Oct. 30, 1962 L. A. MOORE ETAL 3,060,843

CALENDER STACK DEFLECTION CONTROL

Filed Nov. 9, 1961 2 Sheets-Sheet 1

Fig. 1

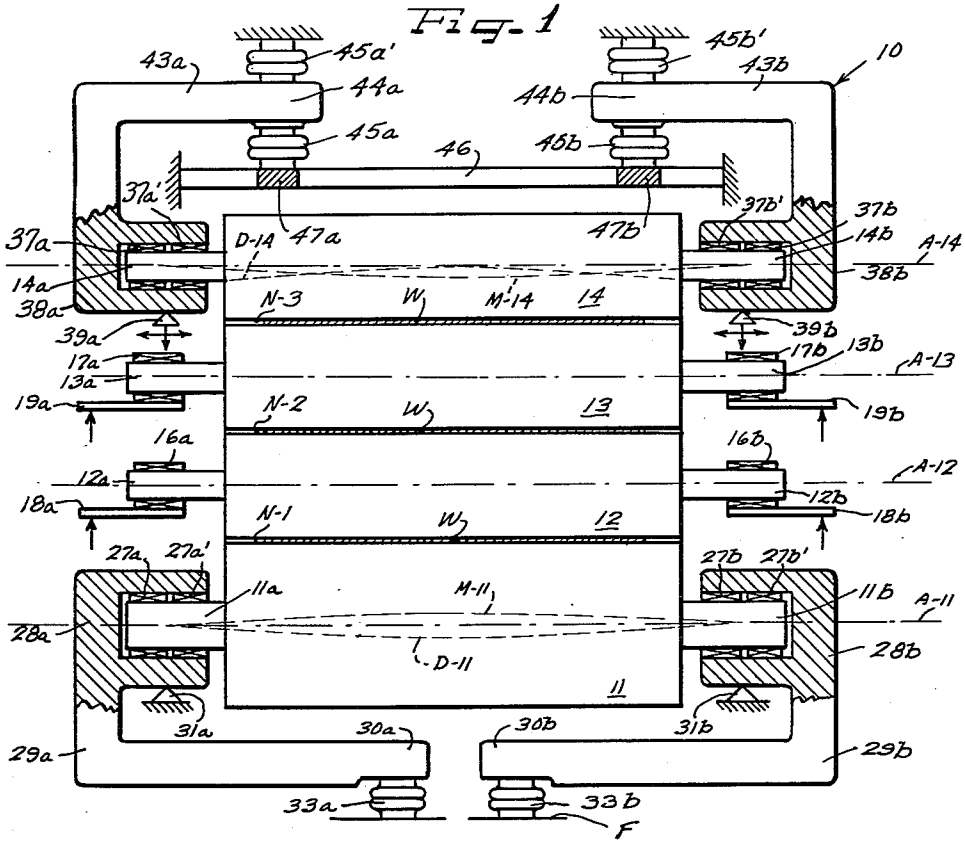


Fig. 2

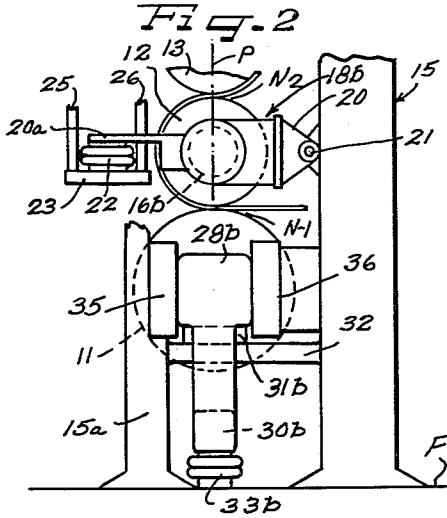
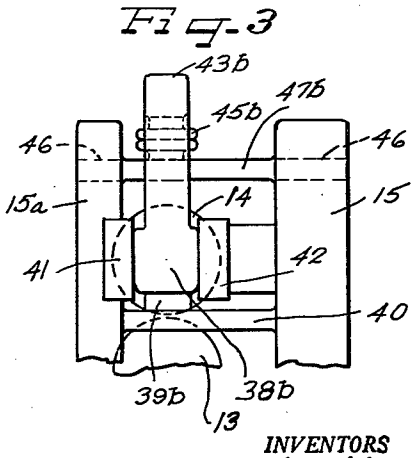


Fig. 3



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Fig. 4

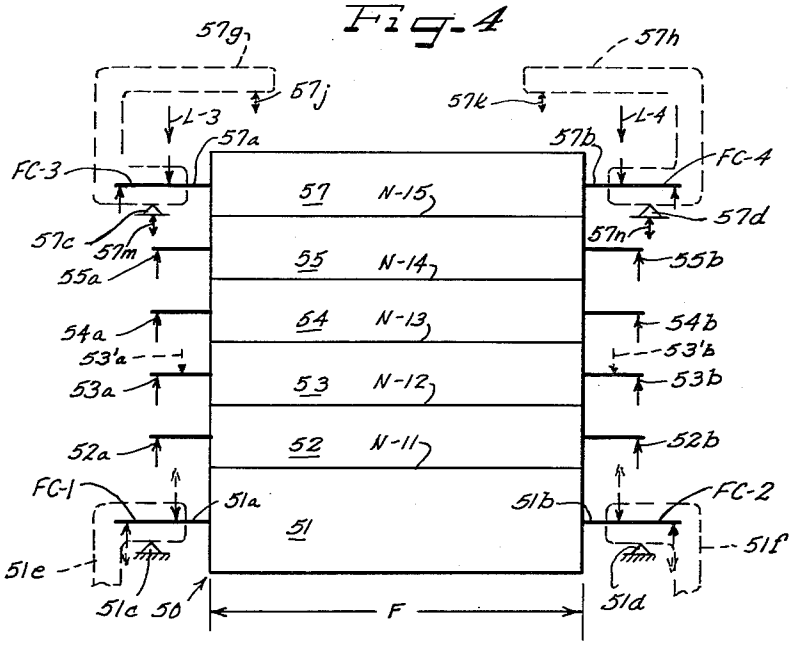
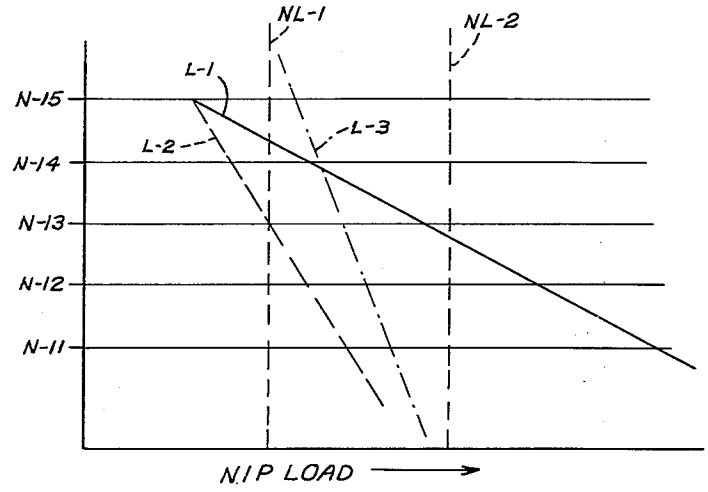


Fig. 5



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CALENDER STACK DEFLECTION CONTROL

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20 Claims. (Cl. 100—41)

The instant invention relates to the portion of the paper machine known as the calender or calender stack, and more particularly, to an improved multi-nip calender.

Although the invention may have utility in a number of fields involving the pressing, smoothing, ironing or the like treatment of a strip of flexible material, including the various calenders used in a number of fields, a specific preferred use is in the paper machine calender. The operation of the calender in a paper machine is well known and understood in the art. The purpose of the calender stack is to compact the paper to some extent and give it a fine smooth finish. This effect is obtained on both sides of the paper by the use of friction and pressure. The calender stack comprises a plurality of conventionally upright or vertically aligned calender rolls, which may be thought of as lying in a generally vertical plane (i.e., the generally vertical plane defined by the nips of the calender). Although calenders are known wherein the rolls are not stacked in exact vertical alignment and the principles of the instant invention are readily applied to such calender arrangements, the conventional calender arrangement and the one preferred for use in the practice of the instant invention does involve vertically stacked rolls and the invention will be described primarily in connection with this type of calender (although rolls could be horizontally aligned or aligned in other non-vertical arrangements).

In the conventional vertically aligned calender stack, the lowest or bottom roll of the stack is driven mechanically and it, in turn, drives the roll immediately thereabove, and so on, by friction. There is a certain amount of work between these rolls and the result is that there is a substantial amount of work performed on the paper as it passes through each of the calender nips. The paper web is directed first to the top roll of the stack and it passes either over the top roll and through the top nip or directly through the top nip from which it follows the next roll down to the next nip and is transferred thereon to the surface of the third roll and so on, until the web passes through the bottom nip between the bottom or king roll and the roll immediately thereabove.

In most instances, efficient calendering of paper requires a relatively large number of nip treatments at relatively low pressures or at pressures at least sufficiently low to prevent crushing of the paper while ironing it smooth. In general, the rolls are so mounted in the ordinary calender that the entire weight of each roll rests on the roll therebelow. This is accomplished by mounting the roll so as to permit limited vertical movement. The full weight of a plurality of heavy rollers is thus applied to the paper web passing through the bottom nip in the stack; and the bottom or king roll is usually formed with a slight "crown" or enlarged cross-sectional area at the middle thereof in order to compensate for the deflection of the king roll downwardly which is brought about by the application of the weight of the rolls thereabove to the king roll.

The correlation of the various nip loads in order to obtain a desired result in present-day calenders presents a number of problems, some of which are not fully understood, some of which remain unsolved, and some of which have been at least partially solved. For example, one source of uneven nip pressure resulted from the fact that the superimposed rolls in the stack carry very heavy bearings at opposite ends thereof and these bearings were so heavy that they tended to bow the ends of the superimposed rolls downwardly and create excessive nip pressures along the edges of the web passing through nips defined by these rolls. A solution to the problem is presented in Hornbostel U.S. Patent No. 2,850,952, wherein means are proposed for urging these bearings upwardly to relieve the effect of the excessive bearing weights on the individual rolls.

Another problem which has been diligently studied by a number of workers in the prior art relates to the deflection that is produced in the king or bottom roll as a result of the overall load applied thereto. This deflection of the centroidal axis of the bottom roll would ordinarily result in a downward dip in the middle of this roll, if the roll were supported at opposite ends by conventional bearings and was formed with a substantially uniform diameter throughout its length. To compensate for this downward dip, the bottom rolls are conventionally crowned or formed with a slightly enlarged diameter in the middle portion thereof. Under certain sets of operating and force conditions, such a crown may serve to effect a substantially uniform nip pressure across the full width of the nip defined by the bottom roll and the roll immediately thereabove, but the operation of most calender stacks requires a number of variations in loading and loading conditions, such that a given crown on the ring roll (which crown is fixed) will not be satisfactory for all operating conditions.

In order to compensate for this type of deficiency in the flexibility of operation of the bottom roll, Shapiro U.S. Patent No. 2,897,538 suggests the application of a bending moment to the bottom roll ends using pairs of bearings to mount opposite ends of the roll, with one bearing of each pair being fixed in position and the other being carried by a lever arm actuated by means moving generally parallel to the axis of the roll for applying a bending moment to the end of the roll. Goulding U.S. Patent No. 2,611,150 also shows the use of a pair of bearings to rotatably receive a shaft at one end of a roll for the purpose of applying a force couple thereto, wherein one of the bearings is fixed and the other movable, although Goulding is concerned primarily with a plastic sheeting device.

One aspect of the instant invention resides in an arrangement for applying a bending moment to the ends of rolls in a calender or related device which does not involve the application of a so-called "end load" to the bearings carrying the roll. In other words, the force couple is applied to a given roll shaft at a specific location in the calender stack by the use of a pair of bearings, but this pair of bearings is mounted in a housing which is capable of tilting movement for applying the couple without subjecting the bearings to any significant "end load" or load applied generally parallel to the axis of the shaft, which type of load is undesirable from the point of view of wear on the bearings.

Another particularly significant aspect of the instant invention resides in the concept of correlating the mounting of all or most of the bearings carrying the roll ends in a calender stack in such a manner that predetermined desirable nip loads may be maintained throughout the entire length of each of the nips in the stack. This correlation of the overall nip load arrangement is effected by the

use in combination of means for relieving the weights for intermediate rolls in the stack combined with means for applying bending moments to both the top and bottom rolls in the stack in a predetermined manner. In particular, the instant invention contemplates the use of suitable means for applying a bending moment to the top roll in a calender stack so as to correlate nip pressure throughout the entire calender stack.

It is, therefore, an important object of the instant invention to provide an improved multi-nip calender stack assembly, with improved correlation of nip loads throughout the stack and throughout the width of the nips.

It is a further object of the instant invention to provide an improved mounting for the top roll of the calender stack for purposes of correlating nip loads throughout the stack.

It is another object of the instant invention to provide an improved mounting for a nip-defining roll by applying a force couple to end portions of the roll without applying an "end load" to the bearings.

Other and further objects, features and advantages of the present invention will become apparent to those skilled in the art from the following detailed disclosure thereof and the drawings attached hereto and made a part hereof.

On the drawings:

FIGURE 1 is an essentially diagrammatic illustration of a calender stack embodying the invention looking in the machine direction;

FIGURE 2 is an elevational view taken generally from the right side of FIGURE 1, showing a portion of the mounting for the bottom roll of the stack, with parts shown in section and parts shown diagrammatically;

FIGURE 3 is a view in elevation also taken generally along the right side of FIGURE 1 showing a portion of the mounting for the top roll of the calender, with parts shown in section and parts shown diagrammatically;

FIGURE 4 is a diagrammatic view of another calender stack embodying the invention, with forces applied thereto indicated by arrows; and

FIGURE 5 is a graph showing the nip loads at the various nips in the calender of FIGURE 4.

As shown on the drawings:

In FIGURE 1, a calender stack embodying the instant invention is indicated generally by the reference numeral **10** and this calender stack **10** comprises a bottom roll **11** and a plurality of superimposed rolls **12, 13, 14**, including the top roll **14**. As indicated in FIGURES 2 and 3, the calender **10** comprises a generally upright calender frame **15** in which the rolls **11, 12, 13** and **14** are mounted. The rolls **11, 12, 13** and **14** define therebetween nips **N–1, N–2, N–3** lying in a generally vertically aligned plane P (FIGURE 2) and through which passes the continuous web W in conventional manner.

As indicated diagrammatically in FIGURE 1, the intermediate superimposed rolls **12** and **13** (above the bottom roll **11** and below the top roll **14**) are provided with separate and indepenent bearings **16***a*, **16***b*, **17***a*, **17***b* rotatably carrying the ends **12***a*, **12***b*, **13***a*, **13***b* of these rolls **12** and **13**. In accordance with the teachings of Hornbostel Patent No. 2,850,952, separate and independent means, shown diagrammatically at **18***a*, **18***b*, **19***a*, **19***b*, are provided for each of the bearings **16***a*, **16***b*, **17***a*, **17***b*, respectively, for urging such bearings upwardly, to relieve the effect of the weight of these bearings **16***a*, **16***b*, **17***a*, **17***b* tending to bow the ends of the axes **A–12** and **A–13** for these rolls downwardly. As indicated in FIGURE 2, this may be accomplished by the use of an arm **20** mounted on a pivot **21** carried by the frame **15** and extending outwardly therefrom to receive the bearing **16***b* and then to engage at its terminal portion **20***a* suitable means for applying an upward force, in the form of a diaphragm **22** mounted on a stop **23** carried by fixed rods **25** and **26** vertically aligned. The fluid pressure actuated diaphragm **22** acts upon the arm **20** to counteract or overcome the load resulting from the weight of the bearing **16***b*.

It will be appreciated that the centroidal axes **A-11, A–12, A–13, A–14** of the rolls **11, 12, 13** and **14** are subject to deflection in response to various loads applied to these rolls and because of the very substantial length of these rolls in actual practice in paper machine calenders, this deflection gives rise to serious problems. Relieving the load of the bearing weights to minimize the tendency to deflect the ends of the roll axes **A–12** and **A–13** downwardly provides one element in the overall correlation of nip pressures, in accordance with the invention. Another aspect of the instant invention pertaining to the overall control and correlation of nip pressures resides in the concept of using separate and independent bearing means for rotatably carrying the ends of the bottom and the top rolls **11** and **14** on the frame **15** and applying a bending moment to each such roll end of effect a predetermined deflection in the roll axis **A–11** and/or **A–14** and thus a predetermined loading across all of the calender nips **N–1, N–2** and **N–3**.

As shown in FIGURE 1, at opposite ends of the bottom roll **11** there are shaft elements or stub shafts **11***a* and **11***b*. Allochiral pairs of bearings (shown diagrammatically as axially spaced bearing **27***a* and **27***a'* as the left hand pair and **27***b* and **27***b'* as the right hand pair) rotatably receive the stub shafts **11***a* and **11***b*, respectively. These pairs of bearings **27***a*, **27***a'* and **27***b*, **27***b'* are referred to herein as "allochiral" for the reason that they are opposed right and left hand assemblies (looking in the machine direction) although not necessarily entirely symmetrical in every detail. The right hand pair of bearings **27***b*, **27***b'* rotatably receives the stub shaft **11***b*, with the bearings **27***b* and **27***b'* spaced from each other so that they are adapted to apply a force couple in a generally vertical plane P (FIGURE 2) of the roll axis **A–11** and the nips **N–1**, etc. The bearings **27***b* and **27***b'* are securely mounted in a conventional housing **28***b* so that the bearings **27***b* and **27***b'* will remain in a predetermined spaced relationship. The bearings **27***a* and **27***a'* are mounted in rigid assembly in like manner in the left hand housing **28***a*.

Allochiral lever arms **29***a* and **29***b* are rigid (e.g. integral) with respective housings **28***a* and **28***b*. The lever arm **29***a* extends from the housing **28***a* and the bearings **27***a* and **27***a'* carried thereby in the generally vertical plane P (FIGURE 2) downwardly and away from the stack as defined by the rolls proper **11** through **14** and then inwardly from the roll end **11***a* to a terminal lever arm portion **30***a* intermediate the ends **11***a*, **11***b* of the roll **11**. The right hand lever arm **29***b* extends in generally symmetrical relation to a terminal portion **30***b*.

The housing **28***a* is pivotally mounted, on a fixed pivot **31***a*, for limited rocking movement. The pivot **31***a* is preferably positioned intermediate the bearings **27***a* and **27***a'*. A right hand pivot **31***b* carries the right hand housing **28***b* in like manner. It will be appreciated that the pivots **31***a*, **31***b* are shown diagrammatically herein, but any convention pivot arrangement may be used and the pivots **31***a*, **31***b* are carried by a suitable fixed support, for example, as shown in FIGURE 2 the pivot **31***b* is carried on a cross beam **32** of the overall frame assembly **15**. The pivots **31***a*, **31***b* carry substantially the entire weight of the bottom roll **11** plus the load applied thereto along the nip **N–1**.

The terminal portions **30***a*, **30***b* of the allochiral lever arms **29***a*, **29***b* are provided with suitable means **33***a*, **33***b* for moving the same generally toward and away from the stacked rolls **11** through **14** and in the plane P thereof to apply the necessary force couples to the shaft elements **11***a* and **11***b*. The means **33***a* and **33***b* here shown are fluid pressure actuated diaphragms mounted on a fixed support F and engaging the terminal lever arm portions **30***a* and **30***b* (but adapted to be repositioned slightly to the right or left of the position shown in FIG-

URE 1, so as to vary somewhat the application of force through the lever arms 29*a*, 29*b*. The diaphragms 33*a*, 33*b* are adapted for limited vertical movement in their function.

It will be appreciated that, in the absence of the load applied along the nip N–1, the upward movement of the diaphragms 33*a*, 33*b* to effect end moments in the roll 11 would tend to bow the central portion of the roll axis upwardly along a line M–11 which exaggerates the deflection. Because of the load at the nip N–1 (plus the actual weight of the roll 11 itself), the centroidal axis of the roll 11 is not so deflected, however. Instead, the force couples may be applied to the roll ends 11*a* and 11*b* in such a manner as to substantially counteract the tendency for the central portion of the centroidal axis of the roll 11 to deflect downwardly along a line D–11 due to the load applied at the nip N–1. The net result is that by the proper application of the force couples to the roll ends 11*a*, 11*b* it is possible to approximate the true center line alignment of the roll axis indicated at A–11, or to approximate other predetermined positive or negative deflections in the roll axis, depending upon the correlation of the various force factors employed in the practice of the instant invention.

Although it is indicated in an essentially diagrammatic manner, it will be appreciated that it is preferable to mount the bearing housing 28*b* for sliding movement between two vertically aligned tracks 35 and 36 carried by the main frame 15 and a supplemental frame element 15*a*, but other suitable means may be used to maintain the bearing housings, such as housing 28*b* in suitable operating position.

It will also be noted that the axis A–14 of the top roll 14 is subject to deflection and the top roll 14 is provided with allochiral shaft elements or stub shafts 14*a*, 14*b* at opposite ends thereof. Allochiral pairs of bearings 37*a*, 37*a'* and 37*b*, 37*b'* rotatably receive the shaft elements 14*a* and 14*b*, respectively, and are adapted to apply a force couple thereto. The bearings 37*a*, 37*a'* are mounted in fixed relation to each other in a suitable bearing housing 38*a* pivotally mounted on a pivot 39*a*; and the right hand pair of bearings 37*b*, 37*b'* are likewise carried in a housing 38*b* pivotally mounted on a pivot 39*b*. Although the pivots 39*a* and 39*b* are indicated in essentially diagrammatical manner, it will be appreciated that (as shown in FIGURE 3) they are mounted (for limited vertical and/or horizontal movement) on a part of the overall frame, for example, the pivot 39*b* may be suitably mounted on a cross beam 40 interconnecting the main frame 15 with the supplemental vertically aligned frame component 15*a* (or any other suitable conventional mounting means may be employed). The limited vertical and/or horizontal movement or adjustment of the pivots 39*a* and 39*b* (which is indicated diagrammatically) is afforded so that selected variations in the lever action are available. Once adjusted to a given position, however, the pivots may remain fixed during operation. In addition, it will be noted from FIGURE 3 that the bearing housing 38*b* is preferably mounted between vertical tracks 41 or 42 carried on the overall frame assembly 15, 15*a* for maintenance of the proper position of the bearing housing 38*b* during operation. Allochiral lever arms 43*a* and 43*b* (rigid with the bearing housings 38*a* and 38*b*, respectively, and the bearings carried thereby) extend from the housings 38*a* and 38*b* respectively in the generally vertical plane P upwardly and away from the stack of rolls 11 through 14 and then inwardly to terminal lever arm portions 44*a* and 44*b*, respectively (inwardly of both ends of the roll 14). Suitable means in the form of fluid pressure actuated diaphragms 45*a*—45*a'* and 45*b*—45*b'* adapted for limited vertical movement are provided for acting on the terminal portions 44*a* and 44*b*, respectively, of each of the lever arms 43*a* and 43*b* generally toward and away from the stack of rolls 11 through 14 and in the plane P thereof to apply force couples to the shaft elements 14*a* and 14*b* via the allochiral pairs of bearings 37*a*, 37*a'* and 37*b*, 37*b'*.

It will be appreciated that the force applying means 33*a*, 33*b* and 45*a*, 45*b* used with the lever arms 29*a*, 29*b* and 43*a*, 43*b*, respectively act generally in the plane P and generally normal to the axes of the rolls involved. This type of movement effects the formation of the force couple at the roll ends without "end loading" the respective bearing assemblies. Moreover, the extension of the lever arm inwardly from the roll ends in the manner already described affords ideal mechanical advantage for the application of the force couple.

Referring to FIGURE 3, it will be noted that the fluid actuated diaphragm means 45*b* (and of course 45*a* as indicated in FIGURE 1) are suitably mounted on a fixed support that forms a part of the overall frame 15. As here indicated, the support comprises a pair of beams 46, 46 extending the width of the machine and carrying cross beams 47*a* and 47*b* actually mounting the diaphragms 45*a* and 45*b*, but any conventional arrangement may be used.

It will be noted that the conventional bearing assemblies (such as the bearing assemblies 17*a* and 17*b* for the roll 13) as well as the particular bearing assemblies in the housings 38*a* and 38*b* for the roll 14 would, if mounted free at the ends of the roll 14 without the support here shown, tend to deflect the central axis of the roll 14 downwardly along the edges as shown in exaggerated fashion by the deflection line D–14. The total load on the nip N–3 below in such circumstances would, however, be a result essentially of only the total weight of the roll 14 and its bearings, which in most circumstances would be a load insufficient to effect enough pressure at the nip N–3 to obtain any appreciable improvement in the finish of the paper web W passing therethrough. In order to overcome this difficulty the instant invention provides for the application of force couples to the shaft ends 14*a* and 14*b* in order to apply bending moments to the roll 14. If such force couples are applied so as to deflect the centroidal axis of the roll 14 downwardly, the force couples so applied would tend to impart a downward deflection to the centroidal axis along the line M–14 of FIGURE 1, which represents this theoretical downward deflection in exaggerated manner. This theoretical downward deflection curve M–14 has, of course, a greater sag than the sag in the centroidal axis which results from the weight of the roll 14 merely supported at its ends in the absence of the roll 13 below.

In actual practice, of course, a load is usually applied to the roll 14 (via the bearings) at the same time that the force couple is applied. The load application may require a slight downward adjustment of the pivots 39*a*—39*b*. As a matter of fact, in such circumstances, the centroidal axis of the roll 14 is not deflected downwardly along the line M–14 by the application of such force couples at the ends 14*a* and 14*b*, for the reason that the roll immediately therebelow, which is the roll 13, tends to resist this overall deflection. The net result is that the application of the force couples to and the loading at the roll ends 14*a* and 14*b* serves to increase the pressure along the nip N–3 up to a pressure at which substantial improvements in finish of the web are obtained at the very first nip N–3 which receives the web.

For purposes of demonstrating certain important aspects of the instant invention, FIGURE 4 shows a calender stack indicated generally by the reference numeral 50 comprising a bottom roll 51 and a plurality of superimposed rolls 52, 53, 54, 55 and 57, with the top roll being 57. The intermediate rolls 52, 53, 54 and 55 are each provided with separate and independent load relieving devices at opposite ends thereof, at 52*a*, 52*b*, 53*a*, 53*b*, etc., all in the manner previously described although here shown only diagrammatically.

The opposite ends 51*a* and 51*b* of the bottom roll are

suitably supported (as by the pivots 51*c* and 51*d*, respectively, cooperating with bearing housings 51*e* and 51*f*, respectively) for carrying the entire load of the roll 51 and the load applied thereto in conventional manner. In addition, means of the type already described are provided for applying a force couple to the left hand end 51*a*, indicated diagrammatically at FC–1, and a force couple FC–2 to the right hand end 51*b*, for applying a bending moment to the roll 51. As indicated by the arrow heads in dotted lines these force couples FC–1 and FC–2 are reversible, if desired.

The top roll 57 is also provided with means of the type herein described for applying a force couple FC–3 to the left hand end 57*a* and the force couple FC–4 to the right hand end 57*b* of the roll. For purposes of applying the force couples FC–3 and 4, it will be noted that pivotal mounting means 57*c* and 57*d* are provided to cooperate with the allochiral bearing housings 57*e* and 57*f* which in turn are connected to allochiral lever arms 57*g* and 57*h* that are actuated by conventional means shown diagrammatically at 57*j* and 57*k*. As indicated in FIGURE 4, the arrows designating the force couples FC–3 and FC–4 show the application of this force moment in a direction which will be called the positive direction, and it will be understood that the opposite direction would therefore be the negative direction. In addition to the application of the force couples FC–3 and FC–4, the present arrangement involves also the application of a load indicated by the arrows L–3 and L–4 to show the positive direction for the load. In order to permit the application of a positive load without the necessity of applying a force couple, limited vertical movement of the pivots 57*c* and 57*d* is provided for by conventional mounting means 57*m* and 57*n* (which may be diaphragms like 57*j* and 57*k*). A lifting force or negative load would be in the opposite direction to the arrows L–3 and L–4, and this can be done via the means 57*m* and 57*n*.

The calender nips formed between the rolls 51 through 57 are indicated at N–11 through N–15, with the nip N–11 being the bottom nip and the nip N–15 being the top nip.

Referring now to FIGURE 5, it will be seen that the nips N–11 through N–15 are indicated in sequence from top to bottom along the ordinate, and the nip load in pounds per inch of nip is indicated (increasing) along the abscissae. Although there is some variation depending upon the particular type of paper being calendered there is a practical minimum nip load NL–1 at which appreciable improvement of the finish is obtained in a calender nip and below which the improvement of the finish is not appreciable. At nip loads above the practical minimum of NL–1 the desired improvement in finish is obtained up to a practical maximum nip load NL–2, at which damage to the web (e.g. crushing of the paper) results. There is thus a preferred operational area or predetermined range of nip loads from the practical minimum NL–1 to the practical maximum NL–2. This predetermined practical nip load range may vary from a practical minimum for some papers of about 100±25 p.p.i. to a practical maximum for other papers of about 600±100 p.p.i. But for a given paper the practical range would be about 300±100 p.p.i. depending upon the sensitivity of the sheet to reduction in bulk.

The calender stack 50 was designed for the purpose of demonstrating various aspects of the invention, with an overall operating face F or nip width of 228 inches. The diameter of the bottom calender roll 51 is 34 inches, the diameter of the top calender roll 57 is 24 inches and the diameter of the intermediate rolls 52 through 55 is in each case 18 inches. If the calender stack were operated without any load relieving devices of the type hereinbefore described, and the full weight of each of the rolls 52 through 57 was supported in each case by the rolls beneath, the nip load would lie along the line L–1 indicated in the chart of FIGURE 5, which shows that the top nip N–15 would have too little pressure to effect a practical improvement in finish, and the bottom nips N–11 and N–12 would have such great nip pressures that they would result in such damage to the paper web that the calender stack would be inoperative. It is for this reason that many of the prior art calenders are broken down into two sections with only a few rolls to each section, thus avoiding excessive pressures in the lower nips of the calender.

If, in contrast, the load relieving means 52*a*, 52*b*, 53*a*, 53*b*, etc. are actuated for the intermediate rolls 52 through 55 in the calender stack 50, the excessive pressures in the bottom nip N–11 and N–12 are avoided, but adequate finishing nip pressures in the upper nips N–14 and N–15 are not obtained, with the various nip loads being indicated in the chart of FIGURE 5 along the dashed line L–2. The instant invention involves the use of the end load relieving means 52*a*, 52*b*, etc. for the intermediate rolls 52 through 55 in order to avoid excessive nip pressures at the lower nips N–11, N–12, etc., but the instant invention also contemplates the use of loads L–3 and L–4, as well as force couples FC–3, FC–4 to apply end moments to the top roll 57 so as to increase the nip loads substantially uniformly across not only the top nip N–15 but those immediately below (e.g. N–13 and N–14) to the extent that these upper nip loads are also within the operational range. In this way the beneficial use of all of the calender nips N–11 through N–15 is obtained for finishing purposes, without damage to the web, using nip loads represented graphically in FIGURE 5 along the dotted line L–3.

It will also be appreciated that in certain instances it may be desirable to apply force couples to the ends of one or more of the intermediate rolls, as indicated for example by force applying couples 53*a*—53*a*′ and 53*b*—53*b*′ for the roll 53. This provides an addition method of controlling the nature and uniformity of nip loads in the calender.

The nip loads have been computed for several different sets of conditions. In the arrangement employed for purposes of this calculation the force couples FC–3 and FC–4 are defined by allochiral pairs of bearings whose centers are spaced apart 36 inches, with the center of the inboard bearing being 20 inches from the edge of the operating roll face, the pivots 57*c* and 57*d* being centered between the center lines of each of the pairs of bearings and the actuating means 57*j* and 57*k* being aligned only 5 inches inward of the inboard of each of the pairs of bearings defining the force couples FC–3 and FC–4. Also, in the arrangement for the present computations, the bottom roll 51 is mounted so as to have a slight central deflection Δ (which in this case is an actual "positive" or downward deflection as contrasted to a crown which may be called a "negative" deflection). For purposes of the calculation per se, the deflection Δ, of course, can be varied as a result of the overall application of forces loading from above and/or the application of the force couples FC–1 and FC–2 in the manner hereinbefore described (or the operating face of the roll 51 may be machined so as to obtain a desired "positive" or "negative" deflection). Also, in obtaining the figures in the instant computations, it will be understood that the load relieving means 52*a*, 52*b*, 53*a*, 53*b*, etc. are actuated with respect to the intermediate rolls 52 through 55 so as to mount each of these rolls 52 through 55 in such a manner that its deflection conforms substantially with the deflection Δ of the bottom roll 51.

Using a top roll 57 with an actual central crown of 0.018 inch (ie.. increased central diameter) the following conditions are obtained varying the loads L–3 and L–4 from positive (downward) to negative (upward) and the force couples expressed in in.-lbs. from positive (in the directions indicated in FIGURE 4 for FC–3 and FC–4) to zero and later to negative (in the directions opposite to those shown for FC–3 and FC–4 in FIGURE 4).

Table 1

(A) Roll 51 deflection	0.017"	0.019"	0.020"
(B) Load (lbs.)	−6,600	0	+4,400
(C) Force couple (In.-lbs.)	0	+16,000	+22,000
(D) N-11 load (p.p.i.)	192	250	272
(E) N-12 load (p.p.i.)	158	217	243
(F) N-13 load (p.p.i.)	123	185	215
(G) N-14 load (p.p.i.)	88	153	187
(H) N-15 load (p.p.i.)	53	122	155

Using a top roll 57' with an actual crown of 0.038 inch, the following conditions are obtained in Table 2 (below) wherein the lines (A) through (H) have the same meaning as indicated in Table 1:

(A)	0.017	0.019	0.020	0.022	0.016
(B)	−6,600	0	+4,400	−12,000	−10,800
(C)	−13,200	0	+9,600	+24,000	−18,000
(D)	192	250	272	324	167
(E)	158	217	243	300	129
(F)	123	185	215	274	93
(G)	88	153	187	249	56
(H)	53	122	155	224	19

It will thus be seen that the invention also involves the method concept of calendering paper by passing the same through a plurality of superimposed calender nips in a calender stack comprising a bottom roll and a plurality of superimposed rolls including a top roll, all provided with heavy bearings at opposite ends thereof, which method effects the application of pressures at each nip in a predetermined range sufficient to finish the paper without damaging the same by the use of excessive pressures, which method comprises the steps of relieving the weight load of the bearings for each of the superimposed rolls below the top roll whereby each such roll maintains pressures across the nip with the roll below it within said predetermined range and applying a bending moment to the ends of the top roll via its bearings tending to deflect the top roll axis downwardly so as to maintain pressures across the nips with the rolls below the top roll within said predetermined range.

It will be understood that modifications and variations may be effected without departing from the spirit and scope of the novel concepts of the present invention.

We claim as our invention:

1. A multi-nip calender comprising a calender frame, a stack of calender rolls in the frame including a bottom roll and a plurality of superimposed rolls including a top roll, separate and independent bearings rotatably carrying the ends of each superimposed roll below the top roll, separate and independent means for each of said bearings carried by said frame and urging each of said bearings upwardly, and separate and independent bearing means for rotatably carrying the ends of the bottom and top rolls on the frame and applying a bending moment to each such roll end to effect a predetermined deflection in the roll axis and a predetermined loading across the calender nips.

2. A multi-nip calender comprising a calender frame, a stack of calender rolls in the frame including a bottom roll and a plurality of superimposed rolls including a top roll, separate and independent bearings rotatably carrying the ends of each superimposed roll below the top roll, separate and independent means for each of said bearings carried by said frame and urging each of said bearings upwardly, and separate and independent bearings means for rotatably carrying the ends of the top roll and applying a bending moment to each such roll end to effect a predetermined deflection in the roll axis and a predetermined loading across the calender nips.

3. A multi-nip calender comprising a calender frame, a stack of calender rolls in the frame including a bottom roll and a plurality of superimposed rolls including a top roll, separate and independent bearings rotatably carrying the ends of each superimposed roll below the top roll, separate and independent means for each of said bearings carried by said frame and urging each of said bearings upwardly, and allochiral pairs of bearings for rotatably carrying the ends of the bottom and top rolls on the frame and applying a bending moment to each such roll end to effect a predetermined deflection in the roll axis and a predetermined loading across the calender nips.

4. A multi-nip calender comprising a calender frame, a stack of calender rolls in the frame including a bottom roll and a plurality of superimposed rolls including a top roll, separate and independent bearings rotatably carrying the ends of each superimposed roll below the top roll, separate and independent means for each of said bearings carried by said frame and urging each of said bearings upwardly, and allochiral pairs of bearings for rotatably carrying the ends of the top roll on the frame and applying a bending moment to each such roll end to effect a predetermined deflection in the roll axis and a predetermined loading across the calender nips.

5. A multi-nip calender comprising a calender frame, a stack of calender rolls in the frame including a bottom roll and a plurality of superimposed rolls including a top roll, and separate and independent bearing means for rotatably carrying the ends of the bottom and top rolls on the frame and applying a bending moment to each such roll end to effect a predetermined deflection in the roll axis and a predetermined loading across the calender nips.

6. A multi-nip calender comprising a calender frame, a stack of calender rolls in the frame including a bottom roll and a plurality of superimposed rolls including a top roll all in a generally vertical plane, allochiral pairs of bearings rotatably carrying the ends of the bottom roll, fixed pivots on said frame mounting each of said pairs of bearings, allochiral lever arms rigid with each of said pairs of bearings and extending therefrom to terminate generally in the plane of the superimposed stack of rolls inwardly from the pair of bearings with which the lever arm is rigid, and means for acting on the terminal portions of each of said lever arms and applying a bending moment to each such roll end to effect a predetermined deflection in the roll axis and a predetermined loading across the calender nips.

7. A multi-nip calender comprising a calender frame, a stack of calender rolls in the frame including a bottom roll and a plurality of superimposed rolls including a top roll all in a generally vertical plane, allochiral pairs of bearings rotatably carrying the ends of the top roll, fixed pivots on said frame mounting each of said pairs of bearings, allochiral lever arms rigid with each of said pairs of bearings and extending therefrom to terminate generally in the plane of the superimposed stack of rolls inwardly from the pair of bearings with which the lever arm is rigid, and means for acting on the terminal portions of each of said lever arms and applying a bending moment to each such roll end to effect a predetermined deflection in the roll axis and a predetermined loading across the calender nips.

8. A multi-nip calender comprising a calender frame, a stack of calender rolls in the frame including a bottom roll and a plurality of superimposed rolls including a top roll all in a generally vertical plane, allochiral pairs of bearings rotatably carrying the ends of the bottom roll and the top roll, fixed pivots on said frame mounting each of said pairs of bearings, allochiral lever arms rigid with each of said pairs of bearings and extending therefrom to terminate generally in the plane of the superimposed stack of rolls inwardly from the pair of bearings with which the lever arm is rigid, and means for acting on the terminal portions of each of said lever arms and applying a bending moment to each such roll end to effect a predetermined deflection in the roll axis and a predetermined loading across the calender nips.

9. A multi-nip calender comprising a calender frame, a stack of calender rolls in the frame including a bottom

roll and a plurality of superimposed rolls including a top roll all in a generally vertical plane, separate and independent bearings rotatably carrying the ends of each superimposed roll below the top roll, separate and independent means for each of said bearings carried by said frame and urging each of said bearings upwardly, allochiral pairs of bearings rotatably carrying the ends of the bottom roll, fixed pivots on said frame mounting each of said pairs of bearings, allochiral lever arms rigid with each of said pairs of bearings and extending therefrom to terminate generally in the plane of the superimposed stack of rolls inwardly from the pair of bearings with which the lever arm is rigid, and means for acting on the terminal portions of each of said lever arms and applying a bending moment to each such roll end to effect a predetermined deflection in the roll axis and a predetermined loading across the calender nips.

10. A multi-nip calender comprising a calender frame, a stack of calender rolls in the frame including a bottom roll and a plurality of superimposed rolls including a top roll all in a generally vertical plane, separate and independent bearings rotatably carrying the ends of each superimposed roll below the top roll, separate and independent means for each of said bearings carried by said frame and urging each of said bearings upwardly, allochiral pairs of bearings rotatably carrying the ends of the top roll, fixed pivots on said frame mounting each of said pairs of bearings, allochiral lever arms rigid with each of said pairs of bearings and extending therefrom to terminate generally in the plane of the superimposed stack of rolls inwardly from the pair of bearings with which the lever arm is rigid, and means for acting on the terminal portions of each of said lever arms and applying a bending moment to each such roll end to effect a predetermined deflection in the roll axis and a predetermined loading across the calender nips.

11. A multi-nip calender comprising a calender frame, a stack of calender rolls in the frame including a bottom roll and a plurality of superimposed rolls including a top roll all in a generally vertical plane, allochiral pairs of bearings rotataby carrying the ends of the bottom roll and the top roll, fixed pivots on said frame mounting each of said pairs of bearings, allochiral lever arms rigid with each of said pairs of bearings and extending therefrom to terminate generally in the plane of the superimposed stack of rolls inwardly from the pair of bearings with which the lever arm is rigid, and means for acting on the terminal portions of each of said lever arms and applying a bending moment to each such roll end to effect a predetermined deflection in the roll axis and a predetermined loading across the calender nips.

12. In a mounting for a roll whose axis is subject to deflection, said roll having shaft elements at opposite ends thereof and being mounted in a calender stack disposed in a generally vertical plane, in combination, allochiral pairs of bearings rotatably receiving said shaft elements and adapted to apply a force couple thereto, fixed pivots mounting each of said pairs of bearings, allochiral lever arms each rigid with one of said pairs of bearings and extending therefrom in said vertical plane away from the stack and to a terminal lever arm portion inwardly of the roll end having the shaft element received by such one of said pairs of bearings, and means for acting on the terminal portions of each of said lever arms generally toward and away from the stack and in the plane thereof to apply such force couple to said shaft elements.

13. In a mounting for a roll whose axis is subject to deflection, said roll having shaft elements at opposite ends thereof and being mounted at the bottom of a calender stack disposed in a generally vertical plane, in combination, allochiral pairs of bearings rotatably receiving said shaft elements and adapted to apply a force couple thereto, fixed pivots mounting each of said pairs of bearings, allochiral lever arms each rigid with one of said pairs of bearings and extending therefrom in said vertical plane downwardly away from the stack and to a terminal lever arm portion inwardly of the roll end having the shaft element received by such one of said pairs of bearings, and means for acting on the terminal portions of each of said lever arms in a generally vertical direction to apply such force couple to said shaft elements.

14. In a mounting for a roll whose axis is subject to deflection, said roll having shaft elements at opposite ends thereof and being mounted at the top of a calender stack disposed in a generally vertical plane, in combination, allochiral pairs of bearings rotatably receiving said shaft elements and adapted to apply a force couple thereto, fixed pivots mounting each of said pairs of bearings, allochiral lever arms each rigid with one of said pairs of bearings and extending therefrom in said vertical plane upwardly away from the stack and to a terminal lever arm portion inwardly of the roll end having the shaft element received by such one of said pairs of bearings, and means for acting on the terminal portions of each of said lever arms in a generally vertical direction to apply such force couple to said shaft elements.

15. In a mounting for a roll whose axis is subject to deflection, said roll having shaft elements at opposite ends thereof and being mounted to define a pressure loaded nip along a surface thereof defining a plane with the roll axis, in combination, allochiral pairs of bearings rotatably receiving said shaft elements and adapted to apply a force couple thereto, pivots mounting each of said pairs of bearings, allochiral lever arms each rigid with one of said pairs of bearings and extending therefrom generally in said plane and to a terminal lever arm portion spaced from the nip and inwardly of the roll end having the shaft element received by such one of said pairs of bearings, and means for acting on the terminal portions of each of said lever arms generally toward and away from the nip and in said plane to apply such force couple to said shaft elements.

16. A multi-nip calender comprising a calender frame, a stack of calender rolls in the frame including a bottom roll and a plurality of superimposed rolls including a top roll, separate and independent bearings rotatably carrying the ends of each superimposed roll, separate and independent means for each of said bearings carried by said frame and urging each of said bearings upwardly, shaft elements at opposite ends of the bottom roll disposed in a generally vertical plane defined by the calender nips, allochiral pairs of bearings rotatably receiving said shaft elements and adapted to apply a force couple thereto, pivots mounting each of said pairs of bearings, allochiral lever arms each rigid with one of said pairs of bearings and extending therefrom in said vertical plane away from the stack and to a terminal lever arm portion inwardly of the roll end having the shaft element received by such one of said pairs of bearings, and means for acting on the terminal portions of each of said lever arms generally toward and away from the stack and in the plane thereof to apply such force couple to said shaft elements.

17. A multi-nip calender comprising a calender frame, a stack of calender rolls in the frame including a bottom roll and a plurality of superimposed rolls including a top roll, separate and independent bearings rotatably carrying the ends of each superimposed roll below the top roll, separate and independent means for each of said bearings carried by said frame and urging each of said bearings upwardly, shaft elements at opposite ends of the top roll disposed in a generally vertical plane defined by the calender nips, allochiral pairs of bearings rotatably receiving said shaft elements and adapted to apply a force couple thereto, fixed pivots mounting each of said pairs of bearings, allochiral lever arms each rigid with one of said pairs of bearings and extending therefrom in said vertical plane away from the stack and to a terminal lever arm portion inwardly of the roll end having a shaft element received by such one of said pairs of bearings, and means for acting on the terminal portions of each of said lever

arms generally toward and away from the stack and in the plane thereof to apply force couple to said shaft elements.

18. A multi-nip calender comprising a calender frame, a stack of calender rolls in the frame including a bottom roll and a plurality of superimposed rolls including a top roll, separate and independent bearings rotatably carrying the ends of each superimposed roll below the top roll, separate and independent means for each of said bearings carried by said frame and urging each of said bearings upwardly, shaft elements at opposite ends of the top and bottom rolls disposed in a generally vertical plane defined by the calender nips, allochiral pairs of bearings rotatably receiving said shaft elements and adapted to apply a force couple thereto, fixed pivots mounting each of said pairs of bearings, allochiral lever arms each rigid with one of said pairs of bearings and extending therefrom in said vertical plane away from the stack and to a terminal lever arm portion inwardly of the roll end having the shaft element received by such one of said pairs of bearings, and means for acting on the terminal portions of each of said lever arms generally toward and away from the stack and in the plane thereof to apply such force couple to said shaft elements.

19. A method of calendering paper by passing the same through a plurality of superimposed calender nips in a calender stack comprising a bottom roll and a plurality of superimposed rolls including a top roll, all provided with heavy bearings at opposite ends thereof, which method effects the application of pressures at each nip in a predetermined range sufficient to finish the paper without damaging the same by the use of excessive pressures, which method comprises the steps of relieving the weight load of the bearings for each of the superimposed rolls below the top roll whereby each such roll maintains pressures across the nip with the roll below it within said predetermined range and applying a bending moment to the ends of the top roll via its bearings tending to deflect the top roll axis downwardly so as to maintain pressures across the nips with the rolls below the top roll within said predetermined range.

20. A method of calendering paper by passing the same through a plurality of superimposed calender nips in a calender stack comprising a bottom roll and a plurality of superimposed rolls including a top roll, all provided with heavy bearings at opposite ends thereof, which method effects the application of pressures at each nip in a predetermined range sufficient to finish the paper without damaging the same by the use of excessive pressures, which method comprises applying a bending moment to the ends of the bottom roll via the bearings therefor to effect a deflection in the bottom roll, urging the bearings upwardly for each of the superimposed rolls below the top roll to substantially conform each of these rolls with said deflection of the bottom roll whereby each such roll maintains pressures across the nip with the roll below it within said predetermined range and applying a bending moment to the ends of the top roll via its bearings tending to deflect the top roll axis downwardly so as to maintain pressures across the nips with the rolls below the top roll within said predetermined range.

No references cited.