claim as new and desire to secure by Patent patent of the United States is:

1. Web drying apparatus having a passage for an endless web therethrough for controlled diminution of liquid within the surface of an elongated permeable web, having web positioning means to laterally locate a said web relative to the longitudinal edges thereof on passage through said apparatus, a plurality of sound generating whistle means on one side of a path of travel of said web in mutual spaced relation arranged to provide a sound field having a plurality of sequential high intensity zones, spaced along the web path of travel, and to propagate longitudinal sound waves in a direction substantially normal to the web, first gaseous fluid supply means connected to said sound generating means in energizing relation therewith to generate in operation said longitudinal sound waves, second gaseous fluid supply means having outlets intermediately of at least some of said zones to provide a wiping gaseous flow in a direction substantially normal to the plane of the web, plural housing means extending transversely of said web path respectively located adjacent at least some of said high intensity sound zones to provide a plurality of gaseous fluid return flow paths extending away from said web path, to receive said wiping gaseous flow having liquid and vapor entrained therewith, and recirculation means to recirculate a selected portion of return gaseous flow to the web, to provide control of web drying conditions.

2. Apparatus as set forth in claim 1 including sound hood means to intensify said sound field at the surface of a said web.

3. Apparatus as claimed in claim 2 wherein said recirculation means includes fan means for returning said selected portion in downflowing bypass relation with said whistle means; and controllable air admission means to admit additional air for mixing with said recirculation air, in controlling the psychrometric condition of said wiping fluid.

4. Apparatus as claimed in claim 2 including air heating means to provide temperature control of gaseous fluid within said apparatus.

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