APPROXIMATE AND METHOD FOR CONTROLLING ACCELERATED COOLING OF HOT ROLLED STRIP MATERIAL
30 Claim, 4 Drawing Figs.

ABSTRACT: Cooling of hot rolled strip material, such as low carbon steel strip, is controlled while the strip moves along a rolling mill runout table. The table is provided with a plurality of selectable spray banks, each bank applying the same unit amount of liquid coolant from a low pressure source. A time-sharing mill computer receiving operating information signals selects a number of spray banks based on a feed forward calculation of a cooling factor and a calculation of a predicted cooling error term, the latter term being based on stored signals from previous strips cooled. Control means, including a full time special purpose computer, establishes the minimal unit amount of coolant application. When spray bank selection is held constant, this computer takes over the control function and varies the minimal unit amount of coolant proportional to strip velocity error and strip discharging temperature error during strip cooling.
APPARATUS AND METHOD FOR CONTROLLING ACCELERATED COOLING OF HOT ROLLED STRIP MATERIAL

BACKGROUND OF THE INVENTION

This invention relates broadly to cooling apparatus and method. More specifically, it relates to apparatus and method for controlling accelerated cooling of hot roller strip material while moving along a hot runout table.

Although applicable to a plurality of strip materials, the present invention will be described for illustrative purposes in connection with controlling accelerated cooling of hot rolled steel strip to obtain a predetermined cooling temperature within narrow limits, thereby improving strip toughness and refining its grain structure to higher degrees of uniformity than heretofore attainable.

Contemporary steel strip mills generally include an accelerating type of hot strip rolling mill where hot slabs are reduced to hot strip material that travels at speeds up to 5000 f.p.m. The hot strip is immediately cooled along a runout table by spray nozzles and water, banks, water valves, closed spray nozzles or other water on the hot strip passes through a plurality of different spray cooling zones. Each zone differs in the amount of pressure and coolant sprayed onto the strip. In some installations, coolant is applied at the rate of up to tens of thousands of gallons per minute per pressures ranging up to 350 p.s.i.

Also included in such installations is an electronic time-sharing computer which, after performing slabling and rolling control functions, sequentially monitors and controls each spray cooling zone to attain a desired temperature of the strip while leaving the runout table. The cooling control function is performed by the computer after receiving operating signals from numerous information input sources. Such sources include punched cards or tapes of desired mill setup data, and a variety of actual measured variables pertaining to strip thickness, velocity, finishing and cooling temperatures, ambient and coolant temperatures, etc.

In the prior art practice, this computer uses the operating signals in repetitive calculations involving complex, but conventional, heat transfer equations to produce control signals which are applied to each spray cooling zone. Computation of the heat transfer equations are performed each time a new strip is to be cooled and again each time any of the parameters in the equations varies while a given strip is being cooled. This practice has advantages in certain installations but has not gained universal acceptance in others for several reasons. First, it requires comprehensive computer and control equipment for each spray cooling zone which is expensive initially and time consuming to program and maintain. Second, the very nature of the repetitive computing process slows down both current and future computations involving the complex heat transfer equations for spray cooling control, as well as for other time-sharing control functions, thus limiting or otherwise lowering mill operating pace. Third, the use of conventional heat transfer equations does not consider many sources of both short and long term errors which affect runout table cooling efficiency. Such sources of error include variations in cooling spray pressure and atomization, worn valves, closed spray nozzles, erratic controllers, and others, which affect spray cooling. In addition to the foregoing, there are well known disadvantages associated with medium and high-pressure spray equipment which in precision control systems affect its operation and reliability.

SUMMARY OF THE INVENTION

One of the objects of this invention is to provide an improved method and apparatus for controlling accelerated cooling of hot rolled strip material in a single low-pressure cooling zone of variable length.

Another object of this invention is to provide an improved method and apparatus for controlling accelerated cooling of hot rolled strip material in a single low-pressure cooling zone of variable length.

Still another object of this invention is to provide an improved method and apparatus for controlling accelerated cooling of hot rolled strip material in which a high degree of flexibility is achieved in applying liquid coolant to the strip.

Another object of this invention is to provide an improved method and apparatus for controlling accelerated cooling of hot rolled strip material in which a portion of a variable length spray cooling zone is fixed in relation to a runout table cooling factor and an optional term covering different sources of errors.

Other and further objects of this invention will become apparent during the course of the following description and by reference to the accompanying drawings and the appended claims.

We have discovered that the foregoing objects can be attained by passing hot rolled strip material along a runout table, by establishing a variable length spray cooling zone having a plurality of selectable spray banks spaced along the runout table, by determining a runout table cooling factor and an optional cooling error term by computer means where both computations are based on variable operating information by selecting a predetermined number of spray banks based on the cooling factor and optional cooling error term when assuming a minimal unit amount of liquid coolant is applied to each of the spray banks selected, by establishing the minimal unit amount of liquid coolant applied by each spray bank selected, and by controlling coolant flow rate when spray bank selection is held constant by varying the minimal unit amount of coolant applied in proportion to predetermined values of strip velocity errors, and/or strip discharging temperature errors.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic side elevation of one apparatus embodiment of the invention which incorporates a block diagram of a computer control system and illustrates a hot runout table adjacent the last three finishing stands of a hot strip rolling mill. The runout table having a single cooling zone made up of a plurality of top and bottom selectable spray banks, the spray banks being associated with coolant controllers which are selected and varied by separate computers. FIG. 2 is a diagrammatic vertical cross section of the runout table showing top and bottom spray bank nozzles, taken along the line 2-2 of FIG. 1. FIG. 3 is a block diagram of the spray bank selection computer shown in FIG. 1. FIG. 4 is a block diagram of the coolant flow rate computer shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1 and 2, strip 10 is seen passing through the last three finishing stands F1, F2, F3, of a seven stand accelerating type of hot strip rolling mill 11. In this particular mill stand F3 is considered a pivot stand, i.e., one about which thickness and speed setting for the other stands are referred to when making operating changes in the mill.

Strip 10 is immediately discharged from accelerating mill 11 onto hot runout table 12 where a plurality of powered rolls 13 convey strip 10 to the feed end of the spray banks 14. From there strip 10 is passed through pinch rolls 14 and wound on coil 15. Rolls 13 and 14 and coil 15 are all driven in synchronism with mill 11 so that when mill 11 accelerates or decelerates they all change speed correspondingly.

Dimensions of runout table 12 vary according to the type of material to be cooled plus numerous other factors dictated by individual installations. However, as a practical example of one embodiment, a suitable runout table for cooling low carbon steel strip of up to 0.500 inch thick from 1600° F. to about 1100° F. while traveling at speeds up to about 5000 f.p.m., is approximately 455 feet long. This consists of a first variable length radiation cooling zone at least 30 feet long, a variable length liquid spray cooling zone not more than 265 feet long and a second variable length radiation cooling zone at least
Spray cooling means 16 has ten whole and fractional selectable spray banks with top and bottom sections located in the spray cooling zone. The number of spray banks installed in this zone is governed by the unit amount and pressure of coolant applied to the strip. Means 16 delivers up to 45,000 g.p.m. of water, or other suitable liquid coolant, to the top side of strip 10, and up to 15,000 g.p.m. to the bottom side of strip, for a total of up to 60,000 g.p.m. The coolant is applied at pressures of less than about 10 p.s.i., each top section having a minimal pressure of 1 p.s.i. which is varied up to about 6 p.s.i., and each bottom section having a fixed nominal pressure of about 2.2 p.s.i. and adjustable up to about 10 p.s.i.

Spray cooling means 16 is comprised of 10 selectable top section spray banks 17—26, bank 26 being divided into quarter-banks for convenience of coolant selectability, and each fractional bank is further identified as a, b, c, d, respectively; 10 selectable bottom section spray banks 27—36, a whole bank being considered as corresponding top and bottom sections such as 17 and 27, and a pump 37 associated with recirculating source of cooling water (not shown). Pressurized coolant is fed over supply conduit 38 by way of powered control valve 40, each top and bottom section having associated therewith a manner, coolant is fed through powered control valves 38, which is the same as valve 39, to fractional spray banks 26a, and through powered dual control valves 48a, 48b, 48c, 48d, which have two separate flow paths and are similar to valve 39, then to fractional spray banks 26a, 26c, 26d, respectively. In addition, pressurized coolant is also fed over supply conduit 38 through powered control valves 49—58 to each bottom section spray bank 27—36.

Referring to FIG 2 and the above noted exemplary embodiment, each top section spray bank 17—25 consists of a manifold 59 connected to a respective valve 39—47, and includes eight headers 60 spaced 3 feet apart longitudinally, each header 60 being fitted with zero-angle nozzles 61 spaced 3 inches apart laterally so to as to apply relatively solid streams of coolant vertically to strip 10. Top section spray bank 26 is constructed the same as banks 17—25, except that valve 48a is connected to manifold 59 and directly to a first pair of headers 60, and valves 48b, 48c, 48d are connected between manifold 59 and second, third and fourth pairs of headers 60, respectively. Each bottom section 27—36 comprises a manifold 62 connected to a respective valve 49—58, and includes eight headers 63 spaced between table rollers 13 and under headers 60, each header 63 being fitted with conventional flat pattern V-jet spray nozzles 64 spaced 5 inches apart laterally and directed vertically to strip 10.

It is apparent from the apparatus described thus far that strip material 18 is conveyed from mill 11 along runout table 12, is passed through a variable length spray cooling zone consisting of spray banks 17—36 at either a constant or a variable speed, and is subjected to accelerated cooling to a desired discharge temperature in a continuous and uninterrupted operation. As noted above, there are a number of variables affecting the amount of coolant which is required to take place along runout table 12. Hence, the effects of such variables must be considered continuously in determining the correct amount of coolant to be applied to strip 10 at all times.

With the foregoing in mind, the apparatus of the present invention incorporates as a major feature a control system comprising a spray bank selection computer 65, including operator's console 66 and spray pattern indicator 67; mill setup information signal source 68; operating information signal input sources 69, 70, 71, 72, 73, 74, 75; a coolant flow rate computer 76; and flow controllers 77—86 and 87—96 which receive selection and control signals from computers 65, 76, and which operate on control valves 39—48a and 49—58 associated with top and bottom sections of spray banks 17—26a, b, c, d and 27—36 respectively. The variables of these components are placed in different operating modes as described below, the control system provides for selecting and continuously monitoring and adjusting coolant flow controllers responsive to fluctuations in predetermined operating information signals and to compensate for changes in cooling system efficiency.

It will be apparent that operating modes derivable from the combination of elements in the above-noted control system are innumerable. We have found the following four modes of operation advantageous from the standpoint of production capacity of strip having improved properties by virtue of controlling coolant application through:

1. varying the spray cooling zone length, by varying spray bank selection proportional to a computed cooling factor having variable terms including strip velocity and strip temperatures when entering and leaving the runout table, while applying constant but separate minimal unit amounts of coolant to each top and bottom section of spray banks selected;
2. modifying the spray cooling zone length proportional to a computed runout table cooling error term when combined with the cooling factor;
3. establishing a fixed length spray cooling zone, by maintaining a spray bank selection based proportionally on a computed cooling factor having variable terms including strip velocity and strip temperatures when entering and leaving the runout table, while applying a constant unit amount of coolant to each bottom spray bank selected, and while varying a minimal unit amount of coolant applied by each top spray bank selected proportional to strip velocity, or strip velocity and or more strip temperatures when leaving the spray bank region and/or the runout table;
4. modifying the minimal unit amount of coolant applied by each top spray bank selected in mode 3 proportional to a computed cooling error term and further varying the rate at which the minimal unit amount of coolant application is changed proportional to strip velocity error.

Referring to the drawings, particularly to FIGS. 1, 3 and 4, there is shown computer 65, an electronic time-sharing mill computer which, in addition to computing slabbing and rolling mill control functions, performs spray cooling selection and control functions. The latter functions are the only ones described herein.

Spray bank selection computer 65 operation is initiated from the operator's console 66, and is oriented to a solution in which each 66a to a position corresponding to one of the four modes described above. This starts programmer 97 to bid for information from source 68. Mill setup information signals are sent from source 65 over leads 98—104 through arithmetic unit 105 to data processor 106. Signals sent over leads 98—100 pertain to desired values of strip velocity V, and to strip temperatures entering and leaving the runout table, T1 and T2 respectively. Signals on leads 101, 102 pertain to predetermined fixed values of strip thickness H, and to strip grade, or composition, which also reflects thermal properties of the material, respectively. In the present invention, it is presumed that strip thickness specifications are met before cooling requirements are determined and for this reason the value of H is considered substantially constant for each strip discharging from mill 11. Signals on leads 103, 104 are command signals indicating that the signals sent over leads 98—102 represent mill setup information for the current strip, and the next strip, respectively.

Data processor 106, which consists of conventional analog-to-digital and digital-to-analog conversion devices and other signal processing components, upon suitable instructions from programmer 97 directs selected information signals from leads 98—104 to calculating devices 107—110 in arithmetic unit 105, to memory device 111, and to spray bank selector 112.

In addition to mill setup information signals being sent to data processor 106, a number of measured variables and other output 17—36, respectively. Receiving information signals are transmitted thereto from sources 69—73.

Source 69, a total radiation optical pyrometer located ahead of stand Fs, sends a signal designated measured T1 over lead 113 to a companion high speed recorder 114. Recorder
114 includes a transmitting slidewire and a switch (not shown) having a predetermined temperature related contact closure. These devices respectively send a measured \( T_s \) signal and a hot strip presence signal at \( F_s \) over leads 115, 116 to device 106 for subsequent use in calculator 108.

It should be noted that because of the high strip velocities to be dealt with and a predetermined time constant for parameter sensing, cooling factor computation, spray bank selection, and activation of massive coolant control elements, it may be necessary to locate signal sources 69–72 in the vicinity of mill 11 as shown in FIG. 1. Under more favorable operating conditions, these sources could be located as close as the beginning of runout table 12 where \( T_s \) is shown in the dotted line. The main consideration is that coolant application be initiated at all times prior to the leading edge of strip 10 entering the spray cooling zone.

Source 70, a strip velocity tachometer, located on pivot stand \( F_s \), sends a signal indicated as \( V_s \) over lead 117 to multiplier 118 where it is multiplied by a factor of \( K \) to equal the increased velocity of the strip in final stand \( F_s \). The output of multiplier is designated \( V \) and is sent over lead 119 to data processor 106 and computer 76.

Source 71, a load switch located on stand \( F_s \), sends a signal designated \( L_s \) over lead 120 to device 106 and computer 76 for the duration strip 10 is in stand \( F_s \).

Source 72, a load switch located on stand \( F_s \), sends a signal designated \( L_s \) over lead 121 to data processor 106.

Source 73, a total radiation pyrometer located at the discharge end of runout table 12, sends a signal designated \( T_e \) over lead 122 to a companion high speed recorder 123 which is equipped with a transmitting slidewire and switch the same as recorder 114. These devices respectively send a measured \( T_e \) signal, and a hot strip presence signal at the end of the runout table, over leads 124, 125 to device 106 and computer 76.

Data processor 106, upon suitable instructions from programmer 97 also directs selected information, signals from leads 115, 116, 119, 120, 121, 124, 125 to other components of arithmetic unit 105. In addition, it sends a desired \( T_e \) signal over lead 126 to computer 76.

A principle feature of the control system is the computation of a runout table cooling factor signal which considers the cooling requirements for strip 10 of a variable length spray cooling zone as well as a predetermined cooling effect of both radiation cooling zones. This is done in computer 65, not by repetitive calculations of conventional heat transfer equations immediately prior to and during the strip cooling, but by a single calculation using a unique equation during any of the aforementioned operating modes. This equation has three significant variables, namely, \( V \), \( T_e \), \( T \), and a number of predetermined constants. Each predetermined constant represents one or more presolved portions of complex heat transfer equations wherein each different strip thickness and grade, and other parameters, are considered to be constant during cooling of strip 10.

The aforementioned constants, together with other predetermined constants, are computed off-line long prior to cooling without involving computer 65 and are stored in tabular form in device 111. These stored constants are called up as instructed by programmer 97 in relation to a strip thickness \( H \) and grade signals sent over leads 101, 102 and command signals over leads 103, 104. Numerical values of constants suitable for use in the computations below are given by way of example for low carbon steel strip in Table 1 below.

The cooling factor signal is computed in calculator 107 on the assumptions that a minimal unit amount of coolant is applied by spray banks to be selected and that the predetermined cooling effects of both radiation cooling zones varies inversely with the spray cooling effects. Calculator 107 is arranged to cause the cooling factor signal to vary according to the equation:

\[
MS = K_s + K_H V/I(TF)(F_c) + K_T + K_T + K_H V + K_H F(F_c) + K_T + K_T + K_H V
\]

wherein

\[
MS = \text{runout table cooling factor}
\]

\[
V = \text{velocity of strip in feet per minute}
\]

\[
H = \text{thickness of strip in thousandths of inches, (fixed value)}
\]

\[
I = \text{Natural logarithm}
\]

\[
T_f = \text{temperature of strip entering runout table, } ^\circ \text{F}
\]

\[
T_e = \text{temperature of strip leaving runout table, } ^\circ \text{F}
\]

\[
K_s \text{ to } K_T = \text{predetermined constants listed in Table 1 below}
\]

It is to be noted that the seven terms in equation (1), including the numerical values of associated constants \( K \) exemplified in Table 1 below, should be used where highly accurate spray bank selection is desired. Where less accuracy of selection is satisfactory fewer terms are permissible, the first two terms being essential and additional terms being optional. However, when less than seven terms are used in equation (1) different numerical values are assigned to associated constants \( K \) than those values listed in Table 1 below. Thus, it will be recognized that by using equation (1) computer 65 construction and operation is greatly simplified, and the online time required for spray cooling calculations is greatly reduced, as compared to prior art apparatus.

When strip 10 enters stand \( F_s \), signal \( L_s \) causes desired values of \( V \), \( T_e \), \( T \), to be used in calculator 107 to produce an initial cooling factor signal at lead 127. This signal is applied through memory device 128 and algebraic summing device 129 to logic device 130 in spray bank selector 112, where it establishes an initial spray bank selection which is described below.

As the leading end of strip 10 passes source 69, a \( T_e \) signal is generated and appears at lead 115. If source 69 were located at the dotted line position in FIG. 1, this signal could be applied directly to calculator 107. However, since source 69 was located at stand \( F_s \) a computation of \( T_e \) at the entry to runout table 12 must be made. To this end the signal appearing at lead 115 is applied to calculator 108 when a signal appears at lead 116 to compute a \( T_e \) signal according to the equation:

\[
T_e = K_0 + K_s H + K_{v} \text{ where (2)}
\]

\[
T_e = \text{predicted temperature of strip entering runout table, } ^\circ \text{F}
\]

\[
V = \text{velocity of strip, measured, feet per minute}
\]

\[
H = \text{thickness of strip in thousandths of inches, (fixed value)}
\]

\[
K_0 = \text{measured temperature of strip at stand } F_s, ^\circ \text{F}
\]

\[
K_s \text{ to } K_{v} = \text{predetermined constants listed in Table 1 above}
\]

The resulting \( T_e \) signal is fed from calculator 108 to calculator 107 for use as an equivalent of a measured value of \( T_e \) in computing the cooling factor signal according to equation (1) above.

When strip 10 enters stand \( F_s \), the \( L_s \) signal causes measured values of \( V \), \( T_e \), and desired values of \( T_c \) to be programmed into calculator 107 to reproduce a cooling factor signal if actual operating conditions differ from desired conditions. This signal establishes a new spray bank selection, if required, based on operating conditions prevailing at the instant strip 10 entered stand \( F_s \).

Under separating mode 1, the cooling factor signal is permitted to vary responsive to changes in \( V \), \( T_e \), \( T_c \), thus causing spray bank selection and the length of the spray cooling zone.
to vary correspondingly. However, under operating mode 3, both an initial and a final cooling factor calculation are made responsive to LS1, LS2 signals as described above, the final calculation signal being held in memory device 128 responsive to the LS signal, thereby maintaining spray bank selection at a fixed value while coolant application is varied responsive to changes in \( V \), \( Tc \) as described below.

Another important feature of the control system is the computation of a runout table predicted cooling error signal which considers both short and long term error sources in terms of runout table cooling efficiency. None of the sources of error are measured but are considered in relation to the amount of \( Tc \) error. Such sources include variations in atmospheric conditions, coolant temperature and composition, clogged nozzles, erratic controllers in other sources encountered in practice from time to time.

The cooling error signal is computed during operating modes 2 and 4 in calculator 109 when \( Tc \) switching signal appears at lead 125, said term varying according to the term:

\[
-(1 - \frac{H^3}{K_{12}})F_B
\]

wherein

\[ F_B = \text{cooling error feedback parameter signal calculated in calculator 110 described below} \]

\[ H = \text{thickness of strip in thousands of inches (fixed value)} \]

\[ n = \text{power, value related to thermal properties of strip, listed in Table I above} \]

\[ K_{12} = \text{pre-determined constant listed in Table I above} \]

The resulting signal is fed from calculator 109 over lead 131 to memory device 132 which, upon instructions from programmer 97, holds the signal computed for the current strip for use in modifying the cooling factor signal when making a spray bank selection for the next strip. Accordingly, the cooling error signal is algebraically combined with the cooling factor signal in summer 129 and the resulting signal, which varies according to equations (1) and (3), is fed to logic device 130 for determining i-cooling error corrected spray bank selection.

The cooling error feedback parameter signal mentioned above is computed during modes 2 and 4 in calculator 110 when \( Tc \) switching signal appears at lead 125, and is stored in memory device 139 until programmed to be retrieved with device 132, said parameter varying according to the equation:

\[
F_B = F_B \left[ 1 - K_n \left( 1 - \frac{\sum T_{cm} - \text{Last} T_{cm}}{\text{number of counts} \times T_{c, \text{desired}}} \right) \right]
\]

wherein

\[ F_B = \text{cooling error feedback parameter used in equation (3) above} \]

\[ F_{B, n} = \text{previous cooling error feedback parameter stored in memory device 139} \]

\[ K_n = \text{pre-determined constant listed in Table I above} \]

\[ T_{cm} = \text{count of sampled measured temperature of strip leaving the runout table, } ^{\circ} \text{F} \]

\[ T_{cm} = \text{measured temperature of strip leaving the runout table, } ^{\circ} \text{F} \]

\[ T_{c, \text{desired}} = \text{desired temperature of strip leaving the runout table, } ^{\circ} \text{F} \].

The resulting signal is fed from calculator 110 to calculator 109 for use in solving equation (3).

The cooling error signal stored in memory device 132 is fed during operating mode 4 for example, to arithmetic unit 105 where it is assimilated in calculators 133, 134. Calculator 133 produces a minimal coolant pressure setting control signal at lead 135 which is fed to computer 76. Calculator 133 receives a device setting feedback signal from computer 76 over lead 137. Calculator 134 produces a coolant pressure slope setting correction control signal at lead 136 which is fed to computer 76. Calculator 134 receives a device setting feedback signal from computer 76 over lead 138. The purpose of these signals will be described below in connection with computer 76.

Still referring to the drawings, there is shown spray bank selector 112 having logic device 130, receives the algebraic sum of the cooling factor signal and the cooling error signal from summing device 129. The combined signal is referred to as the spray bank selection signal and may, for example, have a numerical value ranging from 0 to 80. Logic device 130, which has conventional components, interprets the selection signal according to predetermined weighted values and energizes one or more top spray bank control valves 140—149 and 48b—48d, and/or one or more bottom spray bank control valves 150—159.

Spray bank selection is affected by weighted values of the spray bank selection signal in accordance with Table II below. Whole bank selection, i.e., one whole top and bottom section, is based on one increment of eight units of the selection signal whereby the number of whole banks increases with increasing increments of selection signal. Fractional bank selection, i.e., a fraction of top bank section 26 or a bottom bank section 36, is based on up to eight whole units of the selection signal anywhere between increments within the entire range of the selection signal, whereby the number of fractional banks increases by alternatingly selecting bottom bank section and an increasing number of fractional top bank sections, until a whole bank is selected, with increasing units of selection signal.

<table>
<thead>
<tr>
<th>TABLE II—SPRAY BANK SELECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection signal, unit increments</td>
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<tr>
<td>Selection signal, unit increments</td>
</tr>
<tr>
<td>0, 8, 16, 24, 32, 40, 48, 56</td>
</tr>
<tr>
<td>1, 9, 17, 25, 33, 41, 49, 57</td>
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<tr>
<td>2, 10, 18, 26, 34, 42, 50, 58</td>
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<tr>
<td>3, 11, 19, 27, 35, 43, 51, 59</td>
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<td>4, 12, 20, 28, 36, 44, 52, 60</td>
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<tr>
<td>5, 13, 21, 29, 37, 45, 53, 61</td>
</tr>
<tr>
<td>6, 14, 22, 30, 38, 46, 54, 62</td>
</tr>
<tr>
<td>7, 15, 23, 31, 39, 47, 55, 63</td>
</tr>
<tr>
<td>In the interest of minimizing longitudinal variations in physical or metallurgical properties along the strip due to variations in cooling, it will be apparent from Table II that spray bank selection is started substantially at the downstream end of the spray cooling zone and increased upstream. In other words, the spray cooling zone lengths in a direction opposite to strip movement. The exception to this is when fractional bank selection is made. In this case the increase in length occurs downstream. This arrangement of spray bank selection is advantageous in that a minimum amount of off specification strip is produced because of the close proximity of the spray banks to source 73 which detects strip discharging temperature error. An additional feature of the control system, under operating mode 3 for example, is the ability of computer 65 to make a single calculation of spray bank selection for current strip cooling and hold the selection constant during coolant application, freeing the computer to perform slatting and rolling calculations, or a cooling calculation for the next strip, while transferring coolant flow control to computer 76. This is achieved by dual channel holding means consisting of current strip memory device 160 and next strip memory device 161 which are operatively associated with logic device 130. Upon receipt of an LS signal and under instructions from programmer 97, logic device 130 causes the current spray bank selection to be stored in device 160. This selection is maintained until released by the current strip leaving the spray cooling zone, or optionally the runout table as evidenced by the absence of a ( Tc ) control signal on lead 125. After the current strip selection is stored in device 160, logic device 130 causes the next strip spray bank selection to be stored in memory device 161, but inhibits activation of the spray banks until receipt of an LS signal. After that, the selection is maintained until released as in device 160.</td>
</tr>
</tbody>
</table>
Considerable savings in coolant consumption may be achieved by deactivating selected spray banks sequentially as the trailing end of the strip travels through the spray cooling zone. To achieve this, source 74, a pulse generator driven by pinch rolls 14, generates pulses whose sum is proportional to the length of strip 10 and sends these pulses over lead 162 to pulse counter 163. Counter 163 is also operating associated with logic device 130. When as n LS signal is deactivated by the trailing end of strip 10 leaving stand F1, device 163 starts counting the pulses after a predetermined number of counts which corresponds to the distance each spray bank is located along the spray cooling zone, logic device 130 sequentially deactivates pairs of top and bottom control valves 140—149 and 150—159, respectively, in an ascending order.

In response to the deactivation of the LS signal, a number of normally open control valves 164—173, which cooperate in flow controllers 77—86 with selection control valves 140—149, are activated momentarily to cause flow controllers 77—86 to hold the coolant flow rate signal from computer 76 at the value prevailing when the end of strip 10 leaves stand F1. These control valves are then deactivated in sequence with control valves 140—149. This allows flow controllers 77—86 to restore from a maximum flow rate setting to a minimum setting in preparation for the next strip spray bank selection in the shortest possible time.

In still another feature of the control system, operator's console 66 includes 23 selector switches 174—196, having manual on, off, and computer (automatic) positions, for controlling the selection of corresponding top and bottom spray bank sections 17—25, 26—26d, 27—36. Spray pattern indicator 67 has for each position on each selector switch, current group of red lights 219—219, white lights 220—242, and green lights 243—265, respectively, and, in addition, blue lights 266—268 for indicating the computer's selection of spray banks for the next strip to be cooled. Red lights designate current strip manual selection of spray banks, white lights spray banks off, and green lights computer selection of current strip spray banks.

Of particular importance is the fact that when selector switch 174—196 is oriented in the manual selection position, based on predetermined cooling data, they synthesize a cooling factor signal which is applied through data processor 106 to the output of cooling factor calculator 107 at lead 127. Each selector switch 174—182, corresponding to banks 17—25, synthesizes a signal valued at 6 units each; each switch 183—195 corresponds to banks 26a—26d and 27—35, synthesizes a signal valued at 2 units each, and switch 196 corresponding to bank 36, synthesizes a signal valued at 1. The synthesized cooling factor signals produced at lead 127 are combined algebraically with the cooling error signal stored in device 132 to produce a cooling error-corrected, synthesized, spray bank selection. This allows an operator to manually perform spray bank selection, which will automatically correct for any cooling error present. In addition the operator may compare the number of red and blue indicator lights turned on for current strip manual selection and next strip computer selection of the same type order, and any difference may be noted as a runout table cooling error prevalent during the last strip to be cooled. This will enable the operator to make suitable adjustments in coolant flow components or other elements in the cooling system.

Turning now to FIGS. 1 and 4, there is shown coolant flow rate computer 76 which, during operating modes 3 and 4 establishes a minimal unit amount of coolant applied to the strip and varies the unit amount of coolant applied relative to strip velocity errors, or strip velocity errors and temperature errors at the end of the spray cooling zone and/or the runout table, and runout table cooling errors. During operating mode 4, it also provides means for manually and automatically adjusting the unit amount of coolant as well as the rate at which the unit amount of coolant is caused to change in proportion to strip velocity errors.

Included in computer 76 is minimal pressure setter 289, a device having, for example, motor 290 driving dual potentiometers 291a, 291b and calibrated indicator 292 in response to signals from motor controller 293. A constant reference signal is fed from source 294 through rheostat 295 to both potentiometers 291a, 291b to establish an adjustable minimal pressure signal at each of their sliders.

The expression minimal pressure is used in the description that follows with reference to the amount of coolant application because the spray bank nozzles are fixed orifices and the only way to vary coolant flow rate under these conditions is by varying coolant pressure.

Rheostat 295 is adjusted to establish a minimum level of the pressure signal. The minimal pressure signal at potentiometer 291 slider is fed over lead 296 to summing junction 297 where it is algebraically summed with velocity error and temperature error signals yet to be described.

The actual value of the minimal pressure signal is established by either an operator depressing push button 298 to signal motor controller 293 to turn the potentiometer to a predetermined position, or by a minimal coolant pressure setting control signal fed over lead 135 to controller 293 from minimal coolant pressure setting calculator 133. This setting is located in computer 65 shown in FIG. 3 and described above.

The minimal pressure signal at potentiometer 291 slider is sent over lead 137 to data processor 106 as a feedback signal in a closed loop type of servosystem with calculator 133.

The minimal pressure signal supplied to summing junction 297 is fed through amplifier 299, gain adjuster 300 and damping adjuster 301 to electromagnetic transducer 302. Devices 300, 301 derive signals which are combined and fed as a feedback signal to summing junction 297.

Electropneumatic transducer 302, a commercially available device, receives a regulated pneumatic signal over conduit 303 from a source not shown. This device converts a 1—5 ma. coolant pressure signal from device 301 to proportional 3—15 p.s.i. pneumatic coolant pressure control signal which is fed over conduit 304 to flow controllers 77—86, the latter being associated with top section spray banks 17—26.

Each of the flow controllers 77—86 have identical construction and operation and differ only in the reference identification of individual components. Each of the controllers receives the coolant pressure control signal supplied over conduit 304 and feeds it through proportional valve 164—173 and commercially available pneumatic flow control devices 305—314 to three-way control valves 140—149, the latter valves affecting spray bank selection as described above.

Control valves 140—149, when deenergized, vent to atmosphere pneumatic operators of pilot valves 315—324. Pilot valves 315—324 operate in a pilot hydraulic circuit to feed a variable pressure control fluid over conduits 325—334 to spray bank control valves 39—48a associated with top section spray banks 17—26.

Minimal pressure setter 289 is adjusted so that the pressure control signal on lead 296 and conduit 304 cause a minimal coolant pressure of 1 p.s.i. to be applied by each spray bank selected by action of control valves 140—149. This produces about 12,500 g.p.m. flow from all of top section spray banks. To insure maintaining uniform coolant flow rates as determined by flow control devices 305—314, manifolds 59 are equipped with differential pressure cells 335—344 which send pneumatic feedback signals of manifold flow conditions back to flow controllers 305—314, thereby producing a substantially uniform pressure at each top spray bank selected.

Bottom spray banks flow controllers 87—96 could, but do not for the sake of simplicity, receive the variable pneumatic control signal fed over conduit 304. Instead they are manually regulated by pilot regulator valves 345—354. These valves operate in a pilot hydraulic circuit in association with normally open spray bank selection control valves 150—159. In this manner, a hydraulic control signal is fed over conduits
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Referring to FIGS. 3 and 4, coolant flow rate computer 76 also includes a strip velocity error signal channel which consists of a conventional track/hold device 365 fed by a strip velocity signal over lead 119 and a LS, control signal over lead 120. This device tracks the strip velocity signal according to the speed of stand F3, but produces no output signal. As mill 11 accelerates, as it generally does after strip enters stand F3, device 365 is commanded by the LS, signal to hold the instantaneous velocity signal and produce a velocity error output signal proportional to the deviation of varying strip speed to the value of the instant speed. This velocity error signal is fed to amplifier 366 for use as described below.

Also included in computer 76 is pressure slope meter 367, a device having, for example motor 368 driving dual potentiometers 369a, 369b and calibrated indicator 370 in response to signals from controller 371. The output from amplifier 366 is fed to potentiometer 369a to establish a proportional velocity error signal at its slider which is fed over lead 372 to summing junction 297. Thus, as mill 11 accelerates the velocity error signal increases and, through action of the electro pneumatic control system described above, causes an increase in coolant application to strip 10. When the trailing end of strip 10 leaves stand F3, the LS, signal ceases and cause track/hold device 365 to restore operation of its tracking mode. This in turn removes the velocity error signal from summing junction 297 and permits coolant application to be restored to its minimal unit amount as described above.

The actual rate of change of the combined control signal at summing junction 297 due to mill acceleration is established by either an operator depressing push button 373 to signal motor controller 371 to turn the potentiometers 369a, 369b to a predetermined position. Alternatively, the rate of change of the control signal may be established by a coolant pressure slope setting control signal over lead 126 to controller 371 from coolant pressure slope setting controller 134 in computer 65 shown in FIG. 3 and described above. To complete a closed loop type of servosystem, potentiometer 369b is connected directly to constant reference signal source 294 and the signal appearing at its slider is sent over lead 138 to data processor and then to calculator 134.

Still referring to FIGS. 3 and 4, coolant flow rate computer 76 further includes a strip temperature error signal channel which consists of a strip discharge temperature Tc loop usable at the discretion of an operator, and an optional strip cooling temperature error signal loop Tt in cascade with the Tc loop.

When using the Tc loop singly, a Tc desired signal is fed over lead 126 from data processor 106, which corresponds to the signal appearing at lead 100, and through amplifier 374 to summing junction 375. In addition, a Tt measured signal is fed over lead 124 from Tt recorder 123 to summing junction 375. The difference between the Tc desired and Tc measured signals at summing junction 375 is designated the Tc error signal and is fed through amplifier 376 to controller 377.

Controller 377 is a conventional 3-mode device having a 1 to 5 ma. output and proportional, reset and rate actions, and is operative under control of manual/automatic unit 378 which enables and disables controller 377 under corresponding operating modes. When in automatic mode, a Tc control signal is fed over lead 125 from Tc recorder 123 to unit 378 so as to enable controller 377 action to take place only after the leading edge of strip 10 passes Tc pyrometer 73. At that time the controller's output signal is fed to summing junction 379 where a zero bias from source 380 is added to establish a positive and negative variable Tc error signal.

The Tc error signal at summing junction 379 is passed through amplifier 381 and to potentiometer 382 which acts as a Tc error signal gain adjuster. The signal appearing at potentiometer 382 slider is fed to terminal 383, through lead 384, terminal 385, operator's selector switch 386, and finally to summing junction 297. Here the Tc error signal is combined algebraically with the signals from leads 296 and 372 to cause an increase or decrease in coolant application if the Tc measured temperature is higher or lower, respectively, than Tc desired.

When using the Tt loop in cascade with the Tc loop, source 75, a total radiation optical pyrometer, sends a signal over lead 387 to a companion high speed recorder 388 which is equipped with a transmitting slide wire and which serves the same as recorder 114. These devices respectively send a measured Tt signal and a hot strip presence signal at the end of the cooling zone, over leads 389, 396 to amplifier 390 and manual/automatic control 395.

Amplifier 390 sends a Tt measured signal to summing junction 391, which junction also receives a Tc desired signal from amplifier 374 output and a manual bias signal from source 392 which is adjusted to a known difference between Tc and Tt desired values. These signals are combined algebraically and fed through amplifier 393 to controller 394.

Controller 394 is a conventional 3-mode device the same as controller 377 and is operative under control of manual/automatic unit 395 which enables and disables controller 394 under corresponding operating modes. When in automatic mode, a Tt control signal is fed over lead 396 from Tt recorder 388 to unit 395 so as to enable controller 394 action to take place only after the leading edge of strip 10 passes the Tt pyrometer 75. At that time the controller's output signal is fed to summing junction 397 where a zero bias from source 396 is added to establish a positive and negative variable Tt error signal.

The Tt error signal at summing junction 397 is passed through amplifier 399 and to a potentiometer 400 which acts as a Tt error signal gain adjuster. The signal appearing at potentiometer slide 400 is fed over lead 402 to terminal 385. With lead 384 disconnected from terminals 383, 385 and lead 401 connected between terminal 383 and summing junction 391, the Tt error signal is fed through switch 386 to summing junction 297. Here the Tt error signal is combined algebraically with the signals from leads 296 and 372 to cause an increase or decrease in coolant application if the Tt measured temperature is higher or lower, respectively, than Tt desired.

When using the Tt loop alone, temperature of the strip leaving runout table 12 is maintained within about ±25°F of Tt desired. When the Tt loop is used in cascade with the Tc loop, temperature of the strip leaving the spray cooling zone is also maintained closer to the desired value and has the added advantage that temperature deviations are shortened when the cascade loop is used.

We claim:

1. Apparatus for controlling the cooling of hot roller metal strip while moving at a variable velocity along a runout table, said apparatus comprising:

a. Spray cooling means for establishing a variable length spray cooling zone along the runout table, said means having a plurality of selectable spray banks in said zone adapted to apply controlled amounts of liquid coolant to said moving strip,

b. Means for affecting a spray bank selection, said means including first computer means operative in response to signals from storage and operating information input sources for selecting a variable number of spray banks proportional to a variable cooling factor signal when assuming a minimal unit amount of coolant is applied by each spray bank selected, said cooling factor signal varying according to the equation:

\[ MS = K_0 + K_iT_1' \ln \left( \frac{T_1}{T_2} \right) + K_f T_1 + K_H V + K_i (T_r - T_1) \]

wherein the first two terms are essential and additional terms optional as described, and

\[ T_1' = T_1 - H \ln \left( \frac{T_1}{T'} \right) \]

wherein V = velocity of strip in feet per minute

H = thickness of strip in thousandths of inches

ln = natural logarithm

T_r = temperature of strip entering runout table, °F.
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3. The apparatus of claim 1 wherein the strip cooling means includes at least one of said spray banks having fractional bank selectability.

4. The apparatus of claim 3 wherein the apparatus cooling error signal is based on measured values of $T_s$ of previously cooled strip and varies according to the following term:

$$-\frac{(1-FB)H}{V}$$

wherein

- $FB$ = summation of cooling variables producing $T_c$ error as described
- $H$ = thickness of strip
- $n$ = power, value related to thermal properties of strip as described
- $K_{14}$ = predetermined constant as described.

5. The apparatus of claim 1 wherein the first computer means includes:

- means for synthesizing the cooling factor signal to effect spray bank selection.

6. The apparatus of claim 3 wherein the first computer means includes:

- means for synthesizing the cooling factor signal and combining it with the cooling error signal to effect a cooling error-corrected spray bank selection.

7. The apparatus of claim 1 wherein the first computer means includes:

- means receiving said storage and operating signals for programming the computation of said cooling factor signal using the desired values of parameters prior to the strip entering the runout table, thereby to effect an initial spray bank selection, and then to recompute said signal using the measured values instead of the desired values of $V$ and $T_s$ to finalize spray bank selection at a predetermined value of $V$ when said strip is about to enter the runout table.

8. The apparatus of claim 1 wherein the first computer means includes:

- logic means operative in response to increases in the cooling factor signal and programmed for spray bank selection to increase the spray cooling zone length in a direction substantially opposite to strip movement.

9. The apparatus of claim 1 wherein the first computer means includes:

- dual channel holding means driven by the cooling factor signals and alternately operative in response to said operating signals for holding the current spray bank selection constant while setting up the spray bank selection for the next strip to be cooled.

10. The apparatus of claim 1 including:

j. means incorporated in the first computer means for producing an apparatus cooling error signal prior to the strip being cooled,

k. means incorporated in the control means receiving the cooling error signal for adjusting the level of the minimal unit amount of coolant applied by the spray banks proportional to the value of said cooling error signal.

11. The apparatus of claim 1 including:

l. means incorporated in the first computer means for producing an apparatus cooling error signal prior to the strip being cooled,

m. means incorporated in the control means receiving the cooling error signal for adjusting the rate at which the $V$ error signal varies the minimal unit amount of coolant applied by the spray banks proportional to the value of said cooling error signal.

12. A method of controlling the cooling of hot rolled metal strip while moving at a variable speed along a runout table, said method comprising:

a. establishing a variable length spray cooling zone along the runout table using a plurality of selectable spray banks in said zone adapted to apply controlled amounts of liquid coolant to said moving strip,

b. affecting spray bank selection including selecting a variable number of the spray banks proportional to a computed variable cooling factor signal using first computer means operative in response to signals from storage and operating information input sources, assuming a minimal unit amount of coolant is applied by each spray bank selected, said cooling factor signal varying according to the equation:

$$M_S = K_d + KV (T_s)(T_c) + K_s T_s + K_A 3 T_s + K_7 H V + K_9 (T_s)(T_c) + K_{10} H + K_{11} V$$

wherein the first two terms are essential and additional terms optional as described, and

$$M_S = \text{runout table}$$

$$V = \text{velocity of strip in feet per minute}$$

$$H = \text{thickness of strip in thousandths of inches}$$

$$\ln = \text{natural logarithm}$$

$$T_s = \text{temperature of strip entering runout table,} \ast \text{ }^\circ \text{F}$$

$$T_c = \text{temperature of strip leaving runout table,} \ast \text{ }^\circ \text{F}$$

$$K_d, K_s, K_A, K_7, K_9, K_{10}, K_{11} = \text{predetermined constants as described}$$

13. The method of claim 12 wherein at least one of said spray banks has fractional bank selectability.

14. The method of claim 13 wherein step (b) includes:

d. computing an apparatus cooling error signal prior to current strip cooling and combining said signal with the cooling factor signal to modify current strip spray bank selection proportional thereto prior to strip cooling.

15. The method of claim 14 wherein said apparatus cooling error signal is based on measured values of $T_s$ of previously cooled strip and varies according to the following term:

$$-\frac{(1-FB)H}{V}$$

wherein

- $FB$ = summation of cooling variables producing $T_c$ error as described
- $H$ = thickness of strip.
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n = power, value related to thermal properties of strip as described.

K, = predetermined constant as described.

16. The method of claim 13 wherein step (b) is carried out by:

17. The method of claim 14 wherein step (b) includes:

18. The method of claim 12 wherein step (b) includes:

19. The method of claim 12 wherein step (b) includes:

20. The method of claim 12 wherein step (b) includes:

21. The method of claim 12 including the steps of:

22. The method of claim 12 including the steps of:

23. The apparatus of claim 1 wherein the spray cooling means is adapted to apply said coolant at pressures of up to about 10 p.s.i.

24. The apparatus of claim 1 wherein the spray cooling means is adapted so that the variable length spray cooling zone is located adjacent to at least one variable length radiation cooling zone along the runout table, and said first computer means is adapted to account for a predetermined radiation cooling effect in computing the cooling factor signal.

25. The apparatus of claim 3 wherein the spray cooling means is adapted so that the variable length spray cooling zone is located adjacent at least one inversely variable length radiation cooling zone along the runout table, and said first computer means is adapted to account for a predetermined radiation cooling effect in computing the cooling factor and cooling error signals.

26. The apparatus of claim 1 wherein the first computer means includes:

n. means receiving said storage and operating signals for computing a signal representing predicted temperature of strip entering the runout table based on a measured temperature made during strip rolling for use as measured Tp when computing the cooling factor signal, said predicted temperature signal varying according to the equation:

\[ T_p = K_p + V_H + K_{10}T_5 + K_{11}H \]

where

- \( T_p \) = predicted temperature of strip entering runout table, °F.
- \( V \) = measured velocity of strip, feet per min.
- \( H \) = thickness of strip in thousandths of inches (fixed value).
- \( T_5 \) = temperature of strip during rolling.
- \( K_p \) to \( K_{11} \) = predetermined constants as described.

27. The method of claim 12 wherein said coolant is applied at pressures of up to about 10 p.s.i.

28. The method of claim 12 wherein the variable length spray cooling zone is located adjacent at least one variable length radiation cooling zone along the runout table, and said computed cooling factor signal includes an accounting for a predetermined radiation cooling effect.

29. The method of claim 14 wherein the variable length spray cooling zone is located adjacent at least one variable length radiation cooling zone along the runout table, and said computed cooling factor and apparatus cooling error signals include an accounting for a predetermined radiation cooling effect.

30. The method of claim 12 wherein step (b) includes:

p. computing a signal representing predicted temperature of the strip entering the runout table based on a measured temperature made during strip rolling for use as measured \( T_p \) when computing the cooling factor signal, said predicted temperature signal varying according to the equation:

\[ T_p = K_p + V_H + K_{10}T_5 + K_{11}H \]

where

- \( T_p \) = predicted temperature of strip entering runout table, °F.
- \( V \) = measured velocity of strip, feet per min.
- \( H \) = thickness of strip in thousandths of inches (fixed value).
- \( T_5 \) = temperature of strip during rolling.
- \( K_p \) to \( K_{11} \) = predetermined constants as described.
It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Co. 1, line 10, "roller" should read --rolled--
Col. 1, line 26, "per" should read --at--
Col. 2, line 51, "strap" should read --strip--
Col. 3, line 26, "48a" should read --48b--
Col. 4, line 28, delete second occurrence of "and"
Col. 5, line 24, "LS7" should read --LS5--.
Col. 5, line 61, delete "a"
Col. 5, line 74, "(TBF)/Tc" to --(Tr)/(Te)--
Col. 6, line 8, being new paragraph with --It is to be noted--
Col. 6, line 54, "K105" should read --K10T5--
Col. 6, line 62, begin new paragraph with --The resulting Tf signal--
Col. 7, line 21, "(1-)Hn" should read --(1-FB)Hn--
Col. 7, line 21, insert --(3)-- after the word "wherein"
Col. 7, lines 28 and 29 begin paragraph with --The resulting signal
Col. 7, line 37, "i" should read --a--
Col. 8, line 33, "149, 48g, 159" should read --149, 48b, 159--
Col. 9, line 8, "as n LS7" should read --an LS7--
It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 9, line 24, "minimum" should read --minimal--
Col. 10, line 28, "servosystem" should read --servo system--
Col. 11, line 1, "150**" should read --150-159--
Col. 12, line 19, "convention" should read --conventional--
Col. 12, line 41, "along" should read --alone--
Col. 12, claim 1, line 49, "roller" should read --rolled--
Col. 12, Claim 1, line 75, "ln" should read --ln--
Col. 13, claim 4, line 34, "(1-FB)H^n" should read --(1-FB)\(\frac{H^n}{K_{12}}\) --
Col. 14, claim 12, line 32, "KVln(T_f)/(T_c)" should read --KVHln(T_f)/(T_c)--
Col. 14, claim 12, line 32, "K\alpha T_f" should read --K\alpha T_f--
Col. 14, claim 12, line 33, "K\gamma V" should read --K\gamma V--
Col. 14, claim 12, line 39, "ln" to --ln--
Col. 14, claim 14, line 63, claim 13" should read --claim 12--
Col. 15, claim 16, line 4,"claim 13" should read --claim 12--
Col. 15, claim 21, line 31, "1" should read --1--
Col. 16, claim 26, line 17, "+9VH" should read --K_9VH--
Col. 16, claim 26, line 17, "K11H" should read --K_{11}H--
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,589,160

Inventor(s) Luther E. Gruver et al.

Page 3 of 3

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 16, claim 30, line 45, "T_f=8" should read —T_f=K_g—

Signed and sealed this 20th day of August 1974.

(SEAL)

Attest:

McCOY M. GIBSON, JR. C. MARSHALL DANN
Attesting Officer Commissioner of Patents