Sept. 2, 1952 H. M. DAVIS 2,608,912

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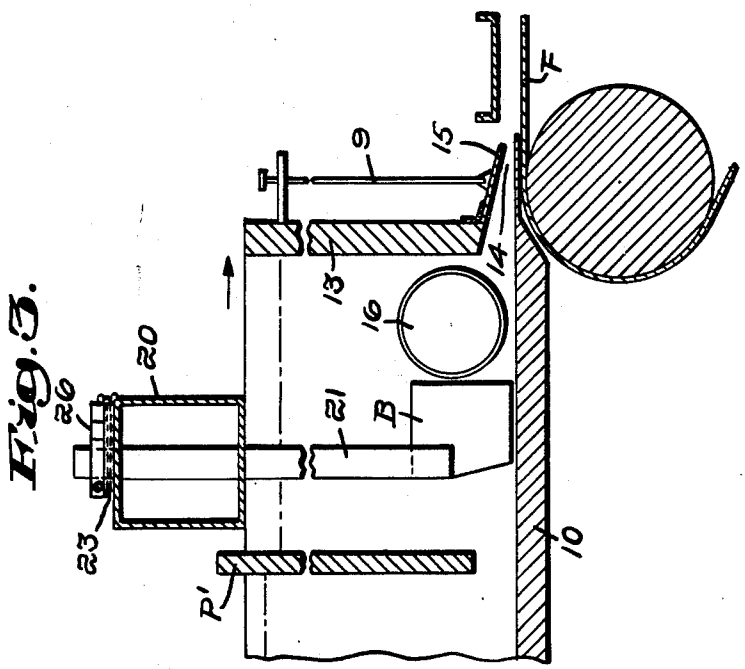


Fig. 3.

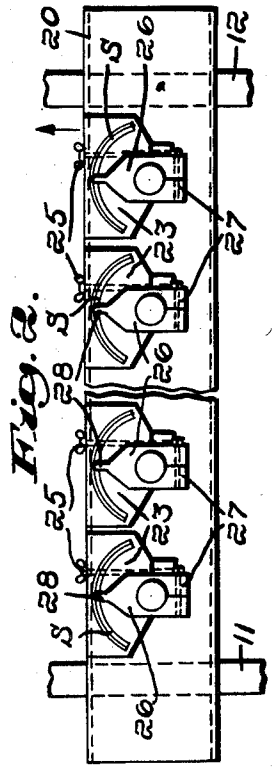


Fig. 2.

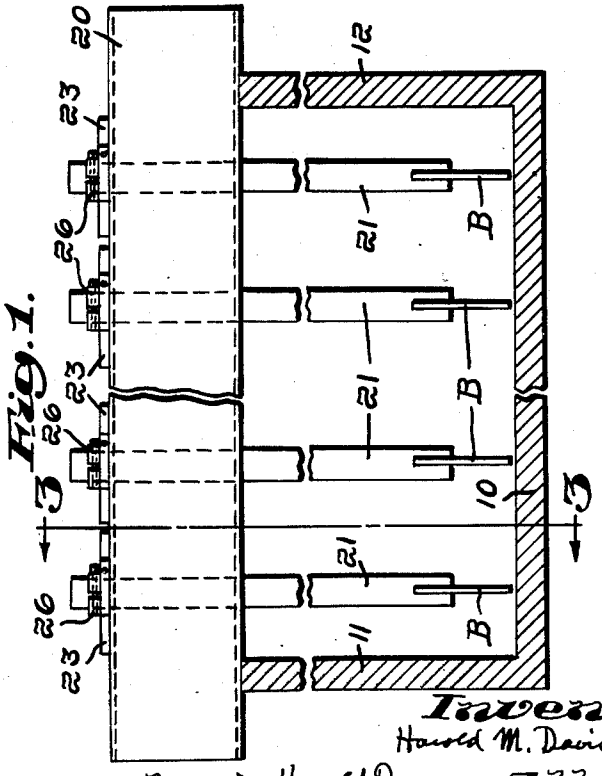


Fig. 1.

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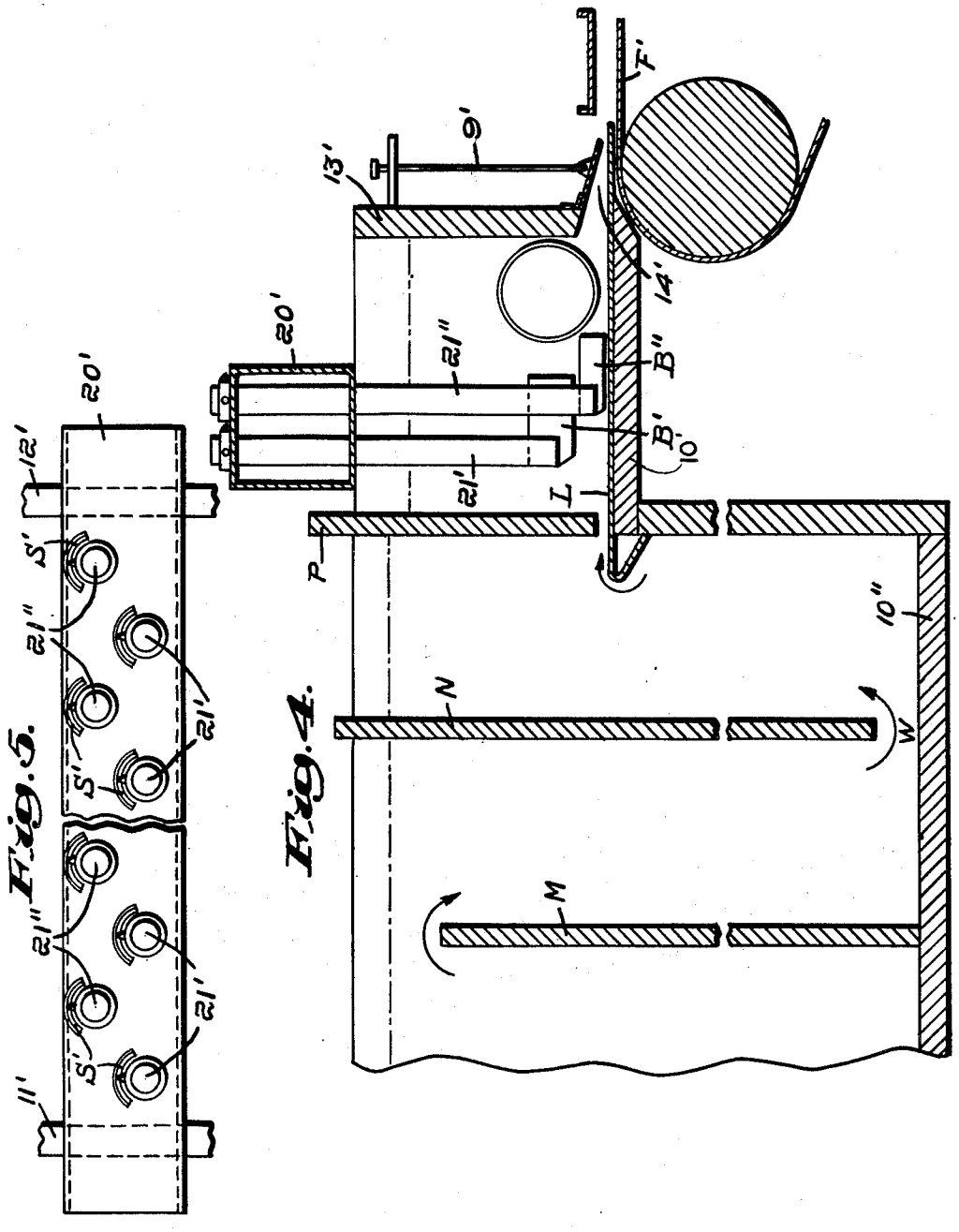


Fig. 4.

Fig. 5.

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Fig. 24.

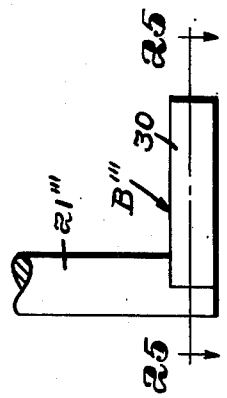


Fig. 25.

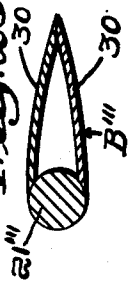
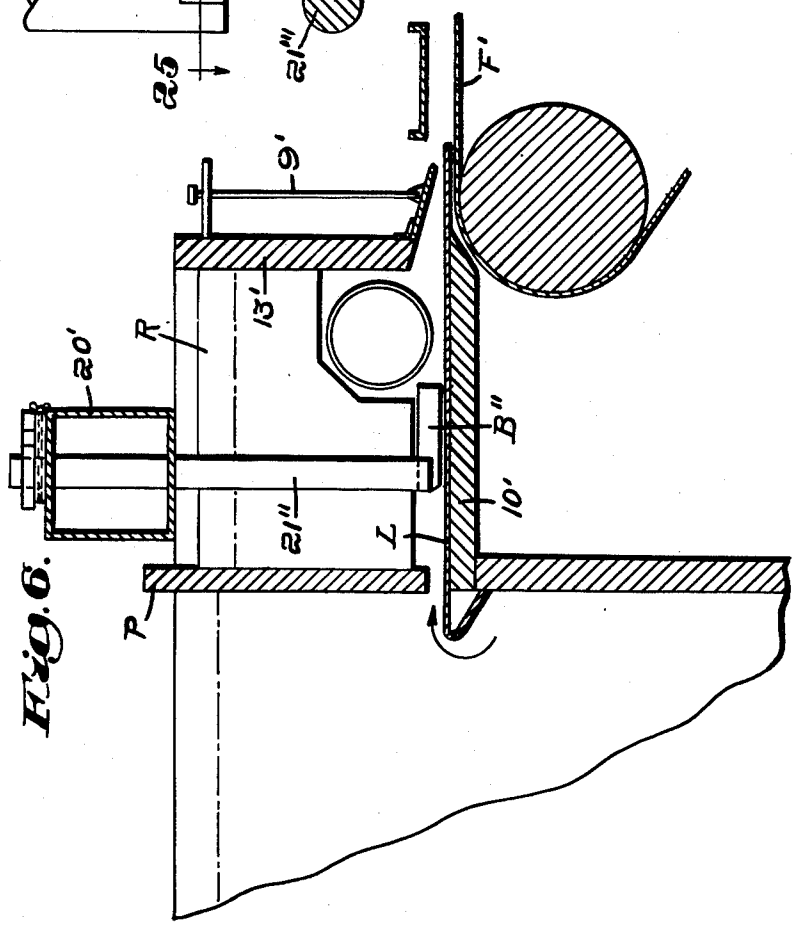


Fig. 6.



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Fig. 7.

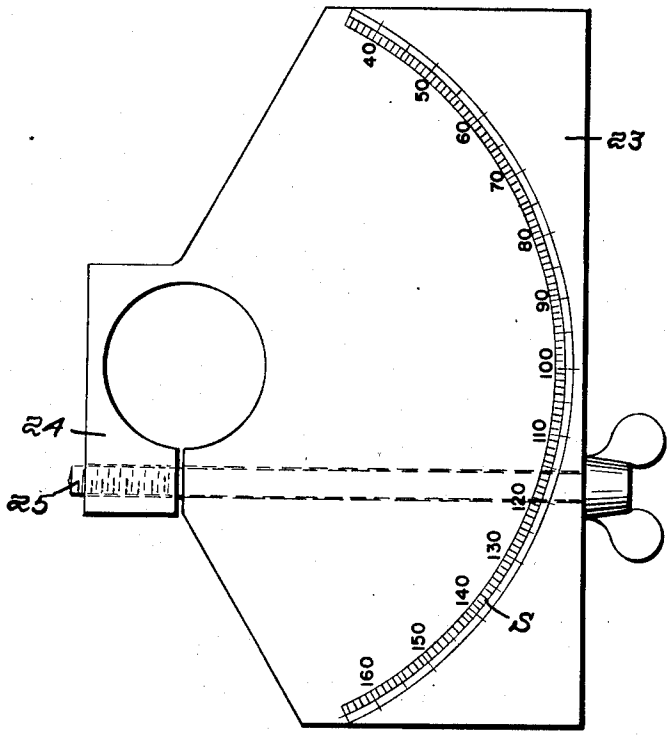
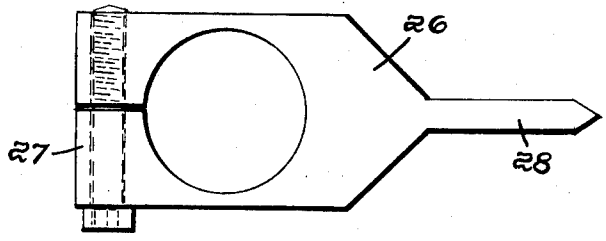


Fig. 8.



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Fig. 9.

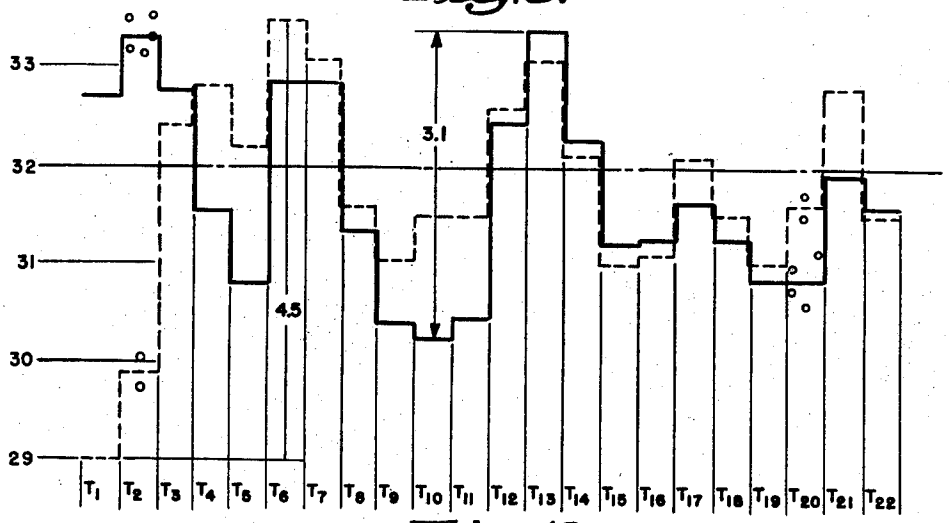


Fig. 10.

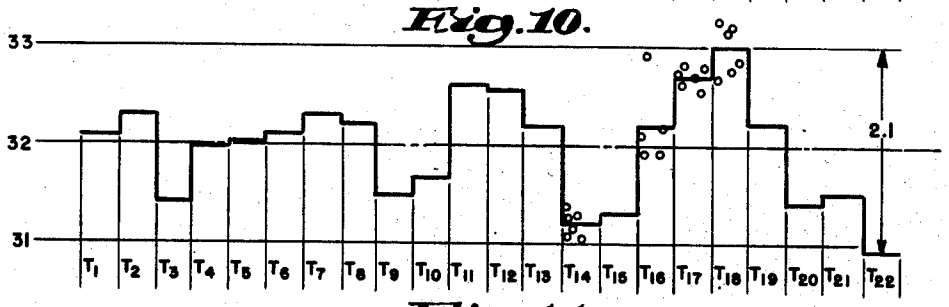


Fig. 11.

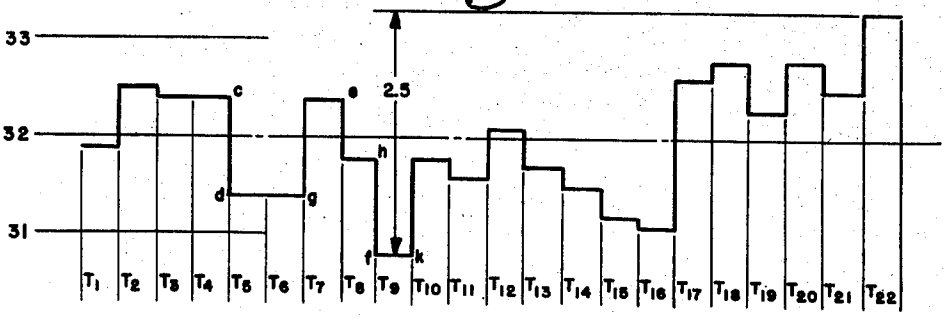
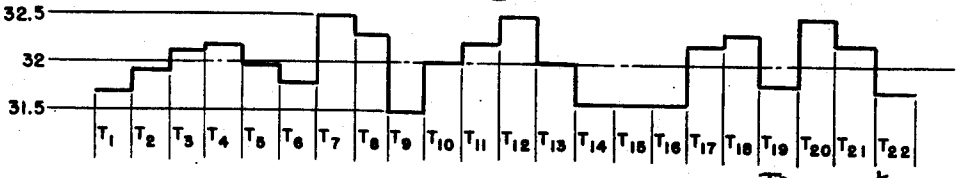


Fig. 12.



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Fig. 13.

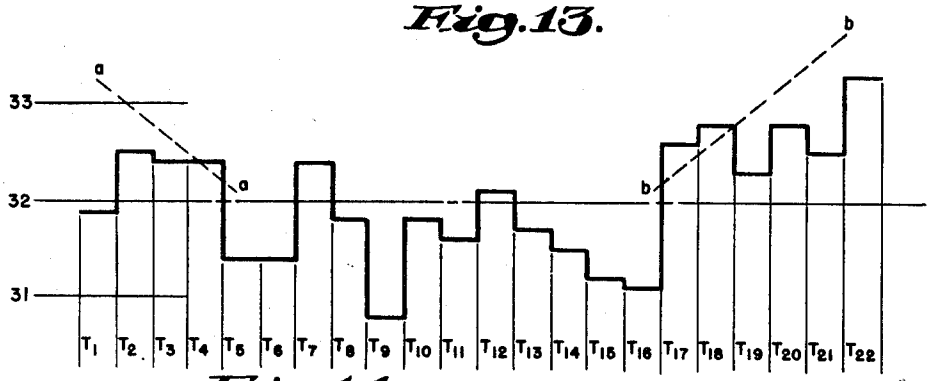


Fig. 14.

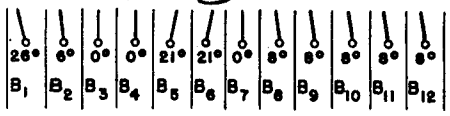


Fig. 15.

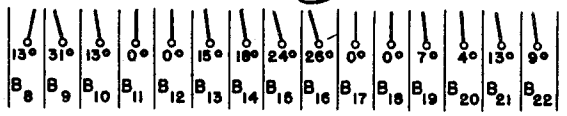


Fig. 16.

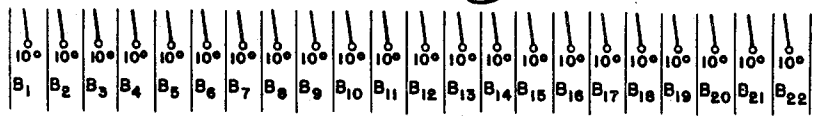


Fig. 17.

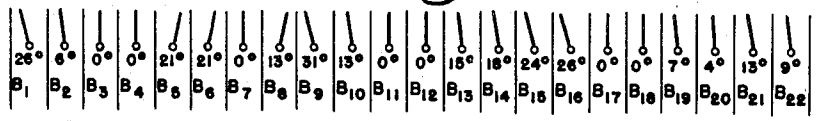


Fig. 18.

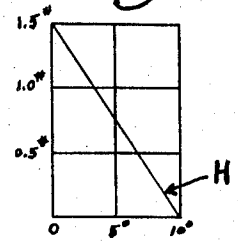
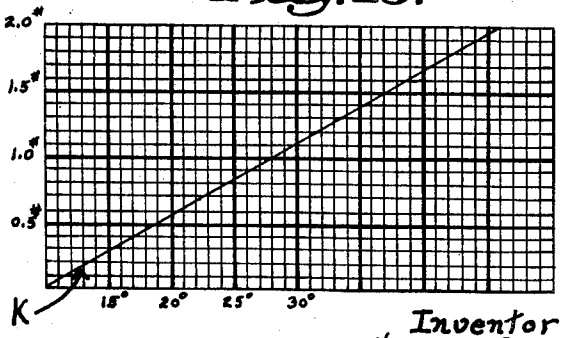


Fig. 19.



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Fig. 20.

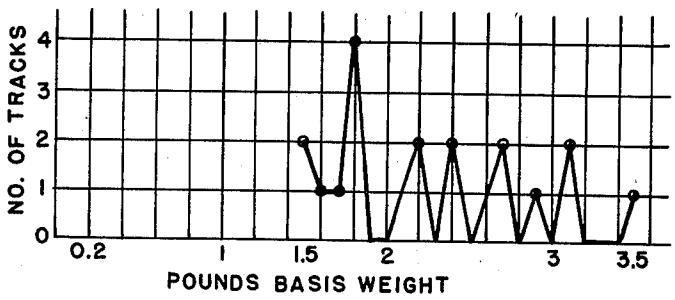


Fig. 21.

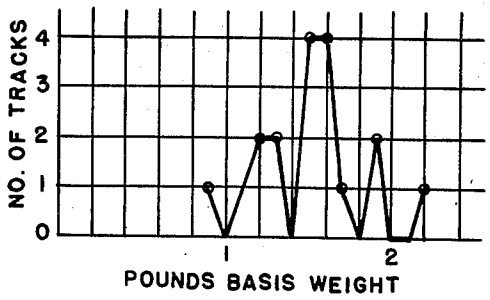


Fig. 22.

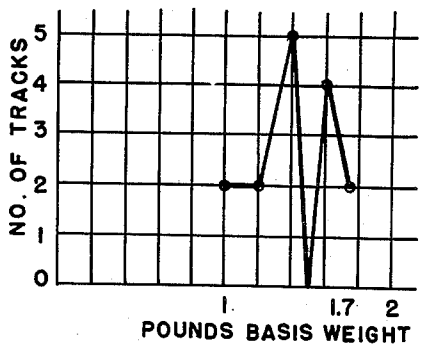
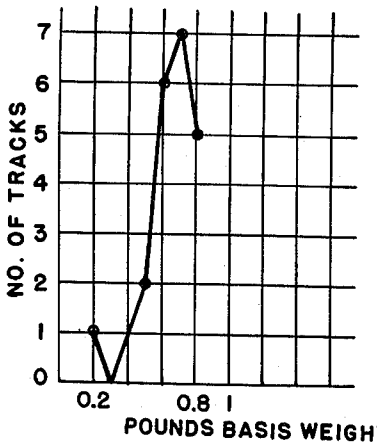


Fig. 23.



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UNITED STATES PATENT OFFICE

2,608,912

APPARATUS FOR PRODUCING PAPER

Harold M. Davis, North Calais, Vt., assignor to Precision Paper, Inc., Calais, Vt., a corporation of Vermont

Application February 23, 1949, Serial No. 77,763

13 Claims. (Cl. 92—44)

1

The present invention relates to the manufacture of paper wherein a stream of an aqueous wood pulp suspension is flowed out of a head box upon a moving screen or wire to form thereon a web of pulp. The web of pulp is subsequently processed, as by drying and calendering, to produce a web of paper. This application is a continuation-in-part of my application, Serial No. 21,813, filed April 19, 1948, now abandoned.

The invention provides a method of and means for controlling the flow and character of the pulp stream as it is about to leave the head box and be deposited upon the movable screen or wire to obtain such a uniformity of flow across the width of the head box, and consequently much uniformity in basis weight, formation and strength, caliper, bulk and final moisture content, as to effect major reductions in paper mill costs, in conversion and printing costs and in the basis weight required by end users, such as bakers, newspapers, printers, etc.

During my extensive research, I have used the following method of selecting samples of the web to determine the action of the paper making machine. In working with a Fourdrinier machine producing a web 132 inches wide, I divided the web into 22 tracks each six inches in width and determined the changes in basis weight which took place in each track. For example, assuming the machine was running at a speed of 550 feet per minute, a piece of paper 72 feet long in the longitudinal direction of the web represented the action of the paper machine during a period of eight seconds of machine running time. By cutting this piece transversely of the web to form six pieces each 12 feet long, I obtained six pieces each representing 1⅓ seconds of machine running time. By cutting each of these pieces in the longitudinal direction of the web to form 22 pieces each 6 inches wide, I obtained six samples each representing the action taking place in 1⅓ seconds of machine running time in each of the 22 tracks into which I divided the web. The basis weight of each sample was determined by weighing.

Employing this method of sampling I found that permanent heavy and light streaks lengthwise of the web of paper were present for mile after mile and caused a variation in basis weight across the web up to three pounds. In this specification, I refer to the heavy streaks as "hills" and to the light streaks as "valleys." I also found that there is a reoccurring cycle of basis weight variations in all longitudinal lines of the web, each cycle corresponding to about 5 seconds of machine running time. I also found a third type of basis weight variation, which is a flash but random variation, in which from two to nine tracks combine for about one second to change basis weight in the same direction but not necessarily

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by the same amount in each track. Both of these flash variations are equally evident in 8-second tests of 72 feet of paper and in many hours of tests sampled once an hour.

These three types of basis weight variation have lead those skilled in the art to erroneous interpretations of the action of paper making machines. It has been common practice to make certain adjustments in the paper making machine, such as adjustment of the slice in the Fourdrinier machine, as dictated by the visual appearance of the flow on the wire and based upon samples selected periodically from the finished paper. The most common sampling practice has been to tear four separate laterally spaced pieces from the end of a reel and trim each to measure 24 by 36 inches.

No set of samples obtained by this common method of sampling furnished accurate information as to the true character of the web of paper being produced. Thus, the portion of the width of the web represented by each sample might contain a high hill or a deep valley or both but no sample indicated this because it gave only the average basis weight of this portion of the web, e. g. the average of the hills and valleys. Furthermore, no set of samples represented the average basis weight of any longitudinal portion of the web formed during any one completed cycle of almost instantaneous changes in basis weight which reoccur and are completed about every 5 seconds.

Based upon this information, the character of the stream of aqueous pulp suspension was controlled by adjustment of the paper making machine to control the character of the web produced. It is obvious that at times and places adjustments were made when they should not have been made and at other times and places no adjustment was made when one should have been made. In view of this and in the light of my discoveries previously mentioned, it is obvious why paper manufacturers concluded that the profile of the web continually changes and never follows a substantially fixed pattern. tI is equally obvious that paper produced under such conditions would vary greatly in basis weight.

An important feature of the present invention is the provision of a method of sampling the web of paper whereby the true character of the profile of the web may be accurately determined. This may be accomplished by selecting a sufficient number of samples from each of the tracks into which the width of the web is divided, to obtain an average of each of the cycles of 5 seconds duration. My preferred method for routine and control sampling will be described hereinafter.

I have also discovered that if the machine is permitted to run without periodic adjustments, the profile can follow a substantially fixed pattern

and that the average profile over a period of about 5 seconds machine running time can be substantially the same as the average profile over a long period of machine running time. I refer to such a profile herein as a stable profile. A stable profile can be obtained easily with the adjusting means normally provided on paper making machines but an unstable profile also can be obtained.

An unstable profile is one consisting of steep, narrow, high hills and deep valleys with almost complete absence of comparatively level places. I have discovered that in such profiles one or more deep valleys will fill in and one or more hills will level off or become valleys resulting in a new profile which lasts for an uncertain period of time and then changes to a different unstable profile which lasts for an uncertain period of time. However, I have discovered not only that these changes take place when there is no change in consistency, freeness or speed but also that variations in consistency, freeness and speed can take place while any of the unstable profiles exists without causing one unstable profile to shift to another.

I have also made a further important discovery. Thus, in a group of stable and unstable web profiles, I have found that the magnitude of the continuously reoccurring almost instantaneous changes in basis weight is much less in stable profiles than in unstable profiles and also is much less in the small than in the large or steep hills and valleys. I have also discovered that these continuous instantaneous changes do not affect the average pattern of a stable profile. Thus, in a stable profile the average basis weight of a number of samples of paper taken from a given longitudinal track and representing a period of machine running time of 5 to 8 seconds is substantially the same as the average basis weight of the same track over a long period of machine running time. I have also discovered that changes in consistency, freeness and speed do not affect the general hill and valley character of a stable profile, or an unstable profile.

The present invention is based upon the discoveries previously mentioned and also upon the discovery that the dynamic hydraulic flow of the stream of pulp can be controlled, when the normal adjustments of the paper making machine have been made to obtain a stable profile, to cut the hills and fill the valleys to substantially the average basis weight of the web. Thus, the invention contemplates a method and apparatus which supplements but does not replace the normal adjustments of the conventional paper making machine. Since the hills are reduced and the valleys filled to produce a substantially level profile, the continuous almost instantaneous changes or fluctuations in basis weight are small and of no concern because technically and economically such instantaneous changes have no importance to the paper mill, the converter or end user and because, as previously pointed out, the magnitude of these changes varies directly with the steepness of the hills and valleys. I have found by many hours of tests that in a stable profile 90 per cent of the 6 inch samples are within ± 0.3 lb. of the basis weight average of the tracks from which the samples are taken.

In the practice of the invention, the web is considered as composed of a plurality of narrow longitudinal tracks. I have found tracks 6 inches wide suitable in producing a web 132 inches wide, but tracks of smaller or greater width may be used. First, the character of the profile of the web being produced by the paper making machine is determined by selecting a plurality of samples of paper from each track such that the average of the samples selected from each track is representative of the average basis weight of the paper in each track. The method of sampling described hereinafter is preferably employed. Second, the paper making machine is adjusted until a web having a stable profile of the desired character is being produced, for example, by adjusting the slice in a Fourdrinier machine. In producing a web 132 inches wide, I prefer a stable profile having two principal hills, one at each edge of the web, connected by a wide shallow valley but additional minor hills and valleys are not particularly objectionable. In a wider machine, a greater number of hills and valleys may be preferred.

When the paper making machine is producing a web having a stable profile, I have discovered that baffles located in the regions of the pulp stream corresponding to the tracks of the valley portions of the web draw pulp from a region corresponding to a hill portion of the web if the baffles are positioned at an angle to the general direction of movement of the web and point downstream away from such region. As a result, the valley portions of the web are filled and the hill portions are reduced or cut. The drawing effect of valley baffles depends upon the angles at which they are positioned and is substantially directly proportional to the magnitude of the angles. I have also discovered that the effect of these valley baffles upon the hill portions of the web may be controlled further by placing baffles in the regions of the pulp stream corresponding to the tracks of such hill portions, thus preventing excessive reduction or cutting of these portions of the web. The desired angular positions of the hill and valley baffles depend upon the character of the profile of the web being leveled and may be determined in accordance with empirically derived data. I prefer to employ one baffle in each of the regions of the pulp stream corresponding to the respective tracks of the web of paper. The combined action of all the baffles affects only a small portion of the total of the pulp stream.

During the adjustment of the machine to produce a stable profile, it is not necessary to have the baffles of the present invention positioned in the pulp suspension. However, during this operation I prefer to position the baffles in the suspension in the head box at a small angle to the general direction of movement of the web. An angle of about 10° is suitable. I prefer this angle because later in leveling the web, the valley baffles usually are set at angles greater than 10° to pull from some hill and many of the hill baffles are adjusted to a smaller angle.

To obtain a web having a stable profile of the desired character in a Fourdrinier machine, the machine is started the same as if the apparatus of the invention was not present in the head box. The slice is adjusted in the usual manner to obtain a profile that makes a satisfactory web and can be expected to remain stable for at least a substantial length of time. The exact profile then is determined by the average of a set of samples from each track. With this information, the slice is adjusted to obtain a profile having, for example, a moderate hill at each edge connected by a broad shallow valley. Any experienced machine tender can do this. However, the following rules should be observed:

1. Always pair the two kinds of slice adjustment, that is, if the slice is raised to increase basis weight at one point it should always be lowered at some other point to cut basis weight.

2. If several adjustments must be made, they should be classified in pairs and each pair made separately.

3. Always keep the two adjustments in a pair as close together as possible, except for a minimum of one unadjusted position between two adjustments.

4. Never open or close the slice much at one time. Two per cent is a large adjustment and one percent is better for all except the largest changes.

The invention will be more clearly understood from the following description in conjunction with the accompanying drawings, in which:

Fig. 1 is a front sectional elevational view of the head box of a Fourdrinier paper making machine embodying devices of the invention;

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

Fig. 3 is a fragmentary longitudinal sectional view of the apparatus as viewed from the right of Fig. 1;

Fig. 4 is a fragmentary sectional view similar to Fig. 3 of a modified form of apparatus;

Fig. 5 is a fragmentary diagrammatic plan view of a portion of the apparatus shown in Fig. 4;

Fig. 6 is a view similar to Fig. 4 embodying a modified feature;

Fig. 7 is a detail plan view of one of the parts shown in Figs. 1 and 2;

Fig. 8 is a detail plan view of another of the parts shown in Figs. 1 and 2;

Figs. 9 to 13 are diagrammatic views of representative profiles of webs of paper;

Figs. 14 to 17 are diagrammatic plan views illustrating the devices of the invention set in certain angular relations to the general direction of flow of the pulp stream;

Figs. 18 and 19 are empirically derived curves;

Figs. 20 to 23 are diagrams illustrating flash variations in basis weight under different conditions;

Fig. 24 is a fragmentary elevational view of a control baffle of modified form; and

Fig. 25 is a sectional view taken upon the line 25—25 of Fig. 24.

In Figs. 9 to 13 the ordinates represent basis weight in pounds and the abscissas represent linear measure in inches. These figures illustrate profiles of webs 132 inches wide divided into 6 inch tracks T_1, T_2, T_3, etc. The dot and dash lines represent the average basis weight of the webs.

In Fig. 9, the irregular solid line represents an unstable profile that held for the first two hours and the last three hours of a test. The dash line represents the profile of the same web for two hours in between. In tracks T_2 and T_{20} basis weight of individual samples are indicated by the center of small circles. In T_2, the five samples from the first two and the last three hours are unmistakeably the same at about 33.3 lbs. The two samples from the third and fourth hours are practically identical but different from the other five. The same is true in T_{20} although the change was not so great. The index of stability is 10 as computed by the empirical formula given hereafter.

The irregular solid line in Fig. 10 represents a stable profile that ran for ten hours without

change. It is the most level profile I have encountered, although the maximum error is 2.1 lbs. Its index of stability is 2.0. In tracks T_{14}, T_{16}, T_{17}, and T_{18}, the centers of the small circles indicate basis weight of typical individual samples. No sample in T_{14} can be mistaken for one in T_{17} or T_{18}. This is not true of the samples in T_{17} and T_{18}. For tracks like T_{17} and T_{18} it is particularly important to get enough samples to average the flash variations. These variations in T_{16} are quite different because one sample jumps up above the T_{17} level but lasts only about one second. This happens about 700 times every hour and is typical of all steep slopes.

The irregular solid lines in Figs. 11 and 13 represent the family of stable profiles I presently prefer for leveling. The index of stability of these profiles is 3.3. It is a good profile to run on a Fourdrinier machine, even if never leveled, because it is high at its edges and low in the center and slit rolls never interweave on the slitter.

The irregular line in Fig. 12 represents the profile of the web shown in Figs. 11 and 13 after being leveled in accordance with the invention.

I have developed empirically a formula suitable for practical use in computing mathematically what I term the index of stability of any given profile. The formula is:

$$\text{Profile index of stability} = \Sigma \frac{A + \Sigma C}{W}$$

where

A is the maximum altitude in pounds of each hill from hill top to bottom of deepest adjacent valley but never below any level profile portion of two tracks or more in width, any hill less than 1.2 lbs. being disregarded,

C is the height of any perpendicular cliff of 0.8 lb. or more,

W is the weighted average width, in tracks, of any hill plus one extra track if unsupported on one side only, and

Σ is a symbol indicating "the sum of."

The use of this formula in computing the index of stability of any profile is illustrated by the following computation of the index of the profile shown in Fig. 11 which is identical to that shown in Fig. 13. Referring to Fig. 11, the profile contains four hills, namely, the hills formed by tracks T_1 to T_4, tracks T_7 to T_8, tracks T_{10} to T_{15} and tracks T_{17} to T_{22}. In the hill formed by tracks T_1 to T_4, the difference in basis weight between the points c and d is less than 1.2 lbs. so this hill is disregarded.

In the hill formed by tracks T_7 to T_8 the difference in basis weight between the points e and f is 1.6 lbs. so A equals 1.6. The basis weight difference between the points g and e and between h and f is 1.0 lb. respectively so C in both instances is 1.0. A plus the sum of C equals 3.6. W is computed as follows: Track T_7 is one track wide and the difference in basis weight between the points e and h is 0.6 lb. so 1 times 6 equals 6. Tracks T_7 and T_8 are two tracks wide and the difference in basis weight between the points h and g is 0.4 lb. so 2 times 4 equals 8. Since this hill is unsupported on one side only, one extra track must be used. Thus, the basis weight difference between points g and k is 0.6 lb. and the number of tracks is three so 3 times 6 equals 18. The sum of the products of these multiplications is 6 plus 8 plus 18 which equals 32. The sum of the basis weights as computed for these three

track groups is 6 plus 4 plus 6 which equals 16. Therefore, W equals 32 divided by 16 which is 2. Thus, in this hill

$$\frac{A+\Sigma C}{W}=\frac{1.6+1.0+1.0}{2}=1.8$$

Computing in the same way, it is found that

$$\frac{A+\Sigma C}{W}$$

for the hills formed by the tracks T_{10} to T_{15} and tracks T_{17} to T_{22} is 0.5 and 1.0 respectively. Consequently, the index of stability equals the sum of 1.8 plus 0.5 plus 1.0 which is 3.3.

Referring to Figs. 1 to 3, and 7 and 8 of the accompanying drawings, the head box is the usual open top box-like construction comprising a bottom 10, a back wall (not shown) connecting opposite side walls 11 and 12 which extend from the back wall in the down stream direction of the machine. A front wall 13 also connects the side walls 11 and 12. The bottom of the wall 13 is spaced from the bottom 10 to provide a passage 14 extending across the width of the head box through which the aqueous stream of wood pulp may flow toward and upon the usual Fourdrinier screen F adapted to form a web 132 inches wide. The usual slice 15 is adjustably carried by the wall 13 for adjustment at a plurality of spaced points across the width of the head box by the usual adjusting devices 9. The slice 15 also is provided with the usual means (not shown) for the bodily adjustment of the slice to change the average basis weight of the web. A mixing roll 16 extends across the width of the head box adjacent the passage 14 and is mounted for rotation in the side walls 11 and 12 so that it clears the bottom 10 by about ⅛ to ½ of an inch.

As illustrated in Figs. 1, 2, 3, 7 and 8, the head box is fitted with apparatus embodying the invention. A girder 20 extends transversely of the head box and is supported and secured in any suitable manner upon the top edges of the walls 11 and 12. The girder 20, preferably formed by welding together two angles or two bent steel plates to form a hollow girder of rectangular cross section, is provided with a plurality of transversely aligned vertical holes in each of which a pipe or rod 21 is mounted for adjustment both about and in the direction of its axis. A baffle B about four inches high is secured to the bottom portion of each of the pipes 21 to extend laterally therefrom about five inches. A plate 23 is secured, as by welding, to the top of the girder 20 adjacent each of the pipes 21 and is provided with a split clamp portion 24 (Fig. 7) surrounding the pipe and is adapted to be tightened thereon by a bolt 25. Each of the plates 23 is provided with a scale S graduated in degrees and is so located that a given corresponding graduation, such as the 90° graduation, of all the scales is located in a given straight line. A second plate 26 is adapted to be rotatably supported upon each of the plates 23 and is provided with a split clamp portion 27 by which it may be secured to a corresponding pipe 21. Each plate 26 is provided with a pointer 28. The plates 26 should be securely clamped upon the pipes 21 so that when the plates 26 rest upon the plates 23 the bottom edges of the baffles B will be spaced usually about 0.01 of an inch from the bottom of the head box. The angle between each of the baffles and its corresponding pointer 28 is identical. The baffles B may be spaced a greater distance from the bottom of the head box if desired, such as ½ inch or more. The machine illustrated is adapted to form a web paper 132 inches wide. There are twenty-two pipes 21 spaced 6 inches apart, one positioned in each of the regions of the pulp stream corresponding to the twenty-two tracks of the web of paper produced.

I have found that the baffles B tend to stabilize the dynamic hydraulic flow in the head box when all are set in a neutral position or at working angles for leveling. In accordance with my present preferred practice, I set each baffle so it extends down stream at an angle of 10° with respect to the general direction of movement of the web of paper to be produced. A smaller or greater angle may be used within a range between about 5° to 15°. The slice 15 then is adjusted so as to produce a web having a stable profile such as shown in Fig. 13.

The practice of the invention may be illustrated by the use of the devices shown in Figs. 1, 2, 3, 7 and 8 in cutting the hills and filling the valleys in a web having the stable profile shown in Fig. 13. The index of stability should be not more than 6 as computed by the formula given herein. It will be understood that this profile is produced by adjusting the slice 15 with each of the baffles B set at a neutral angle of 10° with respect to the general direction of movement of the web and with all the baffles extending in the same direction as shown in Fig. 16, that is, with all the pointers 28 at 100° on the scales S. The character of the profile shown in Fig. 3 is determined by my method of sampling in each 6 inch track across the width of the web as previously described or by the method described hereinafter. I prefer a profile in which the basis weight in each of the edge hills or the connecting shallow valley does not vary more than about 1.5 lbs. from the average basis weight.

In leveling a profile the settings of the baffles B corresponding to the hill tracks are determined from the curve H shown in Fig. 18. In Fig. 18 the ordinates represent basis weight and the abscissas represent degrees from zero to the neutral (10°) settings of the baffles. The curve H is formed by drawing a straight line from the degree graduation of the neutral settings (10°) to the 1.5 lb. basis weight graduation which I have found empirically may be taken as representing the maximum basis weight of any track in a hill.

In leveling a profile, the baffles B corresponding to the tracks of a valley are set pointing away from the hill to be cut and at angles determined by the empirically derived curve K in Fig. 19. The curve K of Fig. 19 is derived in the following manner:

The baffles B are set at a desired neutral angle, such as 10°, and the slice 15 adjusted until the profile of the web produced is stable and contains two edge hills and one central valley. Two or three of the valley baffles then are set at various angles greater than the neutral settings but each at a different angle. Samples of the web are taken both before and after each setting, from the track corresponding to the respective baffles and the basis weights corresponding to the angular settings are plotted to derive the curve K.

As the first step in leveling the profile of the web illustrated in Fig. 13, I draw a construction line *a*—*a* from the point at the inner edge of track T_4 representing 0.2 lb. basis weight above the ideal level line, that is, the dot and dash line representing the average basis weight of the web. The line *a*—*a* has a slope of 0.3 lb. per track which I have found empirically represents

the normal cut in a hill by pull from a valley. The distance between this line and the profile in each track shows the excess or unwanted cut due to the natural pull of the valley baffles. This unwanted cut in track T_1 is 1.2 lbs., in T_2 it is 0.3 lb. and is negligible in T_3. The wanted cut in track T_2 is 0.5 lb., in T_3 is 0.4 lb. and in T_4 is 0.4 lb. Track T_1 needs a fill of 0.1 lb. The average wanted cut in tracks T_1 through T_4 is 0.3 lb. (1.3 lbs. minus 0.1 divided by 4). Curve H (Fig. 18) shows that the baffle setting for 0.3 lb. is 8°. The total of the settings in these four tracks is 32°. I prorate this total in proportion to the unwanted cut in those tracks where there is unwanted cut (1.2 lbs. in T_1 and 0.3 lb. in T_2). Thus, the settings for the baffles B_1 and B_2 corresponding to tracks T_1 and T_2 are 26° and 6° respectively as shown in Fig. 14. Since it is desired to cut tracks T_3 and T_4 by 0.4 lb., the normal pull of the valley baffles is desired and, therefore, the baffles corresponding to tracks T_3 and T_4 are set at 0° as shown in Fig. 14. Thus, the normal pull from the hill by the valley baffles is distorted to conform to the irregularity of the hill.

The fill desired in the small valley formed by tracks T_5 and T_6 is 0.6 lb. for each track, the total fill being equal to the wanted cut in the hill at the left of Fig. 13. The curve K (Fig. 19) indicates a setting of 21° is required for 0.6 lb. fill and each of the baffles B_5 and B_6 corresponding to these tracks is set at 21° pointing downstream away from the hill to be cut as shown in Fig. 14. The first baffle outside the valley on each side must always be set at 0° to check the fill and confine it to the valley, in this case the baffles B_4 and B_7.

I find that the disturbance incidental to adjustments in a hill and valley, such as just described, strengthens the power of an equal number of adjacent baffles but that it may be compensated for by weaker settings of the latter baffles, such as the average settings indicated for the baffles corresponding to the tracks of the hill which in this case is 8°. Consequently, the settings of the baffles B_8 to B_{12} are reduced from 10° to 8° as shown in Fig. 14, the baffle B_7 having been previously reduced to 0°. These 8° settings are temporary and will be changed in a later operation.

The procedure for cutting the hill at the right of Fig. 13 formed by the tracks T_{17} to T_{22} to fill the valley formed by the tracks T_8 to T_{16} is similar to that described for cutting the hill at the left of Fig. 13 and filling its adjacent valley. Thus, the construction line *b*—*b* is drawn similar to the line *a*—*a*. The unwanted cut in track T_{19} is 0.5 lb., in T_{20} is 0.3 lb., in T_{21} is 0.9 lb. and in T_{22} is 0.6 lb. The wanted cut in track T_{17} is 0.6 lb., in T_{18} is 0.8 lb., in T_{19} is 0.3 lb., in T_{20} is 0.8 lb., in T_{21} is 0.5 lb., and in T_{22} is 1.3 lbs., and the average wanted cut per track is 0.7 lb. Curve H (Fig. 18) shows that the required baffle setting for 0.7 lb., is 5½°. The total settings for the hill is 33° (5½ times 6). Prorating 33° in proportion to the unwanted cut in tracks T_{19} to T_{22} shows that the corresponding baffles B_{19} to B_{22} should be set at 7°, 4°, 13°, and 9° respectively as shown in Fig. 15. Since it is desired to cut tracks T_{17} and T_{18}, the setting of the corresponding baffles B_{17} and B_{18} is reduced to 0° as shown in Fig. 15. Thus, the forces holding up the hill are weakened ready to drop it toward the ideal level line when the pull of the valley baffles is applied, but the weakness is so distributed that the normal pull of the valley baffles will be distorted to conform to the irregularities of the hill.

The fill desired in valley track T_{13} is 0.3 lb., in T_{14} is 0.5 lb., in T_{15} is 0.8 lb., and in T_{16} is 0.9 lb. Curve K (Fig. 19) indicates that the corresponding baffles B_{13} to B_{16} should be set at 15°, 18°, 24°, and 26° respectively as shown in Fig. 15. The adjacent baffles B_{12} and B_{17} should be set at 0° to confine the fill power to the valley.

The baffles corresponding to the valley tracks T_8 to T_{11} now are set to fill the valley. The fill wanted in track T_8 is 0.2 lb., in T_9 is 1.2 lbs., in T_{10} is 0.2 lb., and in T_{11} is 0.4 lb. Curve K (Fig. 19) indicates that the corresponding baffles B_8 to B_{10} should be set at 13°, 31° and 13° respectively as shown in Fig. 15. Since the fill for tracks T_9 and T_{10} is pulled from the hill at the right of Fig. 13, the baffles B_9 and B_{10} are pointed away from that hill. The fill for track T_8 is drawn from the hill track T_7 so the baffle B_8 is pointed away from that hill. Since the hill track T_{12} is small and the adjacent valley track T_{11} is small, the corresponding baffles B_{11} and B_{12} are set at 0°.

In general, I have found that best results are obtained following the general plan used and previously described in leveling the stable profile of Fig. 13. Thus, the hills to be cut are paired with the valley to be filled therefrom. The setting of the corresponding baffles of each pair is conducted as a separate operation starting with a hill and valley pair at one edge followed by the hill and valley pair at the other edge, etc., as described in leveling the profile of Fig. 13. In each operation, the baffles corresponding to the hill are set before those corresponding to the valley and the small settings should be made before the larger ones.

While the angular adjustment of the baffles is of major importance, their vertical adjustment also is important for several reasons. Thus, it renders the apparatus adaptable immediately for different installations, where the desired distance between the baffles and the bottom of the head box may be different as where the position of the mixing roll with respect to the bottom may be different. Also, in given instances where leveling requires the angle of a baffle to be reduced from its 10° to 0°, a more desirable action in the same direction may be obtained by raising the baffle slightly or completely removing it from the aqueous pulp suspension.

By cutting the hills and filling the valleys in accordance with the invention, it is possible to produce a web of paper in which the profile does not vary from the average basis weight of the web by more than ±0.5 lb., and may be not more than ±0.3 lb.

While I have illustrated the practice of the invention using tracks 6 inches wide, it will be understood that comparable results may be obtained using narrower or wider tracks, such as tracks from 2 to 12 inches wide.

The baffles B, preferably, are positioned in the head box a short distance in back of the orifice (Fig. 3) and exert their influence principally upon the bottom portion of the stream of pulp since their bottom edges are spaced only a short distance from the surface of the bottom 10 of the head box. The mixing roll 16 may be omitted if desired.

In accordance with my present preferred practice, I employ two sets of baffles. Referring to Figs. 4 and 5, I have shown one set of stationary

baffles B' and another set of control baffles B''. The baffles B'' are supported about 6 inches apart from a girder 20' for angular and vertical adjustment in the same manner as baffles B are supported from the girder 20, that is, by clamping plates 23 and 26 (Figs. 7 and 8), and are positioned and adjusted angularly in the same manner for leveling a web. The baffles B'' are about 4½ inches long and ½ to ⅝ of an inch high and each is secured to the end of a rod 21'' about one inch in diameter. The thick rounded edge of the baffles B and B'' provided by the rods 21 and 21'' with decreased thickness toward the other end is advantageous. Each may be shaped like baffle B''' (Fig. 24) to provide a tapering surface contour similar to an aeroplane wing, two metal sheets 30 being united at one end and their other ends welded to rod 21'''. The baffles B' are each secured in a rod 21' and may be about six to eight inches long and about 8 inches high. The rods 21' are centered about 6 inches apart in a plane spaced a few inches in back of the plane in which the rods 21'' are centered, the rods 21' being positioned about 3 inches from the rods 21'' in the transverse direction of the head box. Preferably, the baffles B' are positioned with their bottom edges at about the same level as the top edges of the baffles B''. Although, the baffles B' remain stationary during leveling of a web, they may be supported for angular and vertical adjustment the same as baffles B. The baffles B' may be set at 0° to 15° with respect to the longitudinal direction of movement of the web of pulp and serve to guide and steady the dynamic hydraulic flow.

The girder 20' may be secured upon the top edges of the side walls 11' and 12' of the head box. In the head box shown in Figs. 1 and 3, its bottom is substantially coextensive with the bottom lip of the orifice 14. The head box shown in Fig. 4 is a type slightly different and has the portion 10' of its bottom wall adjacent the orifice 14' raised about 4 feet above the main bottom wall 10''. Partitions M and N extending between the side walls 11' and 12' cause the pulp to flow through the head box in a path indicated by the arrows, the level of the aqueous pulp suspension being indicated by the dotted line. The partition N provides a deep well weir W. I have found that the magnitude or range of the flash variations is reduced considerably and that leveling of the web is facilitated if I provide a partition P extending between the side walls 11' and 12' parallel to the front wall 13' and spaced therefrom, preferably, about 12 to 24 inches. The partition P extends from above the aqueous pulp suspension level to a line spaced from the bottom wall 10' about ½ to 2 inches to provide a shallow passage therebetween. The partition P serves to guide and steady the hydraulic flow and to direct the stream of aqueous pulp suspension toward the orifice 14'. I may employ the partition P in conjunction with the control baffles B'' either with or without the stationary baffles B'. The stationary baffles B' may extend above the aqueous pulp suspension level or I may employ stationary baffles or longitudinal partitions R (Fig. 6) extending between the front wall 13' and the transverse partition P with their top edges above the aqueous pulp suspension level that is, substantially at the same height as the top edges of the walls of the head box, and their bottom edges about at a level with the top edges of the baffle B''. In order to assure a smooth surface adjacent the control baffles, the portion 10' of the bottom wall may be covered with a sheet of stainless steel L. The sheet L may extend rearward or the partition P may be positioned forward one or two inches from the rear edge of the portion 10' to cause the stream to follow a horizontal course through and from the shallow passage.

I presently prefer to provide the head box shown in Figs. 1 and 3 with a transverse partition P', similar to the partition P of Figs. 4 and 6, extending between the side walls 11 and 12 and with its top edge above the liquor level and its bottom edge spaced from the bottom wall 10 about ½ to 2 inches.

While I have illustrated a transverse girder supported at the top of the head box as a means for carrying the baffles B, B' and B'', it will be apparent to those skilled in the art that various other means may be employed for carrying these baffles and their associated adjusting mechanism. Thus, the rods to which the baffles are secured may extend upwardly through the bottom wall of the head box with the baffles secured thereto at their upper ends.

In the practice of the invention, it is desirable first to check the head box to make sure that the slice and adjusting means therefor are in good order so that when the various adjustments have been made the position of no part of the slice will change. The device of the invention functions as a sort of vernier that supplements the slice. The control baffles, as illustrated, work on the very bottom of the flow and most of it goes by without any interference. Thus, these control baffles provide obstacles in the flow of the lower portion of the pulp stream. Once tracking has been established, the effect of the obstacles may be increased or decreased by separate adjustment of any desired control baffles to draw pulp from the hills into the valleys and to protect the hills against overdraw. Whether or not the control baffles are employed alone or together with either or both the stationary baffles and the transverse partition or weir, which directs the pulp flow toward the control baffles, depends under the conditions normally existing in the head box as determined by my method of sampling.

The method of sampling the web of paper to determine the character of the hills and valleys of the profile of the web is an important feature of the invention. In the practice of the invention, the paper making machine is looked upon as producing a plurality of narrow longitudinal strips or tracks which nevertheless are integral and taken together make up the entire width of the web. Consequently, it is necessary to sample each strip. I prefer strips 6 inches wide but the width may be greater or less. In order to obtain a true indication of the exact nature of the profile of the web being produced, the interpretation should be based upon the average of a number of samples. In practice I take advantage of the fact that four or five samples from the four or five outer turns of an ordinary reel cover all phases of the 5 second cycle. The number of turns to be sampled and the length of each sample may be suited to fit the conditions in any mill. I prefer to employ eight samples but a greater or smaller number may be employed, the essential being to obtain an average which is representative of the average of each of the reoccurring cycles of 5 to 8 seconds duration.

My preferred method of sampling, suitable for either research or control, to determine the hills

and valleys is the following. Periodically, for example once every 24 hours, tear across the entire width of a reel of paper a narrow strip simultaneously from each of the eight outer convolutions and discard. This is merely to provide access to the eight outer convolutions. These eight superimposed sheets then are folded simultaneously to form a crease line across the reel near the torn edge and are torn along the crease line to form a smooth edge. A multiple sample is removed from the superimposed sheets by tearing along a crease line parallel to and about twenty inches from the smooth edge. The twenty inch dimension is reduced to 18 inches by trimming to provide a multiple sample containing eight superimposed sheets having 18 inches as one dimension and the width of the reel as its other. It then is cut in the longitudinal direction of the web into strips 6 inches wide to provide a plurality of multiple samples each containing eight superimposed sheets 6 by 18 inches which equals the area of the common 24 by 36 inch (24/36 500) sample and may be weighed on the customary ream scales. The eight sheets in each sample from the eight outer convolutions of the reel averages the flash variations in basis weight. If the edges of the reel have been trimmed, the edge samples will be slightly less than 6 inches wide and their weights may be adjusted by interpolation.

In this method of sampling, the size of the samples may be changed to adapt them to be weighed upon any customary ream scales. Thus, instead of samples 18 inches long slightly longer samples may be used so that the combined area of the eight sheets in each multiple sample is 950 instead of 864 square inches if 25/38 ream scales are used.

Figs. 20 to 23 are diagrams representing the range of flash variations in basis weight under different conditions. In each of these figures the ordinates represent number of tracks and the abscissas represent the range per track of flash variations in basis weight in pounds. Fig. 20 is typical of the flash variations in a web of paper produced in a machine having a head box of the type illustrated in Fig. 4 before being modified in accordance with the invention, that is, without the partition P and without the baffles B' and B''. The test involved 360 feet of the web representing 43 seconds machine running time. This was divided into longitudinal tracks six inches wide. Each track was divided into 30 samples 12 feet long. The difference between the maximum and minimum flash variations in basis weight in each track was noted. As indicated by the points encircled in Fig. 20 this difference was as great as 3.5 lbs. for one track and was considerably more than 2 lbs. for the majority of the remaining tracks.

Fig. 21 is typical for the same machine with the partition P in position as shown in Fig. 4 but without the baffles B' and B''. This test also involved 360 feet of the web which in this case represented 36 seconds machine running time. The 360 feet of the web was divided into the same number of samples for each 6 inch track. As indicated by the points encircled the difference between the maximum and minimum flash variations in basis weight for most of the tracks was between 1 and 2 lbs.

Fig. 22 is typical of the flash variations in a machine having a head box of the type shown in Fig. 3 with the partition P' in position as indicated but without the baffles B. The test involved 360 feet of paper representing 43 seconds machine running time. This was divided into 30 samples 12 feet long for each 6 inch track. As indicated by the points encircled the difference between the maximum and minimum flash variations in basis weight for all of the tracks was between 1 and 2 lbs. and comparable with the showing in Fig. 21.

Fig. 23 is typical of the flash variations in a machine of the type shown in Fig. 3 with the partition P' and baffles B in position as indicated and with the baffles in neutral positions. This test involved ten sets of samples, one set from each of ten reels of paper produced over a period of about nine hours. Thus, there were 10 samples 12 feet long from each 6 inch track. As indicated by the points encircled the difference between the maximum and minimum flash variations in basis weight for all the tracks was considerably less than 1.0 lb.

The typical flash variations in basis weight under the different conditions and in different machines as indicated in Figs. 20 to 23 illustrate the contribution of the partitions P and P' and the baffles B, B' and B'' in quieting the dynamic hydraulic flow and reducing the magnitude of flash variations. The showings of Figs. 20 to 23 are typical and, of course, corresponding data will vary slightly with different profiles of different webs of paper. As previously pointed out the more nearly level the profile the less is the magnitude of the flash variations.

While my investigations have been confined to the Fourdrinier type of machine, I believe that the same general principles apply to the cylinder type machine.

Of course, in the practice of the present invention, the consistency of the pulp stream should be tested periodically by any conventional method and should be maintained as uniform as possible. I prefer to test for consistency by the following method. Cut a narrow strip from each reel the full width of the web. Thus, if the web is 132 inches wide, this strip should be 132 inches by a little more than 7 inches. This strip then is trimmed on a guillotine cutter to equal the area of the usual 24 by 36 inch sample. Each trimmed strip is weighed and the weights plotted on a chart as a permanent record.

The advantages resulting from the production of paper having such a small variation in basis weight as is made possible by the invention are many in all parts of the paper industry. For example, my research has shown that a ± 0.5 lb. tolerance in basis weight effects major cost reductions on printed waxed bread wrappers of 25%, in ink, 20% in wax, 40% in waste and 20% in machine time. The invention reduces many of the limitations affecting the speed at which the paper making machinery may be operated. Thus, the drying time limitation may be reduced because there are no deep hills to dry out. The wet web is stronger because there are no deep (weak) valleys and, consequently, the web may be moved at a greater speed. Because of the greater uniformity in basis weight, the moisture content is more uniform and a higher moisture content is permissible. I have found that the moisture content may be increased by at least 2 per cent, thus reducing rewinding and also calender cuts and calendar cut breaks or other breaks at either end of the paper machine or on customer printing presses or other converting machines. The greater uniformity of the web produced by the practice of the invention, due principally to

its greater strength in the wet condition, makes possible a reduction of about 20 per cent in the amount of sulfite required to hold the wet sheet together. Mullen tracks much as basis weight tracks. Poor formation (low Mullen) seems to be related to hills and valleys. Leveling hills and valleys improves the strength of the sheet.

The advantages derived from the practice of the invention are illustrated further in the production of very heavy paper of 97 lbs. basis weight used for the International Business Machine tabulating cards about 3.5 by 7 inches. In such paper the magnitude of the flash variations is slightly greater than in the 32 lb. paper. Prior to the present invention, difficulty has been experienced due to bad cards which are porous, absorb moisture on damp days, and expand in thickness and jam the machines. The porosity is due to the presence of valleys or light weight flash variations which are not compressed by the heavy steel calender rolls, the latter being held up by the hills. Leveling hills and valleys reduces the magnitude of the flash variations and makes possible setting specifications for basis weight, caliper, bulk and moisture so that the lightest paper will always be sufficiently compressed. Prior specifications permitted 4.5 to 6.5 per cent moisture and caliper of 0.0062 to 0.0072 inch. Paper produced by the practice of the invention permits specifications of moisture of 7 to 9 per cent and caliper of 0.0062 to 0.0068 inch only and thus overcomes the difficulties previously encountered with tabulating cards due to expansion in thickness.

In my method of sampling paper, the length of the individual samples longitudinally of the web is not particularly critical. I use 18 inches from each of the eight outer turns of the reel because this provides a sample size suitable for weighing on scales most commonly available in paper mills. I find that the results obtained check within 0.1 lb. the average obtained with my research method using 72 feet in six 12 foot lengths. Instead of the 18 inch length I might use samples one-half as long or considerably longer but different more accurate scales would be required for weighing.

I claim:

1. In a machine for producing a web of paper having a head box adapted to discharge a stream of an aqueous pulp suspension upon a moving screen to form a web, the combination therewith of means in close proximity to the region of said discharge providing a shallow passage adapted to direct said suspension toward said region of discharge, a plurality of baffles, means for supporting the baffles in the head box close to the bottom thereof between said passage and said region of discharge and in spaced relation transversely of the head box and substantially perpendicular to said bottom for separate rotative movement about axes substantially perpendicular to said bottom, and means for holding each of said baffles in a desired angular position, said plurality of baffles being positioned between said means providing a shallow passage and said region of discharge.

2. In a machine for producing a web of paper having a head box adapted to discharge a stream of an aqueous pulp suspension upon a moving screen to form a web, the combination therewith of means in close proximity to the region of said discharge providing a shallow passage adapted to direct said suspension toward said region of discharge, a plurality of narrow elongated baffles, means for supporting the baffles in the head box close to the bottom thereof between said passage and said region of discharge and in spaced relation transversely of the head box and with their narrow dimension substantially perpendicular to said bottom for separate rotative movement about axes substantially perpendicular to said bottom, means for holding each of said baffles in a desired angular position, and a second set of a plurality of baffles supported in said head box between said passage and said region of discharge to extend substantially in the longitudinal direction of the head box and with the bottom edge of each at substantially the same depth as the top edges of the first mentioned baffles.

3. In a machine for producing a web of paper having a head box adapted to discharge a stream of an aqueous pulp suspension upon a moving screen to form a web, the combination therewith of a partition in the head box extending transversely thereof with its bottom edge spaced from the bottom wall of the head box to form a shallow passage in close proximity to the region of said discharge, a plurality of baffles, means for supporting the baffles in said head box in said suspension close to the bottom of the head box between said partition and said region of discharge and in spaced relation transversely of the head box and substantially perpendicular to the bottom thereof for separate rotative movement about axes substantially perpendicular to said bottom, and means for holding each of said baffles in a desired angular position.

4. In a machine for producing a web of paper having a head box adapted to discharge a stream of an aqueous pulp suspension upon a moving screen to form a web, the combination of a partition in the head box extending transversely thereof with its bottom edge spaced from the bottom wall of the head box to form a shallow passage in close proximity to the region of said discharge, a plurality of narrow elongated baffles, means for supporting the baffles in said suspension in said head box close to the bottom of the head box between said partition and said region of discharge and in spaced relation transversely of the head box and with their narrow dimension substantially perpendicular to the bottom thereof for separate rotative movement about axes substantially perpendicular to said bottom, means for holding each of said baffles in a desired angular position, a second set of a plurality of baffles supported in said head box to extend substantially in the longitudinal direction of the head box and with the bottom edge of each at substantially the same depth as the top edges of the first mentioned baffles.

5. In a machine for producing a web of paper having a head box adapted to discharge a stream of an aqueous pulp suspension upon a moving screen to form a web, the combination therewith of means in close proximity to the region of said discharge for directing said suspension toward said region, a plurality of narrow elongated baffles, means for supporting the baffles in the head box close to the bottom thereof between said directing means and said region and in spaced relation transversely of the head box and with their narrow dimension substantially perpendicular to said bottom for separate rotative movement about axes substantially perpendicular to said bottom, means for holding each of said baffles in a desired angular position, and a plurality of baffles in said head box supported between said directing means and said region to extend substantially in the longitudinal direction

of the head box and with the bottom edge of each at substantially the same depth as the top edges of the first mentioned baffles.

6. In a machine for producing a web of paper having a head box adapted to discharge a stream of an aqueous pulp suspension upon a moving screen to form a web, the combination therewith of web-leveling means positioned in the head box for effecting changes in the flow of said stream before it reaches said screen, said leveling means comprising a plurality of narrow elongated baffles in the head box close to the bottom thereof in close proximity to said region of discharge and in spaced relation transversely of the head box and with their narrow dimension substantially perpendicular to the bottom of the head box for separate rotative movement about axes substantially perpendicular to said plane, means for holding each of said baffles in a desired angular position, and a second set of a plurality of baffles supported in said head box to extend substantially longitudinally thereof and with the bottom edge of each at substantially the same depth as the top edges of the first mentioned baffles.

7. In a machine for producing a web of paper having a head box adapted to direct a stream of pulp suspension upon a movable screen to form a web, the combination therewith of web-leveling means positioned in the head box for effecting changes in the flow of said stream before it reaches said screen, said leveling means comprising two sets of a plurality of baffles, means for supporting the baffles of each set in said suspension in said head box opposite a bottom portion of said head box and in spaced relation transversely of and substantially perpendicular thereto, each of the baffles of one set extending substantially in the longitudinal direction of movement of the web and being positioned closely adjacent the baffles of the other set, the supporting means for said other set permitting separate rotative movement of each baffle about an axis substantially perpendicular to the direction of movement of the web, and a holding device for securing each of the baffles of said other set in a desired angular position with respect to one another whereby each baffle of said other set in a first region of the stream corresponding to a valley portion of the web may be adjusted angularly to cause pulp to be drawn from a second region of the stream corresponding to a hill portion of the web and each baffle of said other set in said second region may be angularly adjusted to control the amount of pulp drawn from said second region into said first region, there being a baffle of each of said sets in each of a plurality of narrow adjacent longitudinal portions of the stream.

8. In a machine for producing a web of paper having a head box adapted to direct a stream of pulp suspension upon a movable screen to form a web, said head box having means for adjusting the flow of the stream to change the character of the profile of the web produced, the combination therewith of web leveling means positioned in the head box for effecting changes in the flow of selected portions of said stream before said stream reaches said screen, said leveling means comprising a plurality of baffles, means for supporting the baffles in said suspension in the head box in close proximity to a bottom portion of the head box and in spaced relation transversely of and substantially perpendicular thereto for separate rotative movement about axes substantially perpendicular thereto, and a holding device for securing each of said baffles in a desired angular position with respect to one another, said baffles being arranged for positioning in each of a plurality of narrow adjacent longitudinal portions of the stream whereby each individual baffle in a first region of the stream corresponding to a valley portion of the web may be adjusted angularly to cause pulp to be drawn from a second region of the stream corresponding to a hill portion of the web and each individual baffle in said second region of the stream may be angularly adjusted to control the amount of pulp drawn from said second region into said first region.

9. A machine as described by claim 8 having means for adjusting the position of each of said baffles to locate them at desired elevations in said suspension.

10. A machine as described in claim 8 in which said supporting means includes a separate supporting member secured to each baffle to rotate therewith.

11. In a machine for producing a web of paper having a head box adapted to direct a stream of pulp suspension upon a movable screen to form a web, the combination therewith of web leveling means positioned in the head box for effecting changes in the flow of selected portions of said stream before said stream reaches said screen, said leveling means comprising a plurality of separately adjustable and transversely spaced means in said suspension inside the head box in close proximity to a bottom portion of the head box and in a first region of the stream corresponding to a valley portion of the web adapted to be adjusted to cause pulp to be drawn from a second region of the stream corresponding to a hill portion of the web, and a plurality of separately adjustable and transversely spaced means in said supension inside the head box in close proximity to a bottom portion of the head box and in said second region adapted to be adjusted to control the amount of pulp drawn from said second region into said first region.

12. A machine as described by claim 11 having an adjustable slice.

13. A machine as described by claim 8 in which each of said baffles is a narrow elongated baffle with its narrow dimension perpendicular to the bottom of the head box, said machine having a second baffle supported in the suspension in the head box to extend in the longitudinal direction thereof in each of said narrow adjacent longitudinal portions of the stream with its bottom edge at substantially the same depth as the top edges of the first mentioned baffles.

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