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MEANS AND METHOD FOR STRIP EDGE CONTROL

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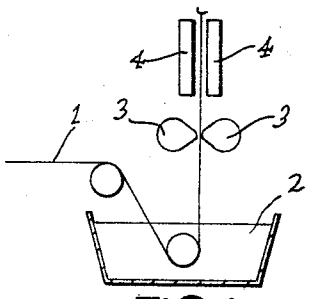


FIG.1

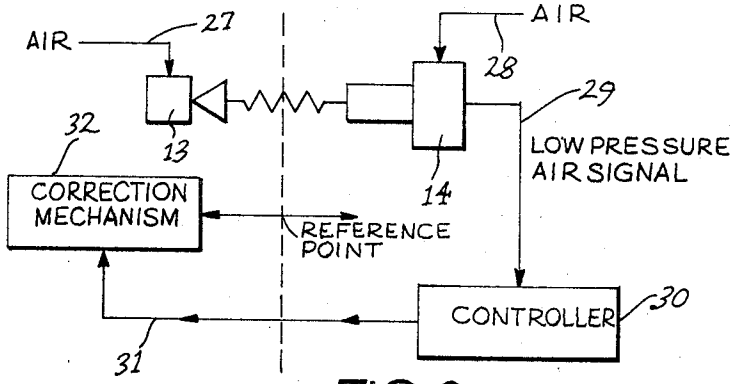


FIG. 2

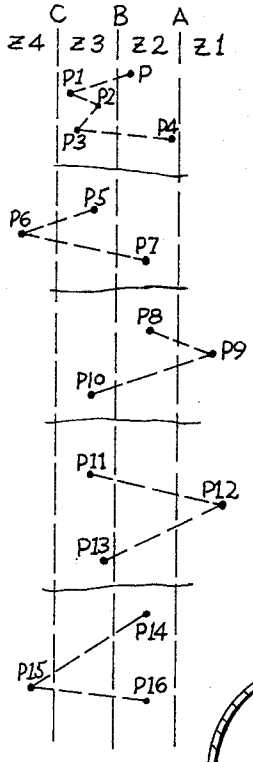


FIG.3

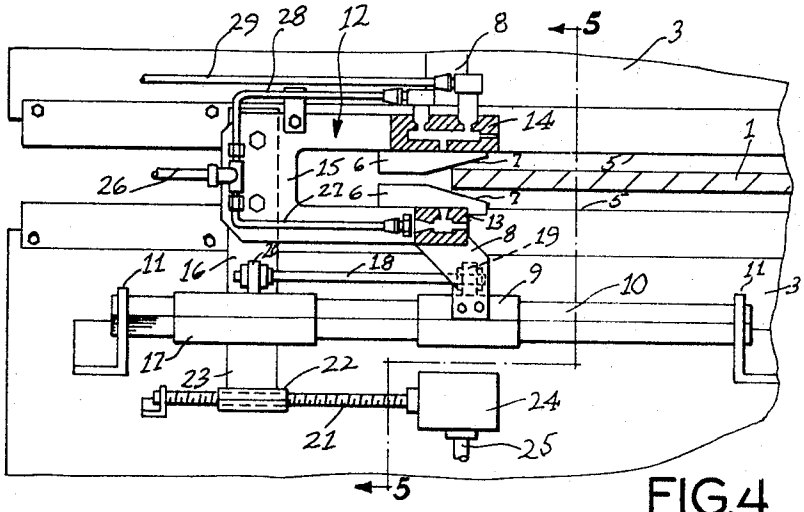


FIG.4

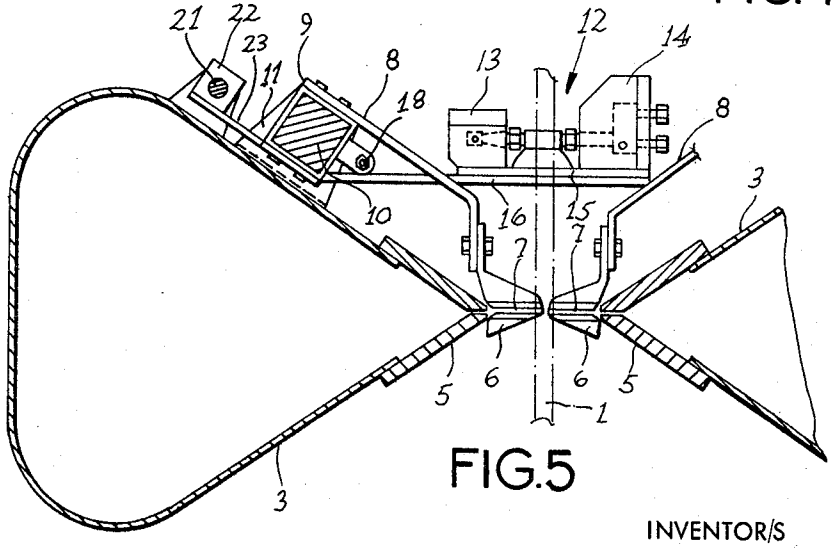


FIG.5

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MEANS AND METHOD FOR STRIP EDGE CONTROL

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U.S. Cl. 34—54 21 Claims

ABSTRACT OF THE DISCLOSURE

The sonic sensing of the position of a moving strip and the utilization of means actuated by a fluidic signal generated by a sonic sensor to effect relative correcting movement between the strip and an operating means positioned to act upon the strip.

BACKGROUND OF THE INVENTION

Various sensing means have hitherto been employed to monitor the position of a moving strip or web and initiate corrective movement of the strip should it move out of a predetermined path of travel. For example, photocells have been widely utilized for such purposes, the photocells and their coacting light sources being arranged so that variations in the position of the strip edge will result either in the energization or deenergization of the photocells, depending upon the system employed, the associated circuitry acting to energize mechanism operative to effect adjusting movement of the strip or web. Various mechanical sensing devices also have been employed which physically contact the strip, with variations in strip position sensed mechanically and corrective movement initiated.

There are, however, situations wherein sensing devices of the foregoing character cannot be effectively utilized, either because of the inability to mechanically contact the strip, as where it might carry a yet unsolidified coating, or where the sensing must take place in an environment which is adverse to the use of photocells or other electronic equipment, as where relatively high temperatures are encountered in the area wherein the sensing takes place.

While from the outset it is to be understood that the present invention may be utilized in diverse instances wherein accurate strip edge sensing is desired, it will be described in conjunction with the edge sensing of a continuously moving strip of steel as it emerges from a molten coating bath and is subjected to an air jet finishing operation to produce a smooth and uniformly coated sheet. While air jet finishing will be described, it will be understood that steam or other gases could be employed as the finishing medium. In the finishing operation, the coated strip travels upwardly between a pair of generally horizontally disposed air knives which extend the full width of the sheet and are arranged to direct continuous jets of air against the opposite sides of the sheet, the air jets acting to remove excess coating material and at the same time provide a smooth and uniform coating. In a finishing operation of this character, it also has been found desirable to provide angularly related nozzle extensions or edge vanes at the opposite ends of the air knives arranged to impinge upon the marginal edges of the strip to prevent the buildup of excess amounts of coating material which otherwise occurs along the marginal edges of the strip. Since the nozzle extensions must lie in close proximity to the edges of the strip, it will be evident that any variation in the path of travel of the strip must be detected and a correcting movement initiated in order to maintain the proper position of the

nozzle extensions or vanes relative to the edges of the strip.

It should be evident that under such circumstances the position of the strip edges must be sensed at a point in close proximity to the finishing means, which of necessity places the sensing device in an area where relatively high temperatures are encountered. This is a highly undesirable environment in which to use electronic sensing, such as photocells, and mechanical sensing means are equally ineffective due to the essentially molten condition of the coating at the time the sensing operation must take place.

The instant invention overcomes the foregoing difficulties by providing a strip edge sensing means and method which is insensitive to an adverse environment and which does not require mechanical contact with the strip being monitored. At the same time the invention provides a sensing procedure in which minor transient variations in strip position will be insufficient to initiate correctng movement thereby preventing unnecessary hunting or tracking by the device; yet at the same time, corrective movement will be initiated whenever the strip edge moves outside a pre-determined operating zone.

SUMMARY OF THE INVENTION

The present invention contemplates the use of a fluidic edge sensing device comprising a sensor composed of a high frequency acoustic whistle and a sound sensitive fluid receiver (fluidic ear) which generates fluid signals in the form of low pressure air signals induced by the application of sonic turbulence to the air flowing through the fluidic ear. The low pressure air signals are fed to a controller incorporating fluidic logic means which act through converters to actuate a correcting mechanism which either moves the strip or moves the sensor and its associated operating components, such as the nozzle extensions of the finishing means, relative to the strip. For example, pneumatic to electric converters may be employed to deliver control signals to an electric motor forming a part of the correcting mechanism, or the low pressure air signals may be used directly to control a high pressure air cylinder forming a part of the correcting mechanism.

In a preferred embodiment of the invention, the fluidic sensor will be mounted on an adjustable support by means of which it may be accurately positioned relative to the path of travel of the strip. In the event the operating components associated with the strip are to be moved relative to the strip, as where the nozzle extensions or edge vanes of the air knives are to be shifted relative to the strip, the support for the fluidic sensor may comprise a part of the support for the nozzle extensions, the arrangement being such that the nozzles and the sensor will move in unison. Where the path of travel of the strip is to be altered, as by the use of adjustable feed rolls or strip deflection means, the fluidic sensor may be mounted on a stationary support. In order to prevent hunting or tracking due to minor transient variations in strip edge position, it is preferred to program the controller to establish a series of operating zones or regions through which the strip edge passes, correcting movement being initiated only upon movement of the strip edge from a pre-established operating zone into adjoining correction zones.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic side elevational view of metallic coating line with which the instant invention may be utilized.

FIG. 2 is a diagrammatic representation of a control system in accordance with the instant invention.

FIG. 3 is a diagram illustrating movement of the strip edge between the operating zones and the correction zones.

FIG. 4 is a fragmentary plan view illustrating the

fluidic sensor associated with the air knives and nozzle extensions utilized in a coating operation of the type illustrated in FIG. 1.

FIG. 5 is a vertical sectional view taken along the irregular line 5—5 of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As previously indicated, while the utility of the invention is not so limited, it will be described in conjunction with a coating line wherein a continuously moving steel strip is emersed in a molten coating bath and, as the strip emerges from the bath, it is subjected to a finishing operation wherein excess coating material is removed and the remaining coating doctored to a smooth and uniform condition by the action of an opposing pair of air knives.

The basic operation is schematically illustrated in FIG. 1 of the drawings wherein the metallic strip **1** is introduced into a molten coating bath **2** from which it travels upwardly between the air knives **3** which perform the finishing operation, whereupon the coated sheet is usually subjected to the action of one or more sets of gas burners **4** which serve to control the cooling of the coating.

Referring next to FIGS. 4 and 5, each of the air knives **3** comprises a conventional fluid jet nozzle of the type widely used in the coating industry. One embodiment of such nozzle is described in detail in U.S. Pat. No. 3,314,-163. The nozzle will be supplied with air under pressure from a suitable source (not shown) and will direct an elongated stream of air transversely of the moving strip **1** through the elongated discharge opening **5**. The nozzle extensions or edge vanes **6** are provided at the opposite ends of the strip, the extensions each having a slot **7** aligned with the discharge opening **5** of the adjoining air knife **3**. The nozzle extensions serve to reduce the distance between the coated strip **1** and the discharge openings **5** of the air knives in relatively narrow zones adjacent the edges of the strip. The extensions thus serve to increase the wiping action along the edges of the strip where excessive coating thicknesses have been found to occur. It will be evident, however, that should the path of travel of the strip vary, a correcting movement must be instituted in order to maintain the strip edges in the proper position relative to the nozzle extensions.

In the embodiment illustrated, each of the nozzle extensions **6** is mounted on an arm **8** secured to a sleeve **9** slidable along rod **10** secured at its opposite ends to supports **11** which may be conveniently affixed to the body of the air knife. It will be evident that the nozzle extensions may be adjusted relative to the strip **1** by sliding them along the rod **10**. The opposing pairs of nozzle extensions may be individually adjusted, although it is preferred to interconnect them for joint movement.

In accordance with the invention, the necessity for adjusting movement of the nozzle extensions is determined by the sonic strip edge sensor indicated generally at **12** which is a fluidic sensing device having a high frequency acoustic whistle **13** and a sound sensitive fluid receiver or fluidic ear **14**. The acoustic whistle and fluidic ear are of known construction and are mounted on the opposite arms of a yoke **15** secured to a bracket **16** which is attached at its outermost end to a sleeve **17** slidably secured to the rod **10**. Thus, the yoke and the sensor mounted thereon may be adjusted relative to the end edge of the strip **1** by sliding the assembly along rod **10**.

Preferably the sensor **12** and the nozzle extensions **6** will be interconnected for joint movement; and to this end they may be joined by an adjustment rod **18** the opposite ends of which are connected by adjustment bolts to the ears **19** and **20** secured to the sleeves **9** and **17**, respectively. The edge vanes and the sensor may thus be initially adjusted relative to each other and to the strip edge, whereupon they may be moved in unison to compensate for variations in the position of the strip. Such adjusting movement may be made by means of the threaded shaft **21** operatively connected to sleeve **17** through internally threaded block **22** and bracket **23**. The threaded shaft may be rotated in opposite direction by means of gear box **24** which will be connected through drive shaft **25** to a suitable prime mover (not shown).

The sonic sensor **12** operates on low pressure air supplied through conduit **26**, there being a branch conduit **27** connected to the acoustic whistle **13** and a branch conduit **28** connected to the fluidic ear **14**. As the air under pressure flows through the acoustic whistle, high frequency sound waves are generated which are beamed toward the fluidic ear **14** wherein the sound waves create turbulence in a stream of air flowing through the ear. A normal turbulence results in the controlled discharge of air at a reduced pressure from the fluidic ear through controller conduit **29**. The air signal thus generated is delivered by the conduit **29** to the fluidic controller **30** diagrammatically illustrated in FIG. 2. The controller contains a fluidic logic board which is responsive to the signals generated by the fluidic ear. Thus, when the sonic waves generated by the whistle **13** are interrupted, as by the movement of the strip edge in the path of the sonic waves, the turbulence induced in the air flowing through the fluidic ear will be altered with a resultant variation in the fluid signals generated by the fluidic ear and delivered to the controller. The new signals act through the fluidic logic board to activate pneumatic-to-electric converters which are operatively connected through circuit means **31** to the correction mechanism **32** which includes the prime mover or other drive means operatively connected to drive shaft **25**. Adjusting movement is thus effected relative to a reference point established by the initial adjustment of the sensor relative to the edge of the strip.

Since the air signals generated by the fluidic ear will vary as the strip edge position varies from a given reference point, it is possible to program the fluidic logic board in the controller to initiate corrective movement only when the strip edge moves outside of a pre-determined region relative to a selected reference point. For example, in a coating line of the character under consideration, corrective signals are generated only when the strip edge moves outside of a one-eighth inch zone. Thus, tracking or hunting is avoided when transient or minor variations occur in strip edge position.

The zone control of strip edge position is diagrammatically illustrated in FIG. 3. As seen therein, the lines A, B and C are reference lines defining zones Z1, Z2, Z3 and Z4. The zones Z2 and Z3 may be defined as the operating zones, lying to each side of reference line B which may be taken to comprise the reference point of the strip edge if precisely in its desired path of travel. Normally, however, the strip edge will lie to one side or the other of reference line B. As the strip advances, the strip edge may cross back and forth between zones Z2 and Z3 without initiating correcting movement. Thus, if reference point P represents the initial position of the strip edge within the operating zone Z2, the position of the strip edge may fluctuate back and forth anywhere within the operating zones Z2 and Z3, as diagrammatically illustrated by the reference points P1, P2, P3 and P4 without initiating correcting movement of the correction mechanism.

If, however, the strip edge position crosses either of the reference lines A or C so as to enter either zone Z1 or zone Z4, then correcting movement will be initiated. Thus, if the strip moves from reference point P5 to point P6, thus crossing reference line C and entering zone 4, correcting movement will be initiated so as to return the strip edge to the point P7. It will be noted that the strip edge has crossed two adjoining reference lines during the correcting movement—it has not merely moved from zone Z4 across reference line C to zone Z3, but rather is brought back to zone Z2, thereby assuring that the strip edge is well removed from the reference line C and hence will not track back and forth between zones

Z3 and Z4 should minor transient variations in strip position subsequently occur.

Similar considerations apply should the strip edge move in the opposite direction from the operating zone Z2 across reference line A into correction zone Z1. Thus, should the strip edge move from point P8 to point P9, correcting movement will be initiated to return the strip edge to the point P10, the strip edge thus crossing both reference lines A and B and hence traveling through operating zone Z2 and entering operating zone Z3.

If the strip edge initially lies in operating zone Z3, as indicated by point P11, and subsequently moves through operating zone Z2 and into correction zone Z1, as indicated by the point P12, correcting movement will be initiated returning the strip edge to operating zone Z3, as indicated by point P13. In similar fashion, if the strip edge moves from operating zone Z2, as indicated by point P14, through operating zone Z3 and into correction zone Z4, as indicated by the point P15, correcting movement will be initiated to return the strip edge to operating zone Z2, as indicated by the point P16.

It will thus be evident that adjusting movement of the strip edge position will be stabilized under all conditions of use to the elimination of hunting or tracking which might otherwise occur. The widths of the operating zones Z2 and Z3 may be chosen to suit the conditions of use. For example, where the sensor is monitoring coated strip, the reference lines A, B and C will be each spaced apart by a distance of one-sixteenth inch, thereby providing an operating zone of one-eighth inch, with correcting movement being initiated whenever the strip edge deviates outside the one-eighth inch operating zone.

The invention thus provides for the sonic sensing of strip edge position utilizing a sensing mechanism which is of simple yet rugged construction, the sonic whistle and the sonic receiver of fluidic ear being usable in environments where relatively high temperatures are encountered. In addition, the sonic sensing equipment is less expensive than its electronic counterparts and requires substantially less maintenance in use.

It is to be understood that various modifications may be made in the invention without departing from its spirit and purpose. The invention has been described as applied to a coating line for applying molten metal to steel sheets, yet it will be readily apparent that the invention will have utility in diverse applications wherein the edges of a moving strip are to be maintained in a pre-determined path of travel, the arrangement being such that relative correcting movement will be initiated upon deviation of the strip from its pre-determined path of travel by any pre-selected increment.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In apparatus for sensing the position of a moving strip edge;

a sonic sensor comprising a sonic transmitter capable of generating sonic vibrations and a sonic receiver capable of receiving sonic vibrations and converting them into fluid signals,

adjustable means mounting said sonic transmitter and said sonic receiver on opposite sides of a moving strip adjacent an edge thereof, said sonic transmitter being positioned to direct sonic vibrations toward said sonic receiver,

a controller operatively connected to said sonic receiver, said controller including actuating means responsive to variations in fluid signals generated by said sonic receiver, and

a correction mechanism operatively connected to said controller, said correction mechanism including means operable by said actuating means to effect relative adjusting movement between the strip edge and said sonic sensor upon deviation of said strip edge from a predetermined path of travel.

2. The apparatus claimed in claim 1 wherein the adjustable means mounting said sonic transmitter and said sonic receiver comprises a yoke having its opposing arms lying on opposite sides of the strip, with the sonic transmitter mounted on one of said arms and said sonic receiver on the other of said arms, and bracket means mounting said yoke for movement parallel to the plane of the strip.

3. The apparatus claimed in claim 2 wherein said bracket means connects said yoke to a sleeve member, said sleeve member being slidably mounted on a supporting rod mounted in parallel relation to the plane of the strip and transverse to its path of travel.

4. The apparatus claimed in claim 3 wherein the means operative to effect relative adjusting movement between the strip edge and said sonic sensor comprises means operative to move said sleeve relative to the rod on which it is slidably mounted.

5. The apparatus claimed in claim 1 wherein said sonic sensor is operatively connected to and jointly movable with a mechanism acting upon the strip.

6. The apparatus claimed in claim 5 including adjustment means for effecting relative adjustment between said sonic sensor and the mechanism acting on the strip.

7. In apparatus for sensing the position of a moving strip edge relative to a predetermined path of travel, including means for effecting relative adjusting movement of the strip when its edge deviates from its predetermined path of travel,

a sonic sensor comprising a sonic transmitter and a sonic receiver capable of converting sonic vibrations into fluid signals,

means mounting said sonic transmitter and said sonic receiver on opposite sides of a moving strip adjacent an edge thereof, said sonic transmitter being positioned to direct sonic vibrations toward said sonic receiver, and

adjustment means for moving said mounting means toward and away from said strip edge in a plane substantially normal to the plane of the said strip, whereby said sonic transmitter and said sonic receiver may be accurately aligned relative to the predetermined path of travel of said strip edge.

8. The apparatus claimed in claim 7 wherein said mounting means comprises a yoke having an opposing pair of arms lying on opposite sides of the path of travel of the said strip, and means operatively connected to said sonic sensor to move it relative to said strip edge upon deviation thereof from its predetermined path of travel.

9. In apparatus for sensing the position of an edge of a moving strip of metal as it emerges from a molten coating bath and is subjected to the action of a finishing means,

a sonic sensor comprising a sonic transmitter and a sonic receiver capable of converting sonic vibrations into fluid signals,

means adjustably mounting said sensor with said sonic transmitter and said sonic receiver on opposite sides of the moving strip adjacent an edge thereof, and

means responsive to fluid signal generated by said sonic transmitter upon movement of said strip edge from a predetermined path of travel to effect relative adjusting movement between said strip edge and said sonic sensor.

10. The apparatus claimed in claim 9 wherein said finishing means includes means movable relative to said strip edge, and actuating means for moving said last named means in response to the signals generated by said sonic sensor.

11. The apparatus claimed in claim 10 wherein said finishing means comprises an air knife, wherein the means movable relative to said strip edge comprises an adjustable edge vane, wherein said edge vane is operatively connected to said sensor for joint movement therewith.

12. A method for sensing the position of an edge of a moving strip which comprises the steps of

establishing a path of travel for an edge of said strip,

beaming sonic vibrations between a sonic transmitter and a sonic receiver lying on opposite sides of said strip, with said sonic vibrations passing through said path of travel,

and causing variations in said sonic vibrations produced by lateral movement of the strip edge from its said path of travel to effect corrective movement to restore said strip edge to said path of travel.

13. The method claimed in claim 12 including the steps of establishing a predetermined width for said path of travel and dividing it medially into a pair of adjoining operating zones, establishing correction zones to the outside of each operating zone, and upon deviation of the strip edge from either operating zone into the adjoining correction zone, effecting corrective movement of the strip edge from the said correction zone into the remote operating zone.

14. The method claimed in claim 13 wherein the said operating zones each has a width of about 1/16 inch.

15. The method claimed in claim 12 including the step of converting the received sonic vibrations into fluid signals, and causing said fluid signals to effect corrective movement of said strip edge.

16. The method of claim 15 including the step of converting said fluid signals into electrical signals and causing electrically operated corrective means to return said strip edge to its said path of travel.

17. The method claimed in claim 12 wherein said corrective movement is effected by jointly displacing said sonic transmitter and said sonic sensor relative to said strip edge.

18. A method for detecting deviations of the edge of a moving strip relative to a selected path of travel and for effecting corrective movement between said strip edge and said path of travel when deviations occur, which comprises the steps of generating sonic vibrations which intersect the edge of the moving strip and are varied by the strip as its edge deviates from its selected path

of travel, monitoring said sonic vibrations, and effecting relative corrective moving in accordance with variations in the monitored vibrations.

19. The method claimed in claim 18 including the step of converting the monitored sonic vibrations into fluid signals which vary with the variations in said sonic vibrations, and causing said fluid signals to effect relative corrective movement between said strip edge and its said path of travel.

20. The method claimed in claim 19 including the step of establishing an operating zone within which deviations of the strip edge from its selected path of travel will be insufficient to generate fluid signals operative to effect relative corrective movement between said strip edge and its said path of travel, and a correction zone lying on each side of said operating zone, whereby deviations of the strip into either of said correction zones will act to generate fluid signals operative to effect relative connecting movement between said strip edge and its said path of travel.

21. The method claimed in claim 20 including the step of dividing said operating zone into two side-by-side parts and, when said strip edge moves into either of said correction zones, initiating corrective movement sufficient to move the said strip edge into the remote part of said operating zone.

References Cited

UNITED STATES PATENTS

3,071,157	1/1963	Robertson et al.	226—22 XR
3,151,197	9/1964	Schultz	34—54 XR
3,214,845	11/1965	Huffman.	
3,240,410	3/1966	Jacobsen	226—22 XR
3,314,163	4/1967	Kohler	34—155
3,383,239	5/1968	Christman	34—155 XR

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