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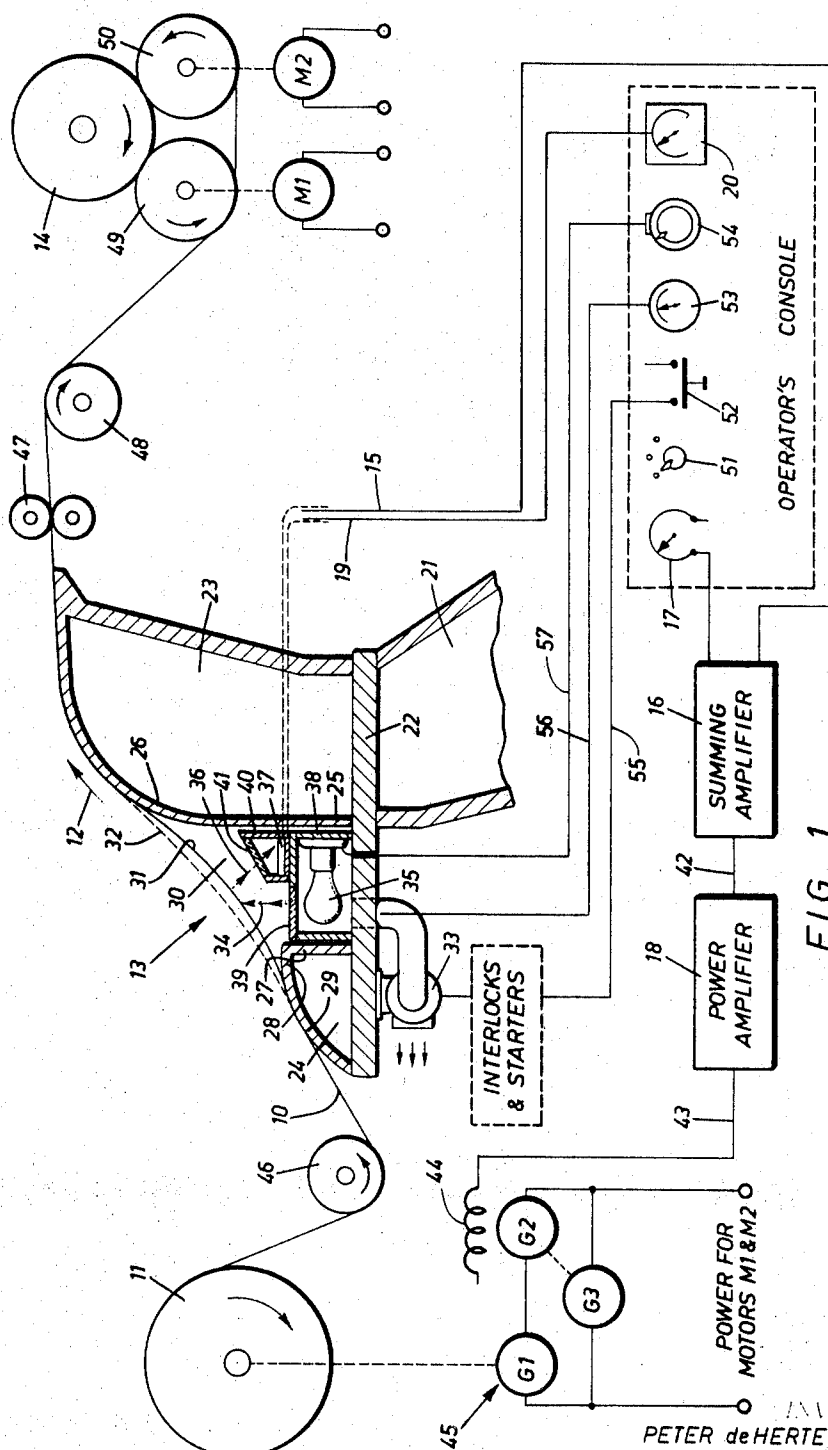
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3,472,439

APPARATUS FOR CONTROLLING WEB TENSION

Filed Jan. 22, 1968

2 Sheets-Sheet 1



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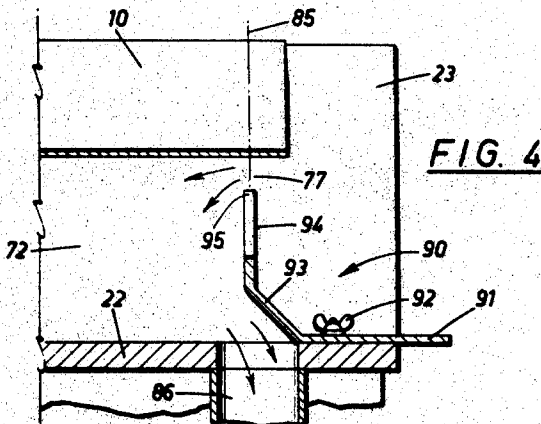
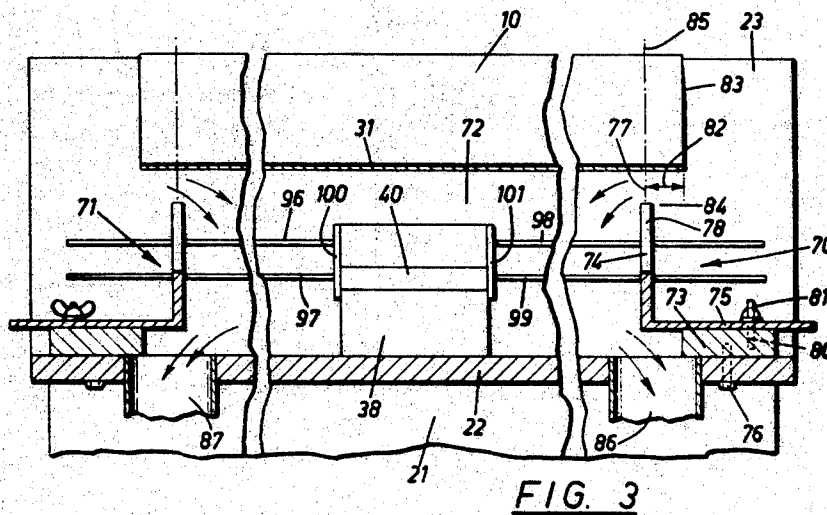
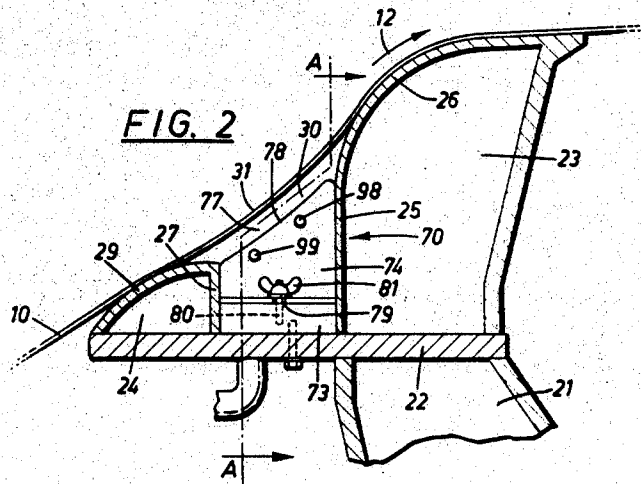
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APPARATUS FOR CONTROLLING WEB TENSION
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981,504

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5 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus for controlling tension in a moving web of paper has an open ended channel from which air is exhausted for drawing a loop in the web. A pair of end stops located in the channel at the edges of the web block air flow along the channel in under the loop. Each stop has a base mounted in the channel for adjustment therealong and a wall extending across the channel but spaced a short distance from the loop to allow for variations in loop depth. The walls are set in from the edges of the web so that a narrow strip along each edge of the web is at atmospheric pressure and therefore free from the pull that the vacuum exerts on the web in drawing the loop.

This invention relates to apparatus for measuring the tension in a moving web of a pliable material such as paper, and in particular to a vacuum device used for drawing a shallow loop in the web through which the tension is measured by electro-optical means.

United States application for patent, Ser. No. 594,721, filed Nov. 16, 1966, now Patent No. 3,379,390, Eastcott, describes apparatus for measuring the tension in a rapidly moving web of a pliable material such as paper. In this apparatus, a shallow loop is drawn in the web by means of vacuum at a relatively constant pressure a little below atmospheric pressure. By keeping the pressure constant the curvature of the loop is made to change with changes in web tension. It is measured by directing a beam of light onto the outer curved surface of the loop at an acute angle to the surface so that some of this light is reflected by the surface in another direction onto an array of solar cells which generate an electrical signal varying in strength with the light striking the cells. Since the light reflected onto the cells varies with loop curvature, the electrical signal represents web tension, and is therefore suitable for tension control purposes.

A loop forming device constructed as taught in the above-identified application consists essentially of a relatively long and narrow channel having a bottom wall and a pair of side walls which terminate in outwardly curved guide surfaces. The channel is of constant width throughout its length, is longer than the widest web that the apparatus can handle, and is located at one side of the web transversely thereof with the guide surfaces against the web and the ends of the channel extending beyond both edges of the web. Vacuum of a relatively constant air pressure a little below atmospheric is applied in the channel by suction means in communication with the channel through a pair of ducts in its bottom wall near the ends of the channel, whereby a length of web is drawn a little way into the channel through its open side in the form of a shallow loop beginning and ending on the guide surfaces and extending uniformly all the way across the web.

In order for the vacuum to hold the loop in the channel, it is necessary to block the free flow of air into the channel at the edges of the web by means of end stops.

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This has been done in two ways, namely, by the use of a pair of end walls extending above the loop near the edges of the web, or by the use of plugs resting in the channel under the loop at the edges of the web. Both types of members must be free of the moving web at all times and adjustable for webs of different widths. They are set so that a controlled amount of air enters the channel through the free spaces between the members and the edges of the web. The plugs have been preferred because a particular setting allows for variations in web movement and width. Frequently webs handled by this apparatus have bad edges which are trimmed off before the web becomes a finished product. Bad edges appear for different reasons: they may be left in the edges of the web during manufacture thereof as weak or very thin spots, or as ragged edges; or they may be caused by careless handling or poor storage of the roll and appear as cracks in the end of the roll or as frayed areas. With the use of either end walls or plugs, the full width of the web, including its bad edges, is subjected to the pull exerted by the vacuum on the web for loop formation. As a result, edges which are already bad may be degraded even further by the vacuum rupturing the weak spots or tearing the ragged and cracked regions. If this happens, wider strips than otherwise necessary must be trimmed off the edges of the web, resulting in more waste than otherwise necessary.

The object of this invention is to provide improved end stops for use in the aforementioned loop forming equipment, end stops which control the air flow into the channel at the edges of the web and yet relieve the edges of the web from the pull exerted by the vacuum on the web for loop formation.

The improved end stops are constructed in such a way that a narrow strip along each edge of the web in the loop is maintained at atmospheric pressure while the remainder of the web in the loop is maintained under suction of a relatively constant air pressure a little below atmospheric pressure. This relieves the edges of the web of the pull of the suction. An end stop constructed according to the invention has a base resting on the bottom of the channel and a wall mounted on the base and standing upright in the channel to a point very near the under surface of the loop. This structure blocks air flow along the channel into the cavity under the loop except for a controlled flow between the loop and the adjacent edge of the wall. The wall is set in from the edge of the web under the loop, and enough air space is left outside the wall under the web that a strip along the edge of the web is in the ambient air and therefore free from the pull of the suction.

The nature and function of the invention will now be dealt with in more detail with reference to the accompanying drawings, in which:

FIGURE 1 is a diagram of a system for regulating the tension in a moving web;

FIGURE 2 is an end view of the tension detecting assembly used in FIGURE 1 and showing an end stop in the channel;

FIGURE 3 is a cross section taken along A—A of FIGURE 2; and

FIGURE 4 is a view like FIGURE 3 of another end stop configuration.

A closed loop regulating system in which the novel end stops can be used will now be described with reference to FIGURE 1. In this figure there is shown a system for regulating the tension in a web 10 of a pliable material such as paper released from a roll 11 and advanced at high speed over a tension detecting assembly 13 in the direction 12 onto a roll 14. An electrical signal obtained in assembly 13 representing web tension is fed via line 15 to a summing amplifier 16 where it is summed

algebraically with an electrical signal set by a rheostat 17. The signal set by the rheostat, in this instance manually by the operator, is a reference representing the particular web tension wanted, and the signal from the tension detecting assembly is a feedback signal which initiates any corrective action necessary to hold web tension within the tolerances of the value set by the rheostat. After summation and amplification at 16, the combined signal is further amplified in power amplifier 18 and thereafter applied to control the tension in the web as it advances from roll 11 to roll 14 in a way to be described later. Another electrical signal also representing web tension and obtained in assembly 13 is fed via line 19 to a meter 20 which is calibrated to read web tension directly in pounds per lineal inch of web width. This meter tells the operator what the measured value of web tension actually is at any particular moment.

Assembly 13 is a structure of the type described in the aforementioned patent application. It consists essentially of a pedestal 21 mounted on a foundation and supporting a flat, horizontal base plate 22 on which there is mounted a draw table 23 directly above the pedestal and a guard board 24 spaced to the left of the table. The table has a wall 25 rising vertically from the base plate and then curving to the right at 26; the guard board has a similar wall 27 spaced to the left of wall 25 and also rising vertically from the base plate but to a lower point 28 where it makes a right angle turn to the left and then curves downwardly at 29. Walls 25 and 27 and plate 22 define a channel 30 in the form of a trough open at both ends. The channel is located transverse to the web with its open side facing the web, and it has its open ends closed at the edges of the web by means of the novel end stops to be described later. These stops have been omitted from FIGURE 1 in the interest of drawing clarity.

The guard board and draw table are adapted to allow web 10 to be drawn freely over them as illustrated with a shallow loop such as that indicated at 31 or 32 drawn into channel 30 by means of suction at a pressure a little below atmospheric applied in any known way, as for example, by means of an exhaust fan at each end of the box having its intake in communication with channel 30 near the end stops; one of these fans is illustrated at 33. The end stops are located under the web at the edges thereof so as to minimize the amount of air drawn in the channel at the ends of the loop. Curved surfaces 29 and 26 guide the web into and out of the loop, maintaining it in the proper relation to the stops.

For any given pressure of the suction in the channel, the curvature of the loop, i.e., radius of curvature or depth of the loop, is an indication of the tension in the web; hence, by holding the pressure reasonably constant a signal representing the tension in the web can be obtained. Fans 33 are a type which can be set to maintain a relatively constant air pressure in the channel a little below atmospheric even though the amount of air exhausted varies considerably. In the system illustrated in FIGURE 1, a beam of light 34 from lamps 35 is directed onto the under surface of the loop at an acute angle thereto. Some of this light is reflected as indicated at 36 down onto a light responsive device 37 located below the reflecting surface; the amount of light reflected will depend on the depth of the loop, the deeper the loop the less light falling on device 37. Lamps 35 are enclosed in an opaque box 38 supported on base plate 22 and having a transparent window 39 in its top side for light 34 to pass through from the lamps to the under surface of the loop. Device 37 is enclosed in an opaque box 40 resting on top of box 38 offset from window 39 and has a transparent window 41 in its top side for admitting the light 36 reflected from the under surface of the loop. In order to utilize a maximum of reflected light 36 for activating device 37, the inside surfaces of box 40 will be reflecting surfaces, and window 41 will be a clear glass window slop-

ing in the general direction of the loop. Device 37 may consist of a number of solar cells which generate electrical signal energy proportional to the lighting level in the enclosure. The cells are connected in such a way that the signal energy is divided in a set proportion between the amplifier and the meter. For example, a number of cells may be placed in a row transverse to the web with every other one of the cells connected in parallel and to meter 20 via line 19, and the remaining cells connected in series and to amplifier 16 via line 15. As the signal level from the cells is very low and readily affected by outside interference, shielded conductors are used at 15 and 19. In some cases, it may be necessary to insulate enclosure 40 from enclosure 38 so that the cells are not overheated by the lamps. The assembly of lamps and cells is supported on base plate 22 transversely of and in the middle of the web.

The electrical signal from device 37, representing the web tension measured in tension detecting assembly 13, is summed algebraically with a reference signal of the same character in summing amplifier 16, the reference signal coming from rheostat 17 and representing the tension that the system is set for. In the system illustrated, the signal from device 37 is DC of varying amplitude and the reference signal is DC. Since meter 20 is energized by a set proportion of the signal energy from device 37 and calibrated in pounds per lineal inch of web width, it gives a direct reading of web tension. After summation and amplification in amplifier 16, the combined signal is fed via line 42 to power amplifier 18 where it is amplified sufficiently to render it useful for web tension control purposes. In the system illustrated the output from amplifier 18 is fed via line 43 to an auxiliary field winding 44 of a booster generator G2 in the electrodynamic braking system 45 for the roll of paper 11 being unwound. Amplifiers 16 and 18 are both well known types.

As web 10 is withdrawn from roll 11, it passes under a roller 46, over tension detecting assembly 13, through a slit 47, over a roller 48, under rollers 49 and 50 onto roll 14. Rollers 46 and 48 guide the web over the tension detecting assembly and through the slit where the edges of the web are trimmed off and the web is cut into a number of strips. Actually, number 14 represents a number of rolls of web, one for each strip. These rolls rest on and are driven by rollers 49 and 50, the rollers which advance the web and wind it up into roll 14. Rollers 49 and 50 are driven by motors M1 and M2 respectively.

In advancing the web, motors M1 and M2 do so against braking torque applied to roll 11 by means of the electrodynamic brake 45. By utilizing the signal output from amplifier 18 in the electrodynamic brake to control the braking torque, it is possible to hold web tension relatively constant within predetermined limits. The electrodynamic braking system illustrated at 45 is a well known system wherein a generator G1 driven by roll 11 is connected in parallel with a main generator G3 and the power output therefrom supplied to motors M1 and M2. In such a system, the energy produced by braking is used to power the driving motors, and not simply wasted. The torque which generator G1 applies to roll 11 is controlled by means of a booster generator G2 driven by the main generator G3 and having its armature connected in series with the armature of generator G1. Generator G2 passes current through generator G1 of a polarity which causes the latter to apply torque to roll 11 at all roll speeds, even at standstill. The magnitude of this torque depends on the current passed, and the current passed depends on the excitation of booster generator G2. Therefore, by applying the output from amplifier 18 to a suitably designed exciting winding in the booster generator, the braking torque applied to roll 11 is, in effect, placed under the control of the regulating system.

In addition to rheostat 17 and meter 20, the operator's console has many other control devices, of which those

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necessary for the operation of the system illustrated are: a selector 51, a pushbutton 52, a vacuum gauge 53, and a voltage adjuster 54. Selector 51 is used to select a mode of operation from three positions, namely, "regenerative" in which none of the controls in the closed loop feedback system operate automatically, "indicate" in which the lamps and fans operate so that an indication of tension is given, and "automatic control" in which the fans and lamps operate and a corrective signal is applied in the system to keep web tension constant at a set level. Pushbutton 52 is used to start or stop the fan motors through a line 55 and a magnetic starter and interlocks. Gauge 53 is connected directly to the tension detecting assembly and gives a direct reading of the negative air pressure therein. Adjustor 54 is a means for adjusting the voltage of a constant voltage source, and it may be an adjustable constant voltage transformer or a regular constant voltage transformer in combination with an adjustable autotransformer. It is connected to lamps 35 through line 57 and used for setting the level of illumination from the lamps.

The end stops referred to above will now be described with reference to FIGURES 2 and 3 where they are identified by numerals 70 and 71. The two stops are of opposite hand but otherwise alike. They are located in the ends of the channel at the edges of the web so as to complete the definition of a cavity 72 under the loop 31 in the web. As indicated for stop 70, each has a base 73 resting on the bottom of the channel and a wall 74 standing upright in the channel transversely thereof on a foot 75 which rests on top of the base. The base illustrated at 73 is a rectangular block of a material such as wood fitting loosely into the bottom of the channel and secured therein for adjustment along the length of the channel so the suction assembly can be set to handle webs of different widths. A cap screw 76 is a simple way of securing base 73 to the channel structure. Wall 74 also extends across the channel from wall 25 to wall 27 as a clearance fit therebetween and rises from base 73 to a point a little below the loop so a small space 77 is left between the loop and the upper edge 78 of the wall. Foot 75 contains a longitudinal slot 79 (FIG. 2) extending from its outer edge to a point near wall 74. A stud 80 anchored in base 73 projects through this slot and has a wing nut 81 threaded onto its projecting end for securing the foot to the base. This slot is relatively long so wall 74 can be set over a wide range of positions along the channel. The base and the wall block off the channel except for the space 77 between the upper edge 78 of the wall and the loop in the web. In practice, any adjustments necessary to accommodate a web of a different width are made by moving the two end walls 74, the bases 73 remaining stationary until the walls reach their limits of adjustment, after which the bases can be relocated as well. Both end stops have a significant range of adjustment so that the tension detecting assembly will handle webs of many different widths.

It will be noted from FIGURE 3 that wall 74 is a relatively thin plate-like member that is set in a short distance 82 from the outer edge 83 of web 10. It will also be noted that there is considerable free space at 84 between the edge portion 82 of the web and foot 75. A relatively large space is left here so the air sucked into cavity 72 through space 77 between the web and the upper edge 78 of wall 74 does not exert an appreciable downward thrust on the edge portion 82 of the web outside the wall. In other words, the suction in cavity 72 has insignificant influence on the air pressure acting on web portion 82; this portion of the web remains in the ambient air, and it is therefore not in tension in the sense that the web inside the wall is. By keeping the narrow strip 82 at the edge of the web relatively free from the suction, weak spots which frequently appear in this strip do not rupture or bad edges, i.e., cracked or frayed edges, do not tear. This keeps the strip along edge 83, which will

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be removed from the web along line 84 as waste, as narrow as possible, usually from one to three inches in width. If the free space at 84 becomes too small, the suction drawing air through the space 77 between the web and the wall will exert a downward thrust on web edge portion 82, but since this is not wanted, the space is kept relatively large as illustrated in FIGURE 3.

The air evacuated from cavity 72 is drawn off through ducts 86, 87 in the bottom wall of the channel by means of the two exhaust fans mentioned earlier, one of which is shown at 33 in FIGURE 1. Referring again to end stop 70 in FIGURE 3, it will be seen that its base 73 overhangs duct 86, partially blocking the entrance to the duct. The extent of this blockage is very limited indeed, depending on the amount of air to be evacuated from cavity 72; in any event, it must not reduce the airflow to the point where the vacuum under the loop is impaired. In order to keep the duct open and yet have wall 74 located directly over it, base 73 is used to raise foot 75 far enough off the bottom of the channel that an adequate passage is left for air to flow into the duct. As pointed out earlier, stop 71 is exactly the same structurally as stop 70 except that it is of the other hand. Functionally, the two end stops are exactly the same; hence any comments made on the function of stop 70 apply equally well to stop 71.

Another configuration for the end stop is illustrated at 90 in FIGURE 4. In this configuration the separate base has been eliminated and the member shaped so that its foot becomes the base and rests directly on the bottom wall of the channel. Stop 90 may be bent into the shape illustrated from a flat metal plate. This configuration has a foot or base 91 secured to base plate 22 by means of a stud and wing nut assembly 92, an angle portion 93 which provides an airflow passage to duct 86, and an upright wall 94 which terminates in an edge 95 spaced below and conforming with the contour of the loop in the web. This stop also extends across the channel and is a loose fit therein so its position can be altered lengthwise of the channel a limited amount for purposes of adjustment. As with stop 70, stop 90 blocks the flow of air into the channel except for a controlled flow through the space 77 between the upper edge 95 of the wall and the loop in the web.

In many applications for tension detecting assembly 13, it is advantageous to equip the assembly with some means for stopping the loop from being sucked all the way down into channel 30 when roll 11 is finished or the web breaks. Once roll 11 is completely unwound, the web will break loose from the core of the roll, and as a result, it can no longer be held in tension by brake 45. Once the web is free of the brake, either through breakage or completion of a roll, some means to keep it from being drawn into the bottom of the channel can be very useful indeed. The end stops just described are readily adaptable for supporting guards which keep the loop in the loose web well up in the channel.

A simple form of guard is shown in FIGURE 3. It consists essentially of two or more rails placed in the channel lengthwise thereof under the loop a little below the upper edges of the walls of the end stops such that the loop sags down onto the rails when it becomes too long. In the embodiment illustrated, two pair of rods 96, 97 and 98, 99 are used as the guard; they are spaced apart in parallel at about the same distance below the loop and are spaced from the side walls of the channel parallel therewith. The rods do not pass over the light source or the light responsive device because, if they did, they could cast shadows detrimental to the measuring of web tension. A simple way of supporting the rods is to pass their outer ends through clearance holes in the walls of the end stops and secure their inner ends to the enclosures 38 and 40 for the lamps and light responsive device. The inner ends of rods 96 and 97 are secured to a plate 100 which in turn is secured to the left end walls of enclosures 38 and 40, and the inner ends of rods 98 and 99 are secured to a plate

101 which in turn is secured to the right end walls of enclosures 38 and 40. By fixing the structure 38, 40, 100 and 101 in cavity 72, the rods are held stationary while the end stops are readily movable as the holes therein for the rods are larger than the rods. This is a convenient arrangement in that it interferes very little with the adjustment of the end stops, and yet secures the rods against movement.

During the normal course of unwinding roll 11, slitting the web at 47 and then rewinding the strips into rolls 14 with selector 51 set for automatic control, the web moves at high speed over tension detecting assembly 13 where a loop is drawn in the web of a curvature or depth depending on web tension. This tension is effective in the entire loop except for a narrow strip along each edge where the web is relieved of the tension through the set-in walls of the end stops. These stops, in effect, keep the suction away from the narrow edge strips, leaving these strips under little or no tension so the bad spots in them are not degraded further by the suction. After leaving the loop, the edge strips are trimmed off the web in the slitter. If the web should break or the trailing end of the web be released from roll 11, the suction in the channel draws the loop down onto the guard rails, where it is held.

Since the vacuum acting on the web to form the loop is held at a constant air pressure, a little below atmospheric, the depth of the loop is proportional to tension. Hence the amount of light from the lamps reflected from the under side of the loop onto the solar cells will cause the cells to generate electrical signal energy of a magnitude representing web tension. The cells connected in parallel energize meter 20, causing it to give a reading visible to the operator of web tension in pounds per lineal inch of web width. The cells connected in series provide a signal for amplifier 16 representing the web tension measured. The amplifier compares this signal with a reference signal set by the operator on rheostat 17 to represent the tension he actually wants. After comparison and amplification at 16, the combined signal is amplified in amplifier 18 and then applied to field winding 44 of booster generator G2 for the control of the torque that generator G1 applies to roll 11.

As soon as roll 11 is completely unwound and its brakes fully applied, the vacuum in the tension detecting assembly shuts off automatically. Usually, the operator discontinues automatic control of tension a little before all the web is removed from roll 11 and completes the run through manual control, the changeover being made by turning selector 51 to the appropriate point. Starting a new roll 11 is also done under manual control, but before the vacuum is restored a reading of the lighting level in the tension detecting assembly is now possible while the web is drawn taut straight across the guard board and the draw table. With the web normally, in a loop now a flat reflecting surface, the light activating the solar cells gives a reading on meter 20 which can be used to check the lighting level against a standard established for the surface finish for that particular web. This reading may appear as a red mark on the face of the meter opposite which the pointer of the meter rests when the lighting level is as it should be. If the level is either too high or too low, the pointer will be off the mark, and the level can then be reset by turning the knob on voltage regulator 54 to raise or lower the lamp voltage as necessary. When satisfied with the lighting level, the operator depresses button 52 to start the fans and thereby restore the vacuum in the tension detecting assembly. He will now return the system to automatic control of tension and observe the vacuum gauge to ensure that the vacuum settles down at the required pressure. Once the system is

back on automatic control, the operator will glance periodically at meter 20 and gauge 53 to satisfy himself that the tension and the vacuum are what they should be.

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

1. Suction apparatus for holding a shallow loop in a web of a pliable material such as paper while the web is advanced at high speed, said apparatus comprising an elongated channel open at one side and having a bottom wall and a pair of uniformly spaced side walls, each of which terminates in a web guide surface at said open side, said channel being located at one side of the web transversely thereof with its ends extending beyond the edges of the web and with said guide surfaces touching the web; means for applying suction in said channel at a pressure a little below atmospheric for sucking a shallow loop of web into the channel through said open side, said loop extending uniformly across the web and beginning and ending on said guide surfaces; a pair of end stops located in the channel at the edges of the web for blocking the flow of air into the channel at said edges, said stops being adjustable lengthwise of the channel for adapting the apparatus to accommodate webs of different widths; each one of said stops consisting of a base resting on the bottom of the channel and a relatively thin and high end wall standing upright on the base transversely of the channel and set in under the loop a short distance from the edge of the web, said end wall having opposite edge portions adjacent said side walls and an intermediate edge portion of the same general outline as the profile of the loop spaced therefrom so as to leave a passage for a controlled amount of air to be drawn into the channel, except for said controlled flow said end stop blocking airflow in said channel, the height of said end wall being great enough that considerable free space remains outside the wall under the overhanging edge of the web so said controlled airflow exerts very little loop forming pull on said overhanging edge; and means for releasably securing said end stops in the channel.

2. The apparatus defined in claim 1 wherein the air is withdrawn from the channel through a pair of ducts in its bottom wall, one near each end of the channel, and wherein each end stop is located in the channel outside the duct with its base at the entrance to the duct and its end wall spaced above the entrance to the duct.

3. The apparatus defined in claim 1 wherein said base is a separate member located in the bottom of the channel and secured to the channel for adjustment along its length and wherein said end wall has a foot resting on the base and secured thereto for adjustment along the length of the channel.

4. The apparatus defined in claim 1 wherein said end stop is a single member having a base resting in the bottom of the channel and secured to the channel for adjustment along its length, an angular portion projecting upwardly from the base, and an end wall standing upright on the angular portion.

5. The apparatus defined in claim 1 wherein at least two guard rails are located in the channel lengthwise thereof under the loop spaced therefrom and supported on the end stops.

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