June 10, 1958 A. V. ALEXEFF ET AL 2,837,834

WEB HEAT TREATMENT AND APPARATUS THEREFOR

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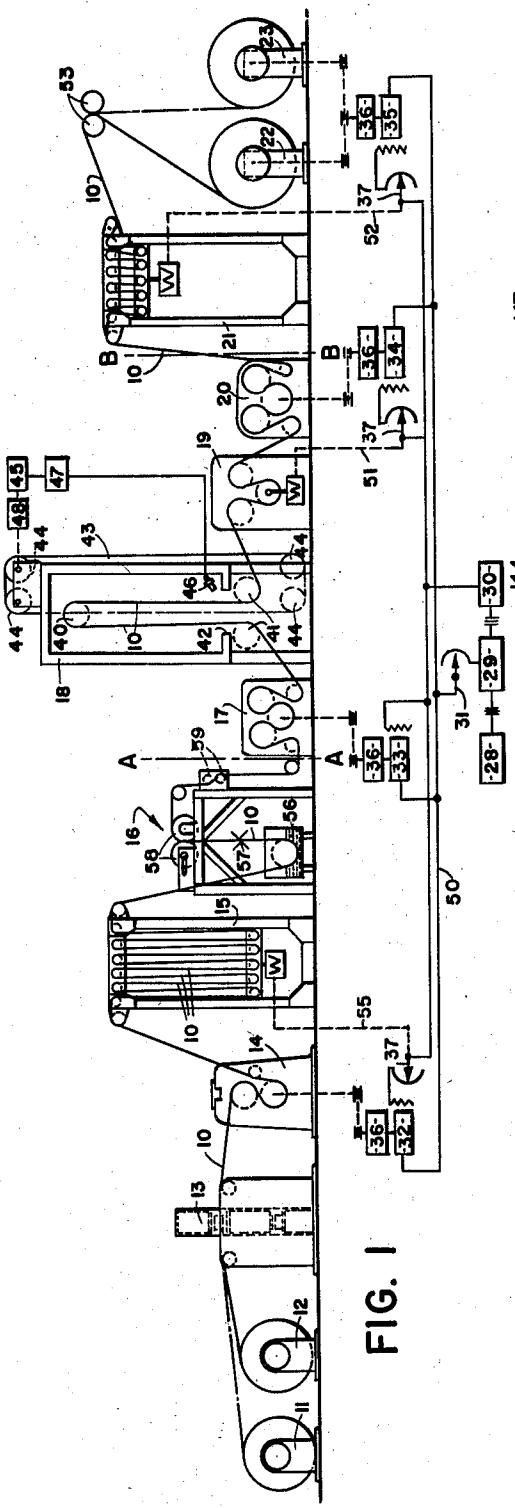


FIG. 1

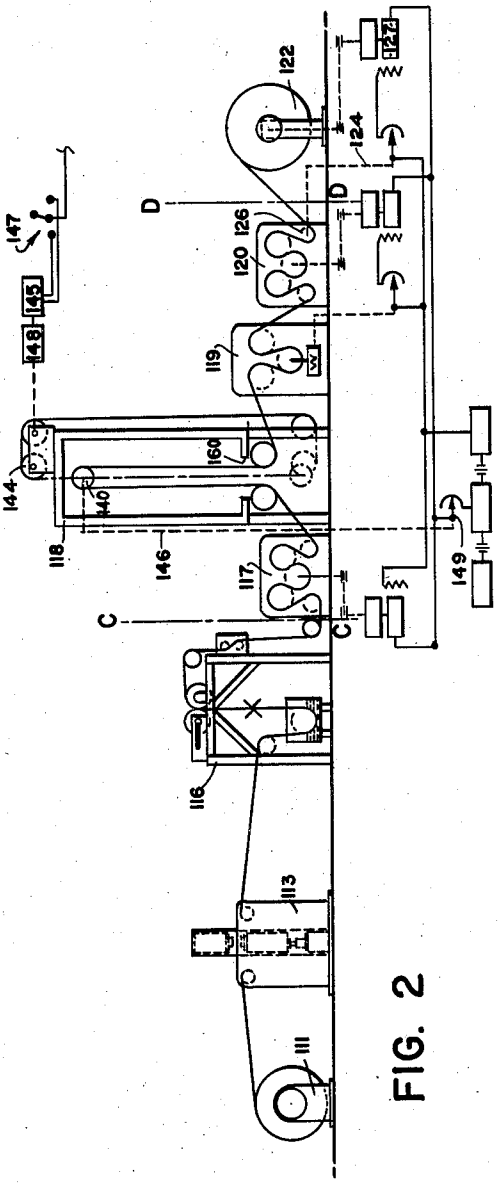


FIG. 2

INVENTORS
ALEXANDER V. ALEXEFF
EDWIN P. HOMBURG
HOWARD RICHARDS
BY
Eby, Page & Hamilton

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FIG. 3

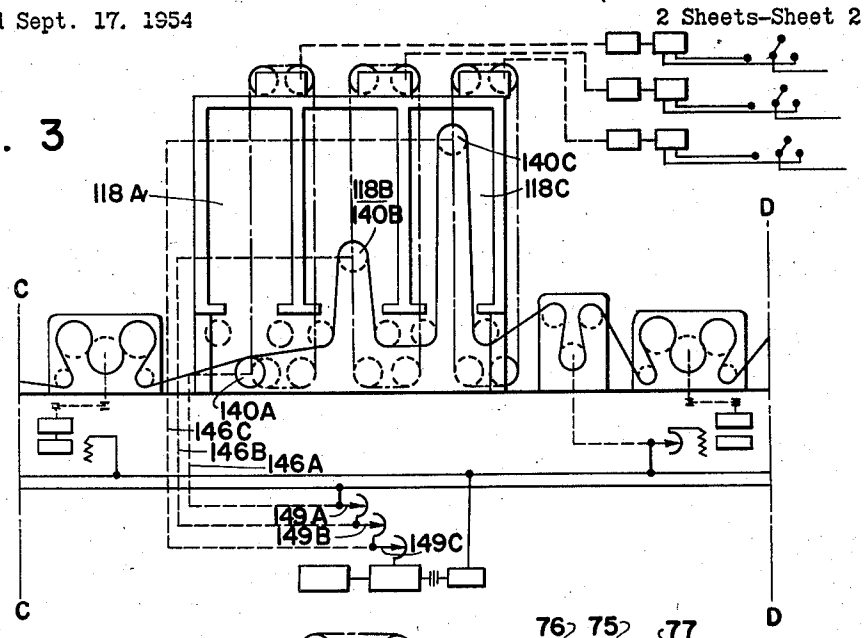
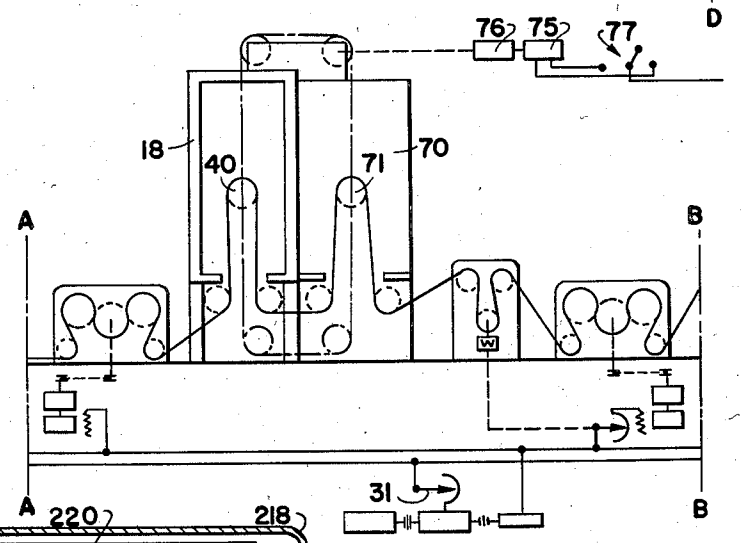


FIG. 4



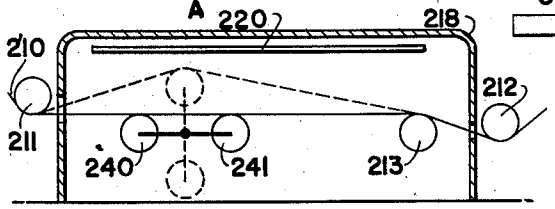


FIG. 5

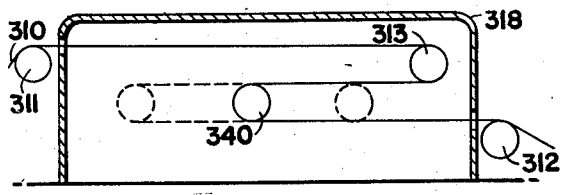


FIG. 6

INVENTORS
ALEXANDER V. ALEXEFF
EDWIN P. HOMBURG
HOWARD RICHARDS
BY
Ely, Pfeger & Hamilton

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WEB HEAT TREATMENT AND APPARATUS THEREFOR

Alexander V. Alexeff, Cleveland, Edwin P. Homburg, Parma Heights, and Howard Richards, Lakewood, Ohio, assignors to Industrial Ovens, Incorporated, Cleveland, Ohio, a corporation of Ohio

Application September 17, 1954, Serial No. 456,691

2 Claims. (Cl. 34—159)

The present invention relates to heat treatment of webs and strands and particularly to method and apparatus for attaining very precise and responsive temperature control of the treated material. For purposes of this application "strands" is to be understood to include monofilaments such as nylon, rayon, and glass fiber as well as wires, cords, narrow tapes and tubings, and "strips" is to be understood to include strands and also webs such as metal sheet, paper, textiles, films and wide tapes.

In a multitude of present-day continuous or semi-continuous processes for the heat treatment of strip, it is necessary to maintain the treated material within critical temperature limits during the actual heat treating step (usually while also maintaining a certain time of exposure or at least not departing from a certain range of exposure times). Any variables which tend to displace strip temperature across such critical limits must, therefore, be counteracted by adjustment of the rate of heat transfer to the web. Such adjustment is accomplished in a number of ways. For example, oven temperature is varied by increasing or decreasing the output of the burners or heating elements which are the source of the heat. It will be apparent that close strip temperature control under quickly fluctuating control conditions cannot be practically attained with this rudimentary arrangement. Another procedure is to provide a standby supply of heat (i. e., heated air) which can be supplied to the oven or drier on demand. Conversely, an overheated oven may be provided which is cooled to the desired temperature by outside air or other cooling medium, the rate of supply of the cooling medium being varied in response to control requirements to counteract any tendency of the strip to exceed temperature limitations. Thus, a degree of strip temperature control may be attained by responsively and continuously damping into the oven or drier an accumulated heating or cooling medium. However, the inherent waste and expense of this procedure renders it impractical for close temperature control. If a relatively wide temperature range is allowed, damping in of the alternative supply used occurs only relatively infrequently, but for close control damping in of the alternative heating or cooling medium must occur almost continuously, representing a prohibitive heat loss. Another possibility is to vary web speed, but in most production set-ups to continuously vary speed of the processing line is obviously impractical. The variation of web speed is, of course, entirely inapplicable to operations in which time of exposure must be maintained at a given figure or within a narrow range.

The above considerations have limited the possibilities of many strip heat treating processes where the ideal would be to closely approach critical temperature without exceeding it. Commercially attainable end results are compromised by the fact that the ideal is attainable only by the use of prohibitively costly and wasteful methods. For example, in hot stretching of nylon fabric following coating or impregnation, it is desirable to approach as

closely as possible the limiting top web temperature at which the fabric will soften and fail or scorch. Conventional hot stretch installations provide elaborate temperature control means for the oven through which the web is to pass. As control conditions vary (the wide variable is usually web speed which, on a continuous line, is adjusted from time to time according to production demand) it is, of course, necessary to vary the oven temperature. Excessive destruction of material during shutdowns, either by overheating or under treatment of portions of the web, must also be avoided. Highly responsive control of web temperature cannot be achieved without completely prohibitive expense due to heat waste and the cost of large auxiliary equipment. Accordingly, compromise is necessary and a considerable margin of safety must be maintained by choosing operating conditions so that the web temperature is well below the critical value which it can stand, despite the desirability of closely approaching this critical value.

An object of the invention is to provide close control of strip temperature during heat treatment, such close control being readily maintained despite rapid fluctuation of control conditions such as strip speed, temperature and humidity of the input side of the strip, ambient air temperature and humidity and any other variables that tend to affect strip temperature during the heat treating step.

Another object of the invention is to make possible a very close control of the amount of stretch of a strip in a continuous or semi-continuous processing operation. In many applications close control of strip temperature is not, in itself, of primary importance, but it is highly desirable that the amount of stretch of the strip be confined within narrow limits. The amount of stretch is generally a function of three variables: strip tension, heating period and strip temperature. The first two of these, strip tension and the time of exposure of the strip, may be very closely controlled by conventional methods. Heretofore, however, the third of these variables, strip temperature, has not been subject to such precise control. Accordingly, another object of the invention is to make possible extremely close control of the amount of stretch of a strip on a continuous processing basis through precise control of the several parameters of the amount of stretch.

Another object of the invention is to provide improved means of controlling strip temperature regardless of whether extremely fine control is required.

Another object of the invention is to provide for quick accommodation of desired changes in strip speed without the necessity of varying oven temperature.

Another object of the invention is to resolve, by radical and simple means, certain problems of heat damage or improper treatment of the strip incident to shutdown.

A further object of the invention is to provide for economical temperature control in continuous or semi-continuous processes over an indefinitely broad range of strip speeds by employing gangs of ovens or oven sections which may be by-passed and completely shut down when not required.

These and other objects and advantages of the invention will become apparent from the following description of specific embodiments of the invention. As will be apparent to those familiar with web or strand processing, specific mechanical, electrical or hydraulic equipment components to be employed in any given installation are a matter of choice within the routine skill of the art. Suitable components in each illustrated embodiment are, therefore, illustrated schematically in the interest of clarity in order that the invention itself may be most concisely and completely disclosed and understood.

In the drawings:

Figure 1 illustrates a relatively refined continuous web processing system employing the invention.

Figure 2 illustrates a semi-continuous web processing system employing the invention in a somewhat different manner than it is employed in the apparatus shown in Figure 1.

Figure 3 illustrates an alternate set-up which may replace the central portion between the lines C—C and D—D of the processing line shown in Figure 2.

Figure 4 illustrates an alternate set-up which may replace the central portion between the lines A—A and B—B of the processing line shown in Figure 1.

Figures 5 and 6 illustrate alternative oven and dancer arrangements.

Figure 1 illustrates a fully continuous web treating installation in which the invention is employed. The illustrated installation might be employed for impregnation and coating a web of nylon fabric with a plastic which is applied to the fabric in a dipping operation, the web then being heated, dried, and simultaneously stretched under considerable tension. In such "hot stretching" it is desirable to approach as closely as possible the upper temperature limit at which the fabric will fail or permanently weaken. In the illustration the web is indicated by the reference numeral **10**.

The main components of the installation shown in Figure 1 comprise a pair of let-off stands **11** and **12**, a splice press **13**, a tension establishing drive stand **14**, a let-off accumulator **15**, a dip station **16**, a first high-tension-capacity pull roll stand **17**, a vertical drying oven **18**, a tension sensing stand **19**, a second high-tension-capacity pull roll stand **20**, a wind-up accumulator **21** and a pair of wind-up stands **22** and **23**.

The installation may employ in any conventional manner a plurality of variable speed D. C. motors as a power and control means for the several web driving members. The power and control system may comprise a motor **28**, generator **29**, field exciter **30**, an overriding or governing speed control rheostat **31**, and a plurality of voltage responsive variable speed D. C. motors **32**, **33**, **34**, and **35**, each of these motors with the exception of the motor **33** being provided with its own subsidiary speed control means such as field voltage rheostats **37**, such several control means being responsive to variation in tension at several points in the system as explained below. A speed reducer **36** associated with each of the motors is mechanically linked with one of the processing line components as indicated in Figure 1.

The drying oven **18** may be constructed and arranged so that both entrance and egress of the web **10** occurs through the port **42** during normal operation, the web being guided into and out of the port by the rolls **41**. Within the oven the web passes around a dancer roll **40**. The dancer roll **40** is mounted for lateral displacement so that it may be shifted up or down in a vertical path within the oven **18** and may furthermore be lowered a sufficient extent to pass completely or at least partially out through the port **42**. For this purpose the ends of the dancer roll **40** may be mounted in blocks which are engaged by an endless cable or chain **43** at either side of the oven. Each cable or chain **43** passes around associated sprockets or sheaves **44**, one of which is powered by a reversible motor **45** through a speed reducer **48**. It will, of course, be understood that other equivalent mechanism may be employed to shift the dancer roll **40**, the choice of the most desirable mechanism being a matter of mechanical expediency in the particular circumstances and conditions.

In this example of the invention, a web temperature detector in the form of a radiation pyrometer **46** is provided to sense web temperature at the output end of web travel through the drying oven. Through a suitable and conventional control potentiometer **47** the motor **45** is controlled in response to sensed temperature so that upon increase in temperature the dancer roll **40** is lowered and upon decrease in temperature the dancer roll **40** is raised.

The overall speed of the processing line shown in Figure 1 is governed by the pull rolls **17**. It will be seen that the speed of the motor **33** associated with these pull rolls is governed directly by the overriding control rheostat **31**, there being no ancillary variable control for the field voltage in this motor **33**. As is conventional, variation of the armature voltage for this motor correspondingly varies armature voltage in the other drive motors **32**, **34** and **35** through the common armature voltage line **50**.

When the web processing line is running under normal conditions, a relatively low tension is maintained between one of the letoff stands **11** or **12** and the tension-establishing drive stand **14** by simple brake friction on the letoff stand. Between the drive stand **14** and the high-tension capacity pull rolls **17**, an intermediate tension is maintained by the normally extended letoff accumulator **15** which has a weight or tension member W exerting a constant force in tension on the festooned web within the accumulator. Shifting of the lower member of the accumulator controls the associated rheostat **37** through a linkage **55**. Thus, as the lower member of the accumulator tends to rise, the rheostat is automatically adjusted through linkage **55** to cause the motor **32** to speed up, which, in turn, tends to free the accumulator causing the lower member of the accumulator to move downward. Thus, a feed back or self-governing control maintains a constant length of web between the drive stand **14** and the pull rolls **17**.

When the letoff roll of webbing is about to become exhausted, the motor **32** is stopped, by suitable means such as a cut-off switch, causing the web to be locked at the drive stand **14**. When this occurs, the lower member of the accumulator **15** proceeds to rise as webbing is pulled along by the pull rolls **17**. However, constant tension is maintained by the existence of the weight or tensioning member W. During exhaustion of the letoff accumulator **15**, the alternate fresh letoff roll from one of the letoff stands is spliced to the tail of the nearly exhausted web at the splice press **13**. Thereupon the web, at the drive stand **14**, is unlocked by cutting back into the circuit the motor **32**. The lower bar of the letoff accumulator is now in an abnormally high position, and, accordingly, the linkage **55** controls the rheostat **37** so as to call for greatly increased speed of the motor **32**. Thus, the accumulator **15** quickly refills, and, as its lower member approaches its normal position, the rheostat is automatically varied through linkage **55** until the speed of the motor **32** is reduced to its normal range, whereupon normal feed back or self-governing control of the motor speed continues within such normal range.

During passage from the drive stand **14** to the pull rolls **17**, the webbing is illustrated as being processed at the dip station **16**, the webbing being dipped into a coating liquid **56**, then passed between scraper bars **57**, squeegee rolls **58** and beater bars **59**.

Between the pull roll stand **17** and the second pull roll stand **20**, a relatively high tension, which may be in the order of several thousand pounds, is maintained in the web by a weight or tensioning spring or other equivalent member W associated with the tension-sensing stand **19**. Any tendency of the tension through this portion of the run to fall off or build up causes shifting of the member W, which, in turn, through its associated linkage **51** and rheostat **37**, speeds up or slows down the motor **34** until the member W is returned to its initial position.

Relatively low tension is maintained between the pull roll stand **20** and the wind-up stands **22** and **23** by the control associated with the wind-up accumulator **21**, this control governing the speed of the wind-up stands and being similar to the control of the drive stand **14** by the letoff accumulator **15**, except that the lower member for the wind-up accumulator is normally in raised position. When a wind-up stand is filled, the motor **35** associated

with that stand is stopped and the guide rolls **53** are locked together. When this occurs the lower member of the accumulator **21** proceeds to fall as webbing continues to be supplied to it by the pull roll stand **20**. Constant tension is maintained between the weight or tensioning member W associated with the wind-up accumulator **21**. During fill of the wind-up accumulator, the web is severed on the output side of the rolls **53** and the alternate wind-up stand is threaded with the webbing, the rolls **53** being either manually advanced or being advanced by a small auxiliary motor a slight amount to permit such threading. Thereupon, the guide rolls are unlocked while simultaneously the motor **35** is cut back into the circuit. The lower member of the wind-up accumulator is now in an abnormally low position and, accordingly, the associated linkage **52** controls the associated rheostat **37** so as to call for greatly increased speed of the motor **35**. Thus, the accumulator **21** quickly empties, and as its lower member approaches its normal raised position, the rheostat is automatically varied through linkage **52** until the speed of the motor **35** is reduced to its normal range, whereupon normal feed back of self-governing control of the motor speed continues within such a normal range.

When the line is operating at speed as determined by the overriding control rheostat **31**, temperature of the web is sensed by the radiation pyrometer **46**. As temperature starts to increase or decrease, the motor **45** is controlled to lower or raise the dancer roll **40**. It will be understod that the temperature within the oven **18** may remain almost constant, varying only slightly according to ambient conditions of temperature and humidity. Even such minor changes are compensated for by the control of the motor **45** by the pyrometer **46**. Thus, it is possible to continuously operate at a web temperature which approaches very closely critical web temperature. If it becomes desirable to change web speed, the setting of the rheostat **31** is varied. As the changing speed begins to reflect itself in a change in web temperature, the pyrometer **46** automatically causes the motor **45** to change the position of the roll **40** in a direction to overcome the indicated direction of change of web temperature.

It will be observed that while sensing of the temperature of the web itself approaches the ideal control, there may be other variables which are straight line or other known or determinable functions of web temperature. Accordingly, it is possible to provide for sensing of such variables rather than providing for direct sensing of web temperature. For example, in some installations web temperature may very closely follow oven temperature and, thus, sensing of the oven temperature may provide for satisfactorily accurate control of web temperature.

It will be apparent to those familiar with web or strand processing techniques and equipment that the electric power and control means may be replaced by conventional mechanical or hydraulic apparatus, and that the specific supports shown may be varied as a matter of expediency to provide for greater range control, more efficient drives, greater practicality of the circuit under given conditions, or for other purposes, all as is conventional in the art.

In Figure 2, a semi-continuous installation embodying the invention is illustrated. This installation may include a let-off stand **111**, a splice press **113**, a tension-establishing tension control drive stand **114**, a dipping station **116**, a high-tension-capacity pull roll stand **117**, a vertical drying oven **118**, a tension sensing stand **119**, a second high-tension-capacity pull roll stand **120**, which includes tension sensing elements and a wind-up stand **122**. It will be seen that the processing line illustrated in Figure 2 is generally similar to that shown in Figure 1, with the exception that no accumulators are provided so that changeover of the letoff and wind-up rolls cannot be accomplished without shutting down the line. Relatively low tension from the stand **111** to the stand **117** is maintained by brake friction at the stand **111**. Through a tension sensing element **126** and a suitable linkage **124** associated with the stand **120**, the motor **127** is controlled to maintain correct tension at the output end of the line. Also, tension between stands **117** and **120** is maintained by the feedback control from the tension sensing stand **119** in a manner which will be apparent from the drawings and is in all respects similar to the feedback control to the tension sensing stand **19** in Figure 1. In the installation shown in Figure 2, positioning of the dancer roll **140** is accomplished by remote control of a motor **145** which, through a speed reducer **148**, raises or lowers the dancer roll **140** by a linkage including the sheaves **144**, such linkage being similar to the linkage which includes the sheaves **44** in Figure 1. The remote control means for the motor **145** is indicated in Figure 2 as a reversing switch **147**. In the installation shown in Figure 2, the speed of the line as a whole is tied in to the position of the dancer roll **140** through the linkage **146** and armature voltage rheostat **149**. Fine web temperature control is not accomplished in the sense that it is attained in the installation shown in Figure 1, that is, varying ambient conditions are not accounted for. However, very rapid changes in web speed may be accomplished without disturbing web temperature and while maintaining constant oven temperature.

When it is desired to shut down the line, the dancer roll **140** may be lowered throughout the length of the oven **118**, thus progressively decreasing web speed while at all times maintaining proper web temperature. The dancer roll **140** may thereupon be lowered finally through the port **160** and the line may be simultaneously stopped. Thus, in change-over wastage due to improper heat treatment of certain portions of the web is avoided and, at the same time, constant oven temperature can be maintained.

It will be understood that a control set-up similar to that illustrated in Figure 2 may be employed on a fully continuous line such as that shown in Figure 1. While the control illustrated in Figure 2 is not as refined as the control originally described in connection with Figure 1, it will nevertheless enable substantial economies to be realized in the oven installation, while still making possible rapid changes in production.

Figure 3 illustrates a modification of the equipment shown in Figure 2, the portion of the equipment between lines C—C and D—D in Figure 2 being replaced by the apparatus shown in Figure 3. The single oven **118** is replaced by a multiple oven or a plurality of ovens **118A**, **118B**, and **118C**, each having its own dancer roll **140A**, **140B**, and **140C**. Each of these dancer rolls is positioned by control means similar to that associated with the dancer roll **140**. Through linkages **146A**, **146B**, and **146C** the position of these dancer rolls controls the heating of series connected armature voltage rheostats **149A**, **149B**, and **149C**. As a run commences, the dancer roll **140C** is raised in the oven **118C**. When the roll **140C** has reached its top-most position, the roll **140B** is then raised, then in turn the roll **140C**. With decreasing speed the rolls are lowered in reverse sequence from their ovens, the roll **140C** being completely withdrawn from its oven upon complete shut-down. In the particular installation shown, it is immaterial which roll is raised or lowered first. It will be apparent, however, that it may be desirable to inter-lock the controls so that raising or lowering of the rolls will have to progress in a definite sequence. It might be desirable to maintain the oven **118C** at temperature, thus at all times maintaining the line in condition to commence or continue operation at one-third of its full speed capacity. The other chambers might be brought to temperature only when higher capacity was called for. Figure 4 illustrates a modification of the apparatus shown in Figure 1, the specific apparatus shown in Figure 4 replacing the portion of Figure 1 be-

tween the lines A—A and B—B. In Figure 4, next to the oven **18**, is provided a cooling tower **70**. The linkage which raises and lowers the dancer roll **40** simultaneously and conversely lowers or raises a dancer roll **71** within the cooling tower. The control of the position of the dancer roll **40** is manual and is accomplished by the motor **75** acting through a speed reducer **76**, the motor being controlled by an on-and-off reversing switch **77**. It will be apparent in this example that web temperature must be varied manually with the control **77**. For example, if the armature voltage rheostat **31** is maintained at a constant position and the temperature of the web (or oven) appears to be rising, the operator would control the motor **75** so as to slightly lower the dancer roll **40**. This embodiment is relatively unrefined as far as automatic control is concerned. However, it illustrates a method of making temperature change very highly responsive to change in the position of the dancer roll. With lowering of the dancer roll, the length of web exposed in the oven is decreased while simultaneously the length of web exposed in the cooling tower is increased. It may be desirable in some installations to reverse the order of the heat cooling towers, making the cooling tower precede the heating tower. It will be understood that this principle may be employed in any of the previously described automatically controlled installations.

While all the above specific examples of the invention have employed similar ovens and similar dancer arrangements, almost unlimited alternatives are possible. In Figure 5, for example, is schematically shown a horizontal oven **218** through which a web or strand **210** is passed. The web is guided by the idlers **211** and **212** outside the oven and by the fixed idler **213** within the oven. A pair of dancers **240** and **241** are mounted for pivoting movement around a common axis in the manner illustrated in the figure. It will be seen that in the dotted line position the web or strand has a somewhat increased path of travel through the oven. Such an arrangement is obviously suitable for only a narrow range of strip speed at a given oven temperature, but within such range this arrangement enables fine strip temperature control to be achieved. If there is a roughly linear or planar heat source **220** within the oven, the arrangement preferably is such that as the web path is lengthened, spacing from the heat source diminishes, the two variables thus affecting web temperature in the same direction.

In Figure 6 is shown another example of an oven and dancer arrangement. Here the web **310** is guided by the idlers **311** and **312** outside the oven **318** and by the fixed idler **313** within the oven. A dancer **340** is mounted for reciprocating movement to vary the length of web within the oven in the manner indicated in the drawing.

The above description of the invention should make it apparent that the invention may be embodied in many different specific strip processing set-ups. Disclosure of the invention will suggest to the art many possibilities for specific installations which are tailored to particular conditions and operating requirements. The scope of the invention is, therefore, not limited to details of the embodiments described above, but is to be defined by the claims set forth below. In the claims it is to be understood that the term "roll" embraces pulleys and sheaves, cylindrical bars and tubes and other equivalent elements.

What is claimed is:

1. In continuous and semi-continuous strip treating apparatus, a heat treating station comprising a heating chamber having port means to receive and discharge strip material to be treated, first roll means including at least one first roll mounted for lateral translation within the chamber, second roll means including at least one second roll mounted for lateral translation without the chamber, said first and second roll means each being in strip-tension-supporting engagement with said strip material, means to guide said strip material toward and away from said heating chamber, means to translate said first roll means over at least one continuous range to vary the length of strip material within the heating chamber, stressed linkage means supporting said first and second roll means against strip tension and extending therebetween to cause strip-tension-supporting loads imposed on said linkage means by said first and second roll means to oppose each other, whereby said varying is accomplished independently of the degree of tensioning of said strip material.

2. In continuous and semi-continuous strip treating apparatus, a heat treating station comprising a heating chamber having port means to receive and discharge strip material to be treated, first roll means including at least one first roll mounted for lateral translation within the chamber, second roll means including at least one second roll mounted for lateral translation without the chamber, said first and second roll means each being in strip-tension-supporting engagement with said strip material, means to guide said strip material toward and away from said heating chamber, means to translate said first roll means over at least one continuous range to vary the length of strip material within the heating chamber, translatory motion coupling means coupling said first and second roll means for translation together in directions of opposite sense with reference to strip-tension-imposed loads on said roll means, whereby said varying is accomplished independently of the degree of tensioning of said strip material.

References Cited in the file of this patent

UNITED STATES PATENTS

1,150,609	Marette	Aug. 17, 1915
1,479,453	Carleton et al.	Jan. 1, 1924
1,543,368	Carrier	June 23, 1925
1,891,225	Fear	Dec. 20, 1932
2,082,411	Merrill	June 1, 1937
2,440,159	Stanley	Apr. 20, 1948
2,501,537	Parkes	Mar. 21, 1950