AIR IMPINGEMENT SYSTEM

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ABSTRACT

Method and apparatus for drying a moving web of paper or the like including one or more impingement boxes which are disposed in spaced relation to the moving web, with means for introducing pressurized air into each of the impingement boxes, each of the boxes including an apertured plate spaced from the web being dried, the plate having relatively small diameter holes centrally thereof and relatively larger diameter holes along the leading and trailing edges to minimize cross flow interference with exhaust spaces being provided along the leading and trailing edges for directing spent drying air into an exhaust plenum.

5 Claims, 3 Drawing Figures
AIR IMPINGEMENT SYSTEM

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of our co-pending Ser. No. 405,142, filed Oct. 10, 1973 (Case No. 72,119).

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention is in the field of drying webs of paper and the like by means of impingement flow, the geometry of the impingement means and the process variables being controlled to provide high heat transfer rates with a minimum of cross flow interference and a minimum pressure gradient existing between impingement jets located at various distances from the exhaust openings.

2. Description of the Prior Art

Impingement flow, that is, flow directed normal to the surface has been recognized as an efficient means for heating or cooling. In recent years, this method of heat transfer has been used in the paper industry for drying of paper. Representative patents in this field are U.S. Pat. Nos. 3,163,502; 3,167,408; and 3,447,247 all owned by the assignee of the present invention.

Air impingement drying is particularly suited for drying of lightweight grades of paper such as tissue paper and for drying coated paper. These applications require higher rates of heat transfer because of the limited drying length and the requirements of high speed operation.

There are various types of air impingement devices in use on paper drying apparatus. One of these types uses slotted nozzles and another incorporates round holes to provide jet orifices for impingement purposes. The slot nozzle arrangements have the disadvantage of requiring a relatively complex system of air removal ducts between the slots. Slot arrangements are also characterized by inefficient performance as measured by the heat transfer coefficient obtainable for a given expenditure of air blower horsepower. In addition, relatively small spacings between the impingement surface and the slot nozzles are required in order to obtain good heat transfer results.

Some of the disadvantages inherent in the slot nozzle arrangement are eliminated in the round hole impingement systems. For example, the heat transfer coefficient is relatively unaffected by the distance from the nozzle to the impingement surface as long as there is a proper ratio of the impingement distance to the hole diameter. Also, when using round impingement holes, it becomes easier to incorporate air exhaust systems between sets of the round holes.

With the demand for increased machine speeds, adequate drying must either be accomplished by raising the drying rate or the heat transfer length. Increased drying lengths require additional capital expenditure for already expensive drying equipment. In tissue drying applications, where the web is pressed on the surface of a large diameter rotating drum, the web must be dried in less than one revolution. Typically, such a drying system employs a large diameter steam filled cylinder surrounded by a high temperature, high velocity air impingement cap. However, these steam filled cylinders are already operating at about the highest practical steam pressures possible and are being built at about the largest practical diameter possible. Therefore, any further increases in speed must come from increased heat transfer rates from air impingement. At the present time, air caps are being operated at temperatures of about 800°F. In order to achieve higher temperatures, expensive high temperature alloys must be employed. In addition, at these higher temperatures problems are encountered in maintaining the dimensional stability of the equipment and as impingement temperatures get higher, more problems will be encountered with drying uniformity.

Inasmuch as air caps in use today in the paper industry are already operating at about the limit of temperature, it becomes necessary to increase the convective heat transfer coefficient in order to increase the heat transfer rate and consequently the evaporation rate. In paper drying applications, a large convective heat transfer coefficient helps to alleviate any nonuniform drying problems. One method of increasing the convective heat transfer coefficient is simply by increasing the impingement velocity. However, for a given system configuration an increase in impingement velocity can only be obtained at the expense of increased fan horsepower. Increases in fan horsepower represent both increased capital cost for equipment and also increased operating expense. Therefore, an upper limit exists whereby increases in heat transfer rate by adding additional fan horsepower are no longer considered feasible.

Another means of increasing the heat transfer coefficient is to increase the number of impinging jets, that is, by increasing the open area of the impingement plate. Published literature indicates that after the open area is increased beyond approximately 2%, no further gains in the heat transfer rate are obtainable. It was thought that the inability to improve the heat transfer rate was caused by interference between adjacent impinging jets, that is, as the open area was increased and the impingement jets became closer and closer together, the adjacent jets interfered with each other thereby reducing the heat transfer coefficient.

More recently published experimental data indicates that this reduction in heat transfer coefficient is not caused by interference between adjacent jets but rather by cross flow interference from the spent air. The jets after impingement must travel to an opening to be exhausted and this means that the spent air must travel across adjacent jets before reaching an exhaust outlet. This exhaust cross flow interference can actually cause the impinging jet to be bent at an angle which is not perpendicular to the surface of impingement. Any deviation of the impingement jet from a line normal to the heated or cooled surface results in a degradation of the heat transfer rate. Consequently, it becomes important to eliminate or reduce cross flow interference if the average heat transfer coefficient is to be increased.

SUMMARY OF THE INVENTION

This invention relates to a method and apparatus for impingement drying by means of which high heat transfer rates are obtained. Cross flow interference caused by spent air interfering with the impingement jets as it flows towards the exhaust passages is minimized while using a minimum number of exhaust openings, thus reducing the complexity of fabricating the air impingement system. With the method and apparatus of the present invention, the pressure gradient existing between jets located at various distances from the exhaust.
openings is minimized. The apparatus of the present invention is relatively simple to construct and install, thereby significantly reducing the cost.

We have found that these improvements can be obtained by utilizing one or more impingement boxes extending across the width of the web to be dried in spaced relation, with the spacing between the boxes being sufficient to provide exhaust passages for exhausting drying air. Each of the impingement boxes is supplied with pressurized air. Each of the boxes includes an apertured plate spaced from the web being dried, the plate having relatively small diameter holes centrally thereof and relatively larger diameter holes along the edges thereof which adjoin the exhaust passages. The spacing of the individual holes from the web and the diameters of the holes are so arranged so that each hole is spaced from the web by no more than four times the diameter of the hole, and is located preferably at a spacing which is from 1 to 4 times the diameter of the particular hole.

**BRIEF DESCRIPTION OF THE DRAWINGS**

Other objects, features and advantages of the invention will be readily apparent from the following description of certain preferred embodiments thereof, taken in conjunction with the accompanying drawings, although variations and modifications may be effected without departing from the spirit and scope of the novel concepts of the disclosure, and in which:

FIG. 1 is a fragmentary cross-sectional view taken substantially along the line 1-1 of FIG. 2;

FIG. 2 is a view partly in elevation and partly in cross-section of one impingement box used according to the present invention; and

FIG. 3 is a rather schematic view partially broken away of an entire air impingement system embodying the improvements of the present invention.

**DESCRIPTION OF THE PREFERRED EMBODIMENTS**

Referring first to FIG. 3, reference numeral 10 has been applied generally to an air impingement drying system which includes a manifold 11 in which are supported a plurality of impingement boxes 12 to 15, inclusive. Each of the boxes 12 to 15 are located in closely spaced relation to a traveling web 16 of paper or the like. Individual inlet conduits 17 through 20 supply pressurized air to the boxes 12 to 15, respectively. The traveling web 16 is carried on a supporting surface 35 such as a belt or a drum surface spaced a predetermined distance from the boxes.

The boxes 12 to 15 are spaced from the walls of the manifold 11 and from each to provide exhaust passages 21 to 25 therebetween. The spent drying air after impingement against the surface of the web 16 is channeled into the exhaust spaces 21 to 25 and collected in an exhaust plenum 26 behind the boxes 12 to 15, inclusive, from which the spent drying air can be vented by means of an exhaust conduit 27.

Each of the boxes 12 to 15, inclusive, has an apertured plate 28 closing off the bottom end of the boxes, one of which is illustrated in FIGS. 1 and 2 of the drawings. Each of the plates 28 has a plurality of relatively small diameter holes 29 located centrally of the plate and between a series of intermediate diameter holes 30 and 31 on opposite sides thereof. Larger diameter holes 32 and 33 are arranged in rows closely adjacent the respective exhaust spaces 22 and 23 as best illustrated in FIG. 1.

While the size of the holes 29, 30 and 32 may be varied depending upon the nature of the material being dried and other factors, the smallest diameter apertures should have diameters on the order of one-sixteenth or one-eighth inch and the larger diameter apertures may range up to three-fourths of an inch or more. The most important parameter from the standpoint of the present invention is the relationship between the hole diameter and its vertical distance to the surface of the web 16. We have found that the ratio of spacing of a given hole to the web should be no more than four times the diameter of the hole and preferably the spacing should be from 1 to 4 times that diameter. In the form of the invention shown in FIGS. 1 and 2, the apertured plate 28 is curved so that substantially the same ratio of distance to diameter exists for the small diameter holes 29 which are spaced a relatively short distance from the web 16, and the larger diameter holes 32 and 33 which are spaced a larger vertical distance from the surface of the web.

It is also possible to employ the improvements of the present invention using a substantially flat apertured plate in conjunction with drying of a paper web on the surface of a rotary cylinder or other arcuate surface where the geometry of the cylinder itself provides the requisite correlation between the aperture size and its distance from the web.

With the system of the present invention, high temperature high pressure air having a velocity on the order of 20,000 to 30,000 feet per minute can be employed as a drying medium while utilizing a web speed of lightweight paper of about 4,000 to 6,500 feet per minute.

With the arrangement described, the small impingement holes 29 are located where cross flow interference is at a minimum and the largest diameter holes 32 and 33, which are least effected by cross flow interference, are located where the cross flow is highest. This arrangement provides high heat transfer with a minimum of exhaust openings. By providing increased vertical spacing for the large diameter holes 32 and 33, the cross flow area is increased and hence the cross flow velocities are decreased. Not only does this variable vertical spacing minimize the cross flow interference but it also substantially reduces the pressure gradient in the axial direction, resulting in more uniform and efficient heat transfer.

In the described system, the exhaust passages are located between each of the impingement boxes and the exhaust is collected in a central plenum chamber surrounding all of the impingement boxes. This places the lower temperature exhaust air around the impingement boxes, minimizing the need for insulating the boxes to prevent heat losses to the surroundings. Another advantage of this system is that the metal ducts eliminate much of the extensive fabrication associated with conventional air impingement devices.

It should be evident that various modifications can be made to the described embodiments without departing from the scope of the present invention.

We claim as our invention:

1. An apparatus for drying a moving web comprising a housing, an smoothly curved apertured plate closing off the housing and extending the width of said web, means for introducing pressurized air into said housing
for flow through said plate, and exhaust means extending the width of said web for exhausting spent air at the edges of the plate, the apertures in said plate including small diameter holes normal to the plane of the web located centrally of said plate and larger diameter holes normal to the plane of the web located at the edges of said plate and in close proximity and parallel to said exhaust means, the smaller diameter holes being in closer proximity to the web than the larger diameter holes so that increased volume of cross flow spent air occurs at the plate edge at the location of the larger holes with higher volume air jets.

2. The apparatus of claim 1 in which the diameter of said holes and their spacing from the web is such that the spacing of any given hole from the web is not greater than four times its diameter.

3. An apparatus for drying a moving web moving in the direction of the length of the web comprising a housing, an apertured plate closing off the housing and extending in a direction across the width of the web, means for introducing pressurized air into said housing for flow through said plate, and exhaust means extending across the width of said web at the leading and trailing edges of said plate relative to the direction of web movement for exhausting spent air, the apertures in said plate including small diameter holes normal to the plane of the web located centrally of said plate and larger diameter holes normal to the plane of the web located at the edges of said plate with the smaller and larger diameter holes respectively each being of a uniform size in a direction across the width of the web so that a uniform drying effect is had by the web across its width due to the air flow against the moving web, the larger diameter holes being located at the areas of higher volume of spent air flow at the edges of the plate.

4. The apparatus of claim 3 in which the diameter of said holes and their spacing from the web is such that the spacing of any given hole from the web is not greater than four times its diameter.

5. The apparatus of claim 3 in which the spacing of any given hole from the web is from one to four times its diameter.

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