

March 17, 1959

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2,877,693

SUCTION BOX EXTRACTION APPARATUS

Filed Jan. 11, 1957

5 Sheets-Sheet 1

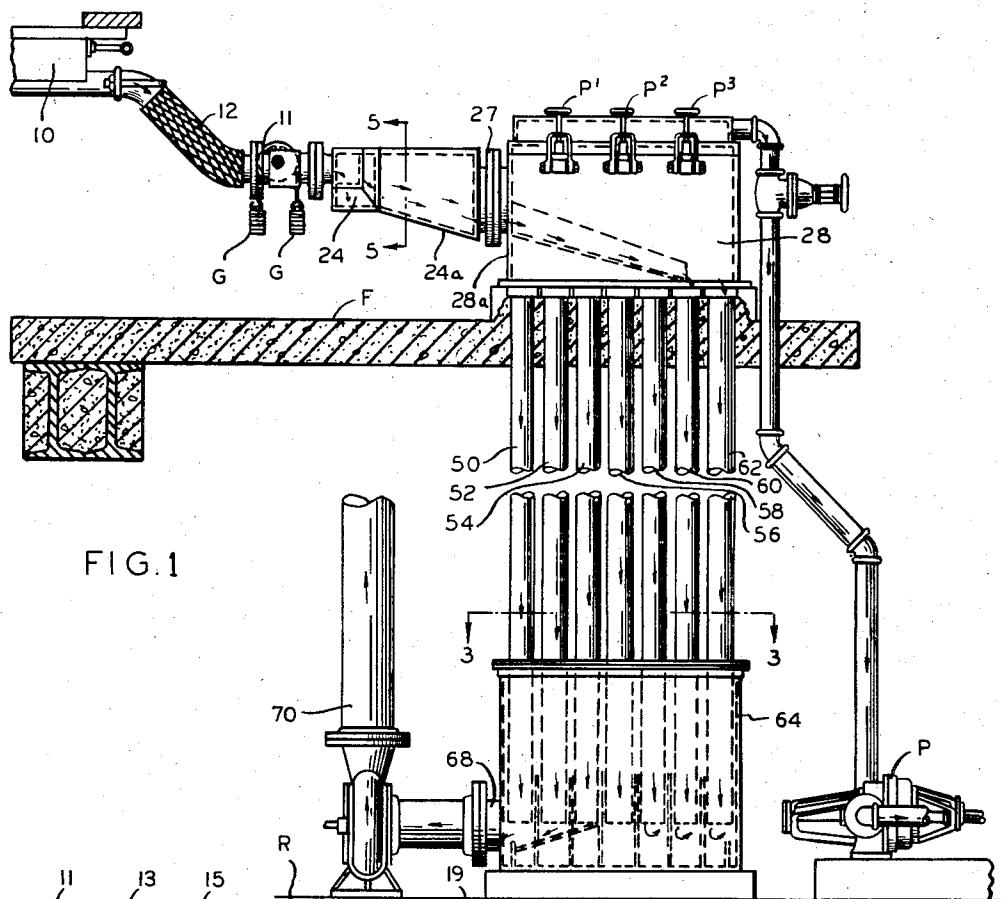


FIG. 1

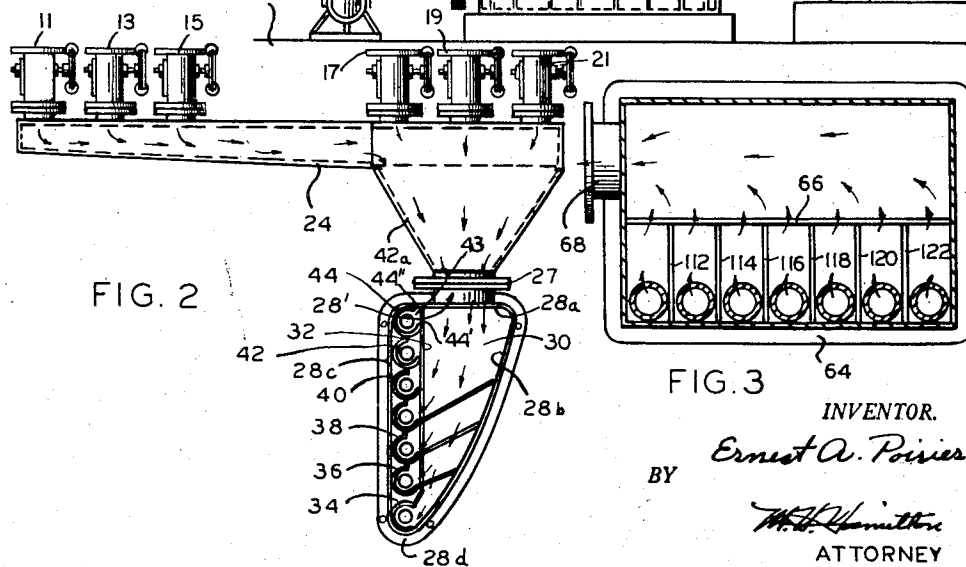


FIG. 2

FIG. 3

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5 Sheets-Sheet 2

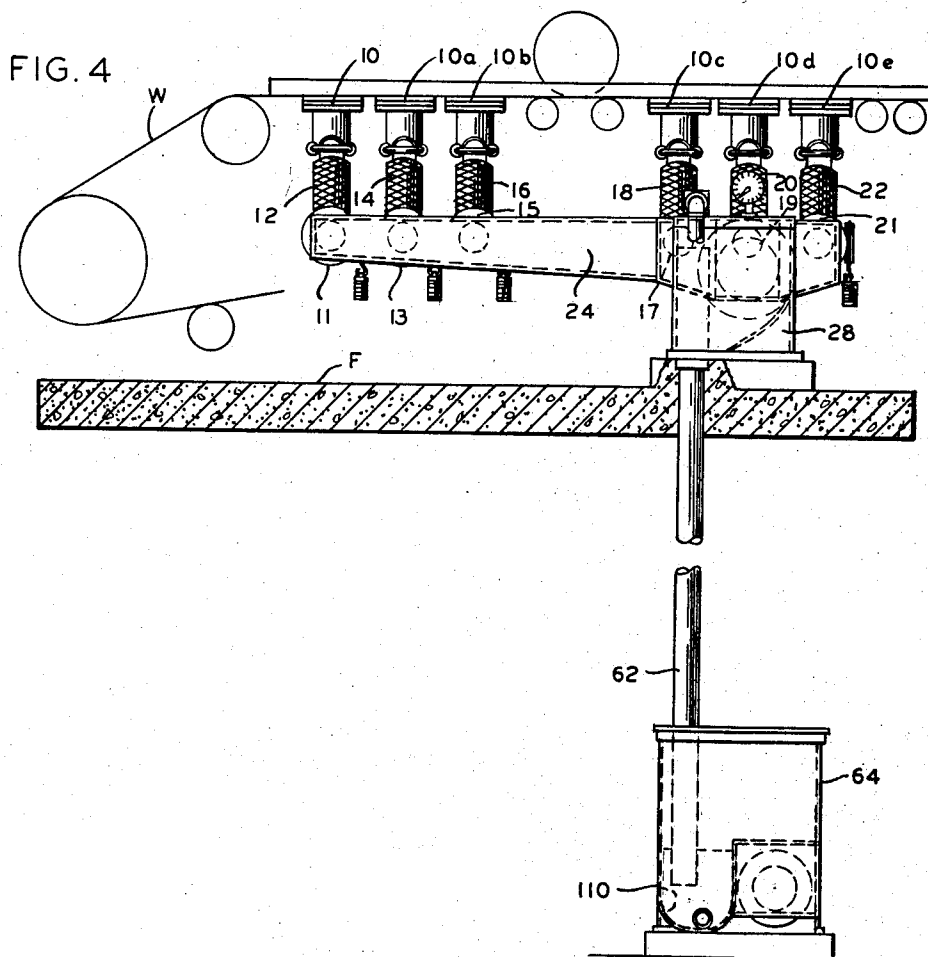
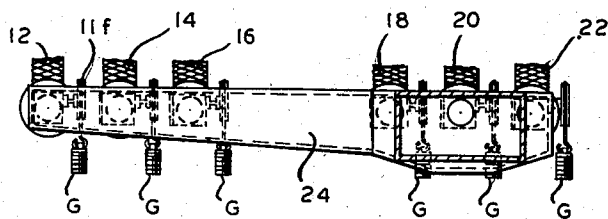


FIG. 5

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FIG. 6

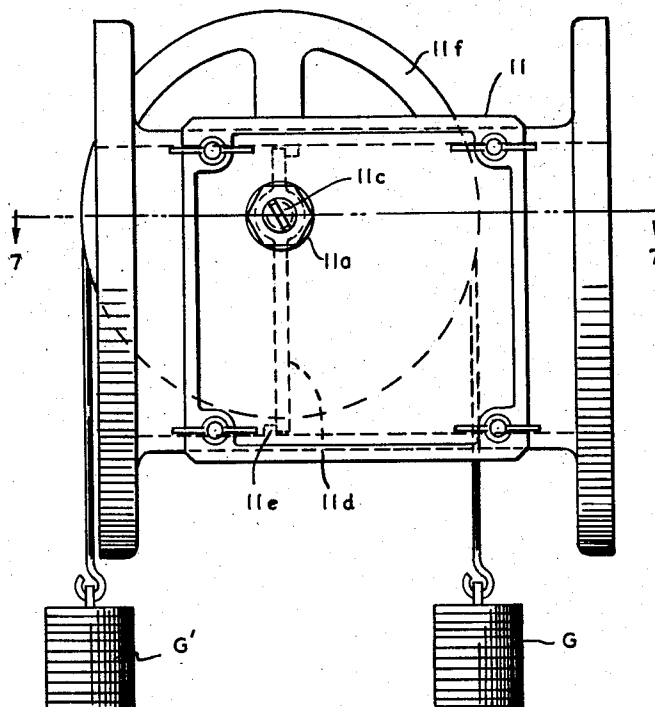
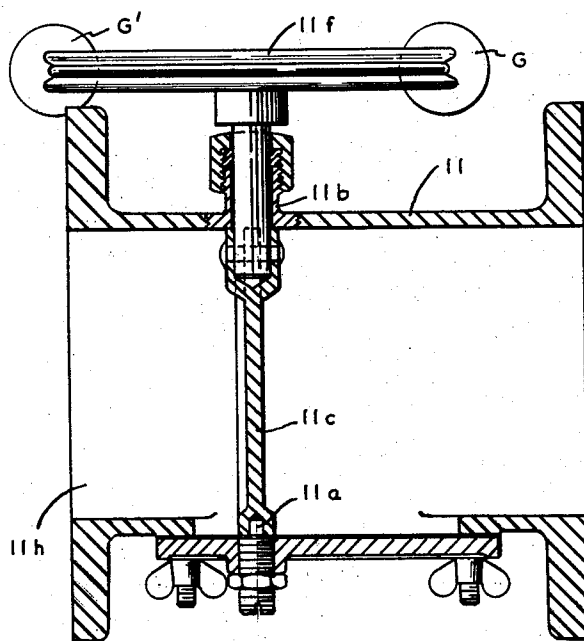


FIG. 7



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Filed Jan. 11, 1957

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FIG. 8

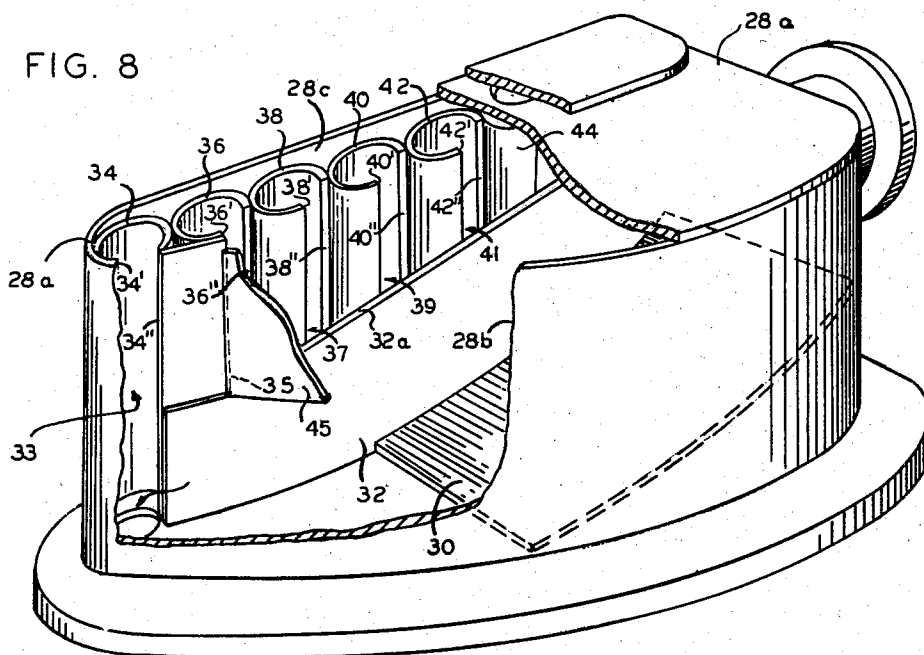
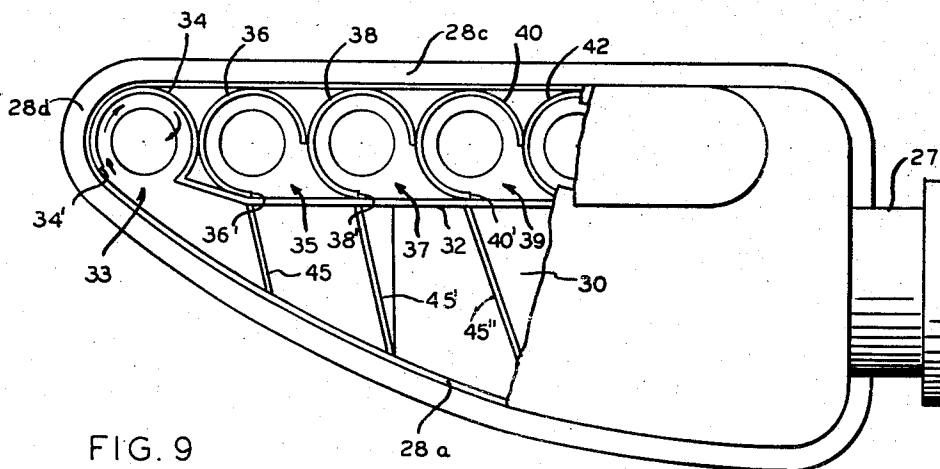


FIG. 9

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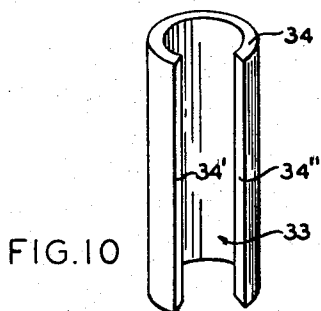
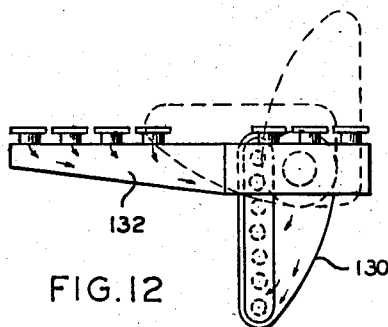
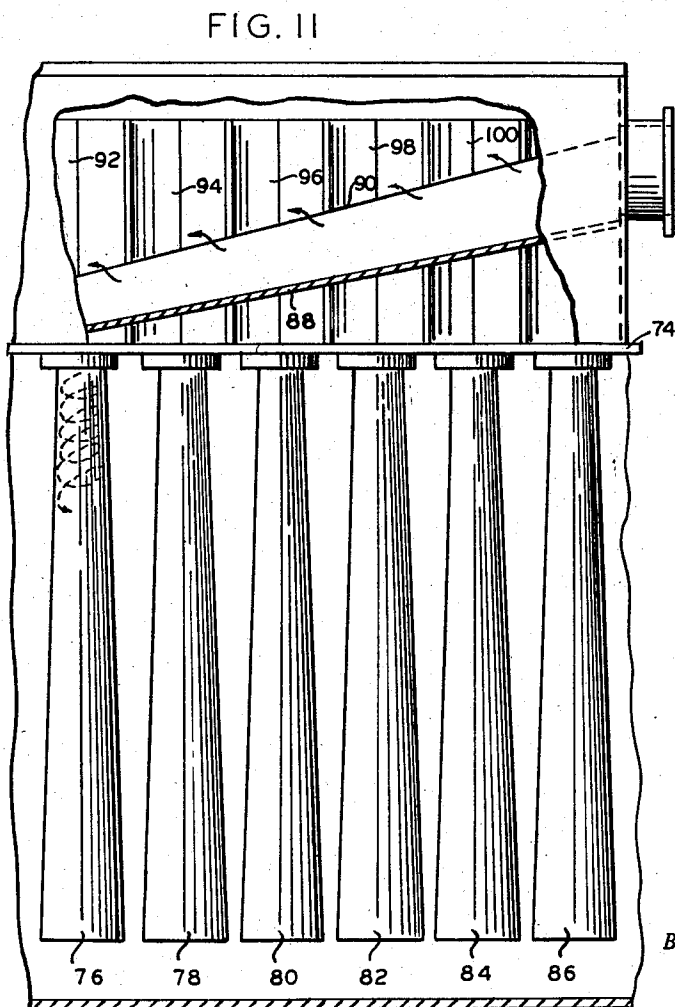
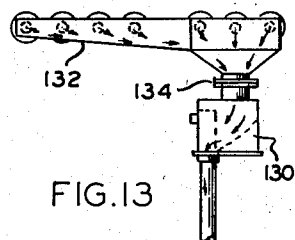
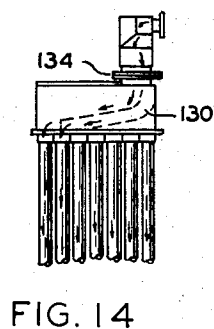
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SUCTION BOX EXTRACTION APPARATUS

Filed Jan. 11, 1957

5 Sheets-Sheet 5



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SUCTION BOX EXTRACTION APPARATUS

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Application January 11, 1957, Serial No. 633,601

7 Claims. (Cl. 92—51)

This invention relates to methods and apparatus for extracting water from a wet web of paper as it is passed over the wire of a paper making machine and, more specifically, the invention is concerned with improved techniques and devices for use in conjunction with the suction boxes or other vacuum devices conventionally employed in handling a wet web of material.

In water extracting systems heretofore proposed, difficulty has been experienced in dealing with variation in the amount of water occurring in the web of paper while providing for both desired paper characteristics and a satisfactorily high rate of water removal through drop legs, manifold, and other water conducting elements of a suction box system. Such difficulty may lead to losses in efficiency of the paper making process as well as changes in the paper produced and, in some instances, interruption in the machine operation. A further factor to be taken into account is that the capacity of a water extracting system may be materially affected by turbulence produced in water drawn off from the web as well as suspension of water in drop legs. Also there may develop foaming and retention of air in the water which is to be reused in the paper making process.

It is a general object of the invention to deal with the problems indicated and to improve water extracting techniques and apparatus of the class employing suction boxes. Another object of the invention is to devise an improved vacuum header construction for receiving extracted water and to provide in the header apparatus a special drop leg arrangement which is characterized by automatic selectivity in moving constituent drop leg elements thereof into and out of operation. Another object is to provide novel control valve means for selectively controlling the operation of individual suction boxes. Still another object is to improve the structural organization of a header and its associated drop leg elements, together with the seal chest into which water is let through the drop leg elements with a view to increasing the velocity of flow of water through the drop leg elements while preventing foaming and turbulence in the seal chest.

These and other objects and novel features of the invention will be more apparent from the detailed description of preferred embodiments of the method and apparatus hereinafter set forth.

From long observation of the above-indicated problems which develop in removing water from a wet web of paper on the wire of a paper making machine, I have conceived of a procedure for controlling the water extraction capacity of a suction box type syphoning system in such a way that I may disregard the requirements present in conventional vacuum extraction systems for maintaining an excess vacuum to prevent equalization of vacuum and air in the system.

In this connection, I have discovered a method of extracting water which makes possible the application of approximately the correct amount of vacuum at all

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times without resorting to any excess vacuum. This, I have found, may be accomplished by automatically increasing and decreasing the extraction capacity of the system in a carefully regulated manner varying in accordance with changes in the volume of water which is drawn off by the suction boxes from the wet sheet on the wire.

I have determined that I may modify and control the operation of the suction boxes themselves to a degree not heretofore realized. I have particularly devised individual suction box valve controls. These valve controls, when used in a manner hereinafter described, may be regulated to be sensitive to predetermined working vacuum conditions so that one or more of the suction boxes may be caused to operate or to be discontinued from operation in accordance with changes in the flow of water which may be taking place from time to time in the vacuum header casing.

In connection with controlling the water extraction capacity of my system in the manner conceived, I have further devised a novel step-by-step drop leg operation employing a special vacuum header casing which is connected to a series of drop legs arranged in a single row at an underside of the header. With this header and drop leg arrangement I combine a specially formed header casing shape together with an overflow partition and a series of cooperating tubular baffles located along one side of the casing and vertically disposed therein above the drop legs.

The vacuum header casing is designed so that it presents a curved side wall and an inclined bottom which, in conjunction with the partition noted, operates to guide a flow of water entering the header at an upper side thereof and conduct this water downwardly and across the header towards its opposite side where the first tubular baffle and drop leg is located and where the partition is at its minimum height. As the flow of water passes along the curved side wall and over the partition and downwardly into the first of the tubular baffles, a vortical or swirling movement is induced which aids in separating air from the water in a very efficient manner.

I have also found that, by proper selection of the height of the graduated partition at a point immediately adjacent to the open end of this first drop leg, I may provide for water rising up to a predetermined level and all of this water may be conducted into the first drop leg. As soon as this level is exceeded, however, with the first drop leg being sealed and a head of water being created over same, further overflow passes across the graduated partition at a higher point and then into the second drop leg. Similarly, as the level of water in the header progressively increases, additional drop legs will be placed in operation, step by step. Also, with a drop in the level of water in the header, the drop legs will fall out of operation, step by step, in the reverse succession.

I have further found that, by thus controlling the flow of water in a vortical path of movement through the tubular baffles, I may also induce discharged portions of water to move through the drop legs in a more accentuated vortical path of travel to aid in separating air. I further control turbulence at the discharge ends of the drop legs by means of a special seal chest member which I construct with a curved bottom section and individual dividing walls. The drop legs are arranged to empty directly into this curved bottom section and their extremities are separated by the individual walls so that the operation of any one of the drop legs is visually apparent at any time. A weir or baffle is also provided, over which discharged water is caused to flow before passing to the white water reusal system. With this arrangement of parts, foaming and excessive turbulence

in the seal chest may be very desirably reduced and controlled and much more efficient use of the white water realized.

In the accompanying drawings, I have illustrated preferred embodiments of a water extracting apparatus of the invention, in which—

Fig. 1 is an elevational view illustrating diagrammatically a water extraction system including portions of a suction box, together with conduit means, a manifold vacuum; header casing and a drop leg and seal chest arrangement;

Fig. 2 is a plan view of the apparatus shown in Fig. 1;

Fig. 3 is a plan view taken on the line 3—3 of Fig. 1;

Fig. 4 is a front elevational view of the header and drop leg unit, together with individual suction valve control mechanism of the invention;

Fig. 5 is a cross-sectional view taken on the line 5—5 of Fig. 1;

Fig. 6 is a detail elevational view of one of the valve mechanisms for the suction boxes;

Fig. 7 is a cross section taken on the line 7—7 of Fig. 6;

Fig. 8 is an enlarged perspective view of the vacuum header construction of the invention;

Fig. 9 is a plan view further illustrating the structure of Fig. 8;

Fig. 10 is a detail perspective view of one of the tubular baffles;

Fig. 11 is an elevational view showing the drop leg construction of the invention;

Fig. 12 is a detail plan view of a modified vacuum header casing construction;

Fig. 13 is an elevational view of the modified construction of Fig. 12, and

Fig. 14 is an elevational view of the modified view of the same structure.

In the apparatus of the invention, there are present a number of novel components referred to above and including specifically a valve controlled suction box arrangement; a special vacuum header construction; a manifold for connecting the suction box arrangement and vacuum header construction in cooperating working relationship; and a drop leg and seal chest assembly for conducting water away from the vacuum header member at relatively high velocity to provide a working vacuum.

In general, it will be understood that this vacuum operates through the vacuum header and suction boxes to remove water from a web of paper moving along a wire member above the suction boxes. Under some circumstances, an auxiliary vacuum pump P may be connected to the vacuum header at points P1, P2 and P3. Thus, auxiliary vacuum may be desired in starting the machine, but for the most part is used only very infrequently.

Considering these several novel components in detail, attention is directed first to Figs. 1 and 4 wherein numerals 10, 10a, 10b, 10c, 10d, and 10e denote a series of conventional suction boxes over which runs a web of paper W on a wire member.

In accordance with the invention, I provide conduits 12, 14, 16, 18, 20, and 22 which, as noted in Fig. 1, extend downwardly and are connected at their lower ends to special valve structures 11, 13, 15, 17, 19 and 21. These valves are best considered in conjunction with two other components, namely, a manifold 24 and a vacuum header casing 28 which is mounted on a floor F or other desired supporting surface.

As will be observed from an inspection of Figs. 1, 2 and 3, the valves referred to are connected at one side of the manifold casing 24 and provide for automatically controlling the operation of any one or all of the suction boxes in response to changes in flow of water through the vacuum header casing. This constitutes an important feature of the invention and is accomplished by selectively employing the valves indicated so that an excess vacuum is not required to be maintained and, on the contrary, a substantially constant working vacuum is provided.

To better understand the working of these valves, reference may be had to Figs. 6 and 7 wherein is illustrated the valve structure 11 consisting of an air-tight housing in which is mounted bearings 11a and 11b. These bearings pivotally support a valve shaft 11c on which is fixed a valve element 11d. In a closed position, the valve element 11d seats against a valve seat 11e. Fixed on the shaft 11c at a point outside the housing is a pulley 11f which, in response to the pull of a variable weight G, acts to yieldably maintain the valve 11d against the force of a flow of water passing into the housing at the inlet 11h. The pulley also supports at its opposite side a second weight G' which can be varied at will.

By selecting a suitable combination of weights G and G', it will be apparent that it is possible to hold the valve 11d in a substantially closed position for a certain vacuum condition at the suction boxes and, yet, permit the valve to open when this vacuum condition is exceeded. Therefore, in the same way, I am enabled to set a predetermined number of the suction boxes, through their respective valves and weights, to remain closed at vacuum conditions above a certain predetermined value while a number of other boxes are similarly set to remain open within the noted range of working vacuum. This valve setting is hereinafter set forth in more detail with specific values being given.

The relatively stabilized flow of water thus realized from a substantially constantly maintained vacuum range working through individually controlled valves as described is, in accordance with the invention, required to be conducted to the header at relatively high velocity. For this purpose, I have designed the manifold 24 with a particular shape. A bottom side 24a is shaped to extend downwardly to communicate with an opening at the top of the header case 28. The sides of the manifold and its top are then formed so as to taper inwardly from a width which includes all of the suction boxes to a relatively constricted passageway which coincides in size with the inlet opening in the header casing and which will provide for high velocity flow just at the point of opening into the header casing. It is pointed out that water is thus drawn from a plurality of points and converged with a minimum of change of direction whereby turbulence is minimized. The manifold may be joined to the header at this point of restriction in some suitable manner as by means of coupling members as 27.

The high velocity flow of water thus produced by the restricted end of the manifold and delivered to the header casing is next guided along a path to provide for step-by-step drop leg operation and to impart vortical flow to the greatest extent possible to this water as it approaches and passes through respective drop legs.

To this end, I have constructed the vacuum header casing 28 with an end wall 28a through which is formed an inlet opening 28' at the upper section thereof. Joined to this end wall 28a is a relatively straight sidewall portion indicated by the numeral 28c and a curved sidewall portion indicated by the numeral 28b. The two wall portions 28c and 28b meet to form a relatively narrow end section 28d in the header casing. I further provide an inclined bottom 30 which extends from a point closely adjacent to the inlet opening 28' downwardly toward the narrow end section 28d of the casing. This bottom, in addition to being inclined, is shaped with a somewhat curved conformation so that water entering the header casing through the inlet opening 28' will be guided downwardly toward the relatively narrow end 28d of the casing and, at the same time, will tend to be diverted in a direction from right to left, as viewed in Fig. 2 of the drawings.

I further mount in the header casing a vertical overflow partition 32 having an inclined overflow edge 32a which constitutes an important component of this header construction and which consists of a rigid wall member arranged to extend in parallel spaced relation to the

straight sidewall portion 28c of the casing body. This overflow partition is, in accordance with the invention, constructed of varying heights, being at a maximum height at points closely adjacent to the inlet openings 28' and at a minimum height at its point of termination in the narrow end section 28d of the casing. In this position, it will be seen, therefore, that a flow of water passing down the inclined curved bottom 30 passes along the partition, and at varying levels will overflow the partition at points therealong.

The partition 32 is especially designed to cooperate with a series of tubular baffles which, as shown in Fig. 2, and in more detail in Figs. 8 and 9, consists preferably of a plurality of cylindrical bodies 34, 36, 38, 40, 42 and 44. These members are recessed throughout a part of their peripheral length to provide vertical edges 34', 36', 38', 40', 42' and 44' lying in spaced relation to vertical edges 34'', 36'', 38'', 40'' and 42'' and 44'' respectively to define fluid entranceways 33, 35, 37, 39, 41, 43. Each of these tubular baffles has adjacent peripheral surfaces joined together in substantially sealed relationship. Also, each of edges 34', 36', 38', 40', 42' and 44' throughout a part of their length is joined as by welding or other means to adjacent surfaces of the partition 32, as may be best seen from an inspection of Fig. 9.

It will be evident, therefore, that a flow of water will first move down to the tubular baffle 34, being confined by the partition of one side and turned inwardly by the curved wall portion on the other side of the casing. As a result of this combined action, the flow is directed into the entranceway 33 of the first tubular baffle 34. The water thus entering becomes further diverted and guided around the inner periphery of the tubular baffle from the edge 34' inwardly to take on an increased vertical movement which is augmented with further downward travel. An excellent opportunity is thus produced for separation of air from the flow of water at this point.

With successively higher levels of water flowing into the header casing, overflow occurs at other points along the overflow edge 32a and a step-by-step drop leg operation then takes place. It is pointed out that, at each succeeding level of overflow, water is constantly sealed from entering the remaining tubular baffles since each baffle is joined to an adjacent one, as described above and shown in Figs. 8 and 9.

I may, in some cases, further provide in the header casing a plurality of transverse partitions as 45, 45', 45'', etc., which are mounted between the curved wall 28a and the partition 32, as shown in Figs. 2, 8 and 9. The bottom edges of these partitions 45, 45', 45'', etc., occur at different levels and in spaced relation to the inclined bottom 30 of the casing so that each partition defines an opening between itself and the bottom of the casing through which water flows as it passes into successive baffles. These transverse partitions operate to retard and control the flow of water into the respective header baffles and the partitions particularly reduce surging of water into the smaller end of the casing where the lowest baffle 34 occurs. It should be understood that the invention may be practiced without using the transverse partitions, although they may be employed by some purpose where it is desired to provide a novel control of surging.

A further desirable handling of water passing from the tubular baffles is carried out by means of a series of drop legs 50, 52, 54, 56, 58, 60 and 62 which, as shown in Figs. 1 and 4, are connected at their tops with respective bottom sections of the tubular baffles above described. Preferably, these drop legs will extend through the floor F to a chamber some little distance below the floor F in order to produce an appreciable drop for the water falling through these drop legs members and thus produce a desired working vacuum. In Fig. 1 there is indicated a second floor or basement level R which supports thereon a seal chest 64 within which the extremities of the drop legs terminate so that a fluid seal is

provided. Water passing out of the drop legs is caused to flow over an overflow member 66 in the seal chest 64 and passes out through an outlet 68. If desired, this water may be carried back into the system by recirculating mechanism 70.

In operating the drop leg and header construction described, water and air which have been extracted from the web of paper is led away from the header inlet down along the inclined false bottom and across the chamber in such a manner that the tubular baffle and respective connected drop leg farthest away from the header inlet fills first. As this first baffle and drop leg fills, a natural vortex is established at both the tubular baffle and drop leg and air separation takes place. Thereafter, an increasing level of water may take place in the header casing. This increased level of water then starts to overflow the graduated partition at a height determined by a point immediately in front of the second drop leg and this second drop leg also begins to receive water in a natural vortex path of flow which does not conflict with the path of flow of water going into the first drop leg. Similarly, increasing levels operate to place in succession the additional drop legs and, if, at any time, the level drops, the drop legs will be successively cut off and the flow will be taken care of by a lesser number of drop legs. Thus, it will be seen that the number of drop legs in use at any given time is dependent upon the volume of water carried away from the web of paper on the wire. With low porosity, an increase in slowness in the paper web, or a heavier weight of paper, the water carrying capacity of the sheet is increased. Since the table rolls of the paper making machine extract less water, a higher gallonage is delivered to the flat suction boxes. These conditions automatically cause additional drop legs to be brought into operation, increasing the extraction capacity of the system.

With an increase in porosity, freeness, or lighter sheet weights, the volume of water delivered to the flat suction boxes is decreased. Under this condition, fewer drop legs are utilized and the capacity of the system is automatically reduced.

It is pointed out that this automatic control of extraction capacity anticipates changes in slowness and freeness, porosity, machine speeds, and other variables with the result that a constant moisture content of the sheet and substantially uniform porosity may be maintained at all times. I may, however, vary the point at which the machine operates for a desired constant moisture content of the sheet by resetting the auxiliary vacuum valve of the auxiliary vacuum pump P, shown in Fig. 1. When the new setting is established, the system will automatically control the moisture content of the sheet at this new setting.

It will be observed that an important feature of this method of control resides in the fact that it is possible to apply almost exactly the right amount of vacuum at all times so that an excessive vacuum need never be applied as is usually the practice in conventional type machines.

Attention is next directed to Fig. 11 in which I have illustrated another important feature of the invention, consisting of a special drop leg assembly. A casing 74 supports a plurality of drop legs as 76, 78, 80, 82, 84, 86. Water is diverted along an inclined bottom 88 of casing 74 and caused to overflow a partition 90 passing into entranceways of a series of tubular baffles as 92, 94, 96, 98, 100. In this form of the invention, the drop legs are constructed with their lower ends of gradually increased diameter to form conically shaped extremities. I have found that by thus enlarging the drop legs I may accomplish two desirable objectives. First, I am able to obtain a greater velocity at the point of water removal. Secondly, I am able to make better use of the vortical path of flow induced by the tubular baffles and to actually accentuate the vortex at each drop leg with additional

opportunity being afforded to separate air from the water.

In conjunction with these tapering high velocity drop leg ends, I also find that the increased velocity and vortical flow overcomes any tendency for water to be suspended in nonoperating drop legs since there may be an appreciable reduction or elimination of friction at the inner peripheral surfaces of these enlarged drop leg portions.

The seal chest 64, as illustrated in Figs. 3 and 4, consists of a rectangularly shaped container which is formed along one side with a curved bottom or trough 110. Water from the drop legs collects in this trough portion of the seal chest and overflows the partition 66 to pass out through the outlet member 68. In the trough portion of this seal chest, I have provided a series of transverse partitions as 112, 114, 116, 118, 120 and 122 which are, as shown in Fig. 3, so arranged as to isolate the bottom of each drop tube within the trough portion. By means of this arrangement, when the apparatus is operating, the problem of determining if any of the drop legs is not operating properly can be readily dealt with, since a visual inspection of any one of the compartments formed by these transverse partitions 112—122 will immediately reveal whether water is flowing out of the end of any one of the drop legs.

It is also pointed out that, in thus confining water which is leaving the bottoms of the drop legs, it is confined somewhat differently than heretofore has been the case in the art, and such water is actually conducted along a path which passes into a separate compartment and then upwardly over the partition 66. This affords an opportunity for reduction in turbulence and the flow of water from the point of discharge at the ends of the drop legs to the overflow partition is facilitated and foaming is minimized.

In actual operation, the extraction system of the invention has been found to provide various important and desirable advantages. For example, in one typical operation of my header with suction boxes on a paper machine wire during a four-month period, it was observed that drainage on the wire was increased from a conventional rate of from 700 to 900 gallons per minute to a new rate of from 900 to 1100 gallons per minute. This increase made it possible to improve sheet formation and to increase production of paper stock upwardly as much as 20% on some grades of paper.

It was also observed that the sheet was drier at the couch and there was a noticeable improvement in drying rate on the driers. The automatic feature in the header noticeably improved general machine operation. It was found that the break line at the boxes could be adjusted and set as desired for any one grade of paper, and vacuum on the boxes would automatically rise and fall, as stock or water varied, to maintain the break line within very close limits. Vacuum held the sheet uniform and it definitely removed more water than previous systems employed.

In running one specific grade of paper which was normally run at a speed of from 400 to 420 feet per minute and at consistencies of from 0.85 to 0.90, it was possible with the method and apparatus of the invention to increase speed to 480—500 feet per minute at consistencies of from 0.70 to 0.75 in the head box. Pressure on the driers increased with speed but, as more water was added to the wire drier, pressure dropped appreciably as much as 10%. It was also found that the method substantially eliminated the problems present in connection with water removal on a short wire.

It will be understood that various modifications may be made in the apparatus described. For example, in Figs. 12, 13 and 14, I have shown a vacuum header casing 130 and manifold 132 with an inlet at the top of the casing and a coupling member 134 mounted in the inlet so that it may be rotated about a vertical axis in order to position the casing and drop leg in varying positions of

adjustment relative to the suction boxes. In many plants, such an adjustable feature is extremely desirable in order to locate the drop leg extremities in a most advantageous place. It will be understood that, with the casing rotated into a desired position, it is then secured and fastened in place by bolts or other fastenings.

Other changes of a similar nature may be made within the scope of the appended claims.

From the foregoing description, it will be evident that I have provided a method and apparatus for extracting water and improving the paper making process in commercially significant degree and that I have materially increased the efficiency and operation of paper making machines.

This application is a continuation-in-part of U. S. application Serial No. 536,648, now abandoned, filed September 26, 1955.

Having thus described my invention, what I claim is:

1. In an apparatus for extracting water from a traveling web of paper, the combination with wire means and a plurality of suction boxes over which the web of paper runs in water extracting relationship, of a vacuum header casing communicating with each of said suction boxes and into which water extracted from the suction boxes is delivered, said vacuum header casing being provided with a plurality of drop legs leading downwardly therefrom to conduct water away from the header casing at a relatively high velocity and produce a working vacuum, the improvement comprising a row of vertically disposed tubular baffles mounted within said vacuum header casing and connected to the drop legs and open at their respective side portions to provide passageways, means extending along one side of the row of tubular baffles to provide for overflow of water into the said passageways of the tubular baffles step by step at successively higher water levels in accordance with change in level of water delivered to the vacuum header casing from the suction boxes.

2. A structure according to claim 1 in which the said means for providing an overflow of water into the passageways of the tubular baffles comprises a partition member having its upper edge varying in height from a minimum at that end of the row of baffles furthest away from the portion of the vacuum header casing into which said water extracted from the suction boxes is delivered to a maximum at the opposite end of the row of baffles.

3. A structure according to claim 1 in which the vacuum header casing is constructed with a curved sidewall portion and a substantially straight sidewall portion which meet to form a relatively narrow casing end portion, said row of tubular baffles extending away from the relatively narrow end portion in close proximity to the said straight sidewall portion of the header casing, said means for providing an overflow of water into the passageways of the tubular baffles consisting of an overflow partition member which extends along one side of the row of tubular baffles, the upper edge of said partition varying in height from a maximum at the portion of the vacuum header casing into which said water extracted from the suction boxes is delivered and extending downwardly toward the said relatively narrow end portion of the header casing.

4. In an apparatus for extracting water from a traveling web of paper, the combination with wire means and a series of suction boxes over which the web of paper runs in water extracting relationship, of a vacuum header casing communicating with each of said suction boxes and into which water extracted from the suction boxes is delivered, said vacuum header casing being provided with a plurality of drop legs extending downwardly therefrom to conduct water away from the header casing at relatively high velocity and produce a working vacuum, the improvement comprising a row of vertically disposed tubular baffles mounted within the vacuum header casing

and having outer adjacent peripheral surfaces joined together in sealing relationship, the bottoms of the said tubular baffles being connected to respective drop legs, each of said tubular baffles further having a peripheral side portion recessed to form spaced-apart edges which define fluid entranceways, a vertical overflow partition located in the vacuum header casing and extending along one side of the row of tubular baffles in contact with outermost peripheral wall portions of each tubular baffle and in close proximity to said entranceways, said partition having its upper edge varying in height to provide for successive overflow of water into the said entranceways of the tubular baffles at progressively higher water levels in the header casing in accordance with changes in level of water delivered to the header casing from the suction boxes.

5. A structure according to claim 4 the further improvement consisting of a manifold member which is connected between the vacuum header casing and the suction boxes and which comprises an elongated conduit body having an inclined bottom which converges at sides and top portions thereof to define a reduced conduit portion for producing a relatively high velocity fluid flow at the point of entrance of fluid to the said header casing.

6. A structure according to claim 1 the further im-

provement in which the vacuum header casing is constructed with an inlet opening at the upper side thereof and said casing having a coupling member rotatable in said inlet opening to locate the header casing in any desired position of adjustment about a vertical axis with respect to the suction boxes.

7. That improvement in methods of controlling a vacuum exerted on a travelling web of paper at the suction boxes of a paper making machine which consists in causing the water extracted from the web of paper to create a predetermined working vacuum which is dependent upon the character of the web and the volume of water being extracted at a given time and then automatically changing the number of suction boxes in operation in accordance with a change in flow of water to maintain the said working vacuum at a substantially constant value.

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