

Feb. 21, 1956

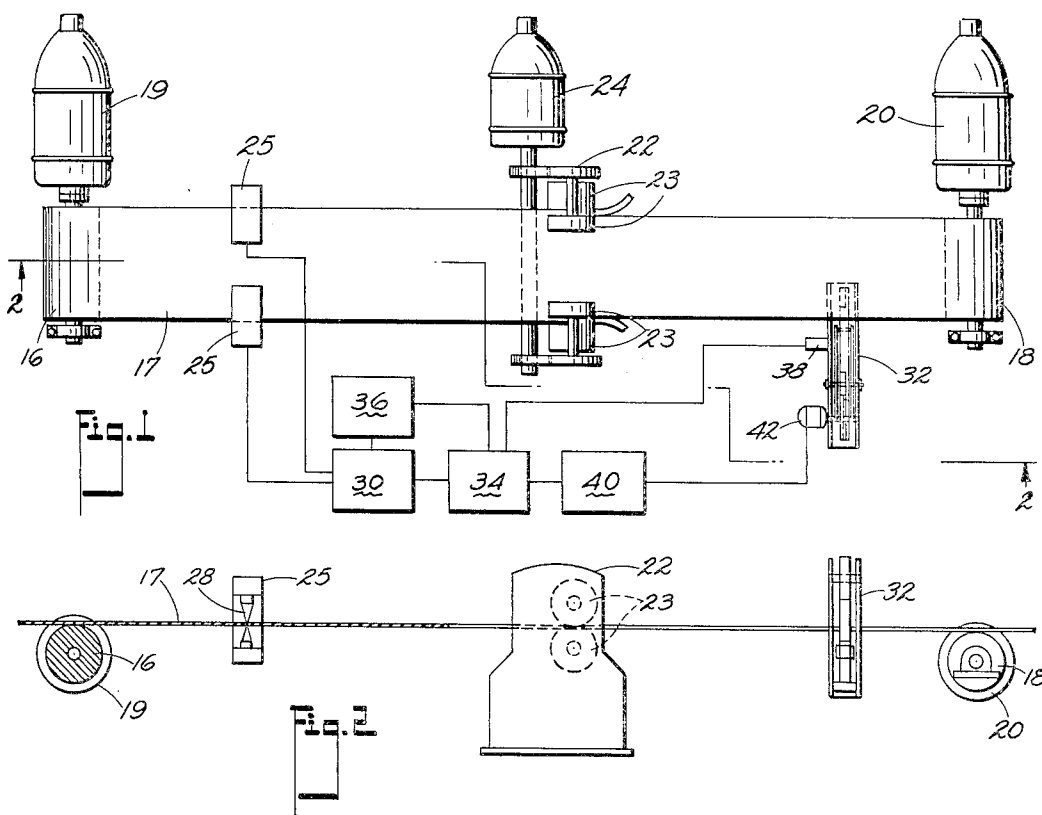
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**2,735,329**

## TEAR DETECTING AND INDICATING MEANS FOR SHEET METAL

Filed March 29, 1950

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

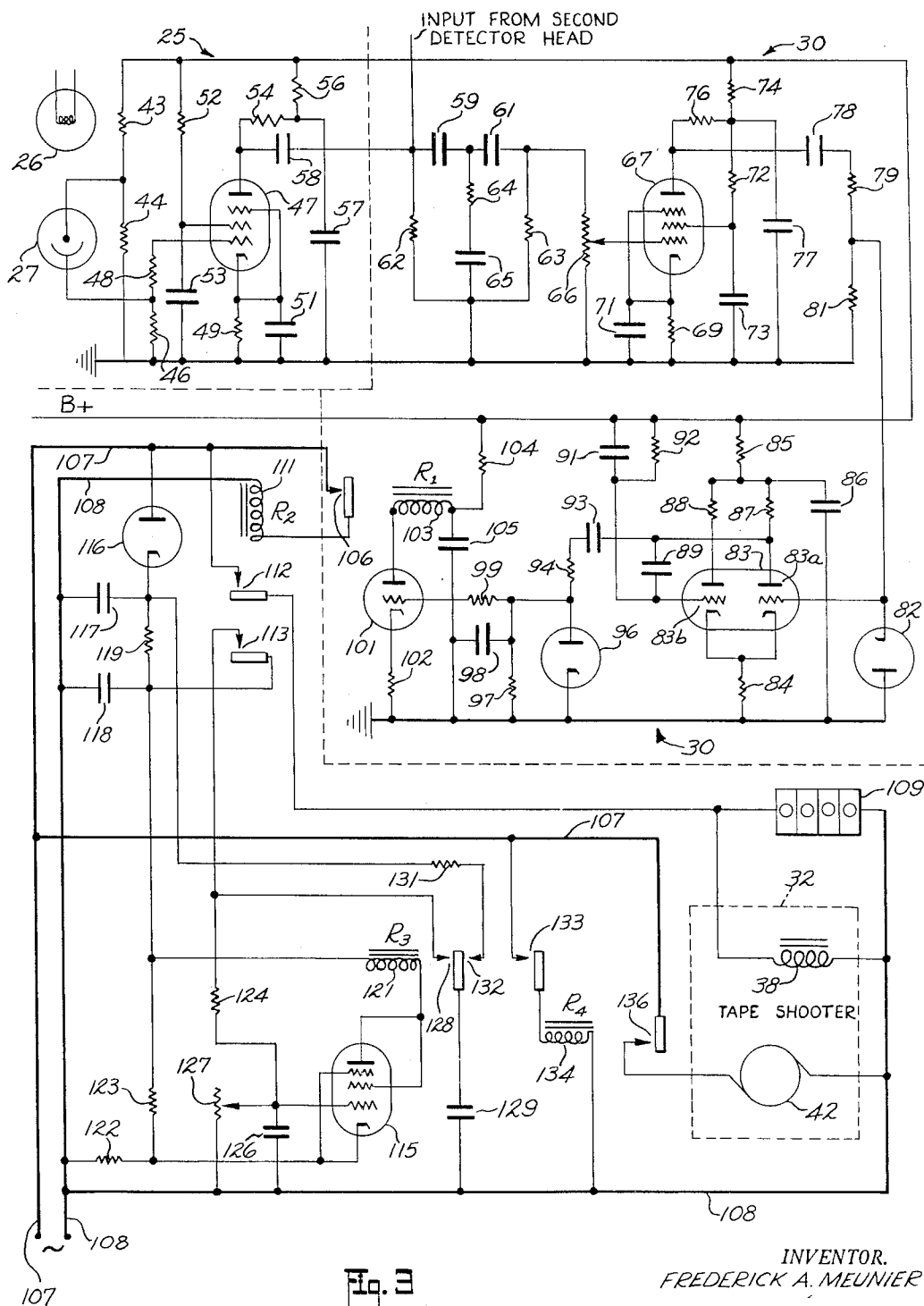


Fig. 3

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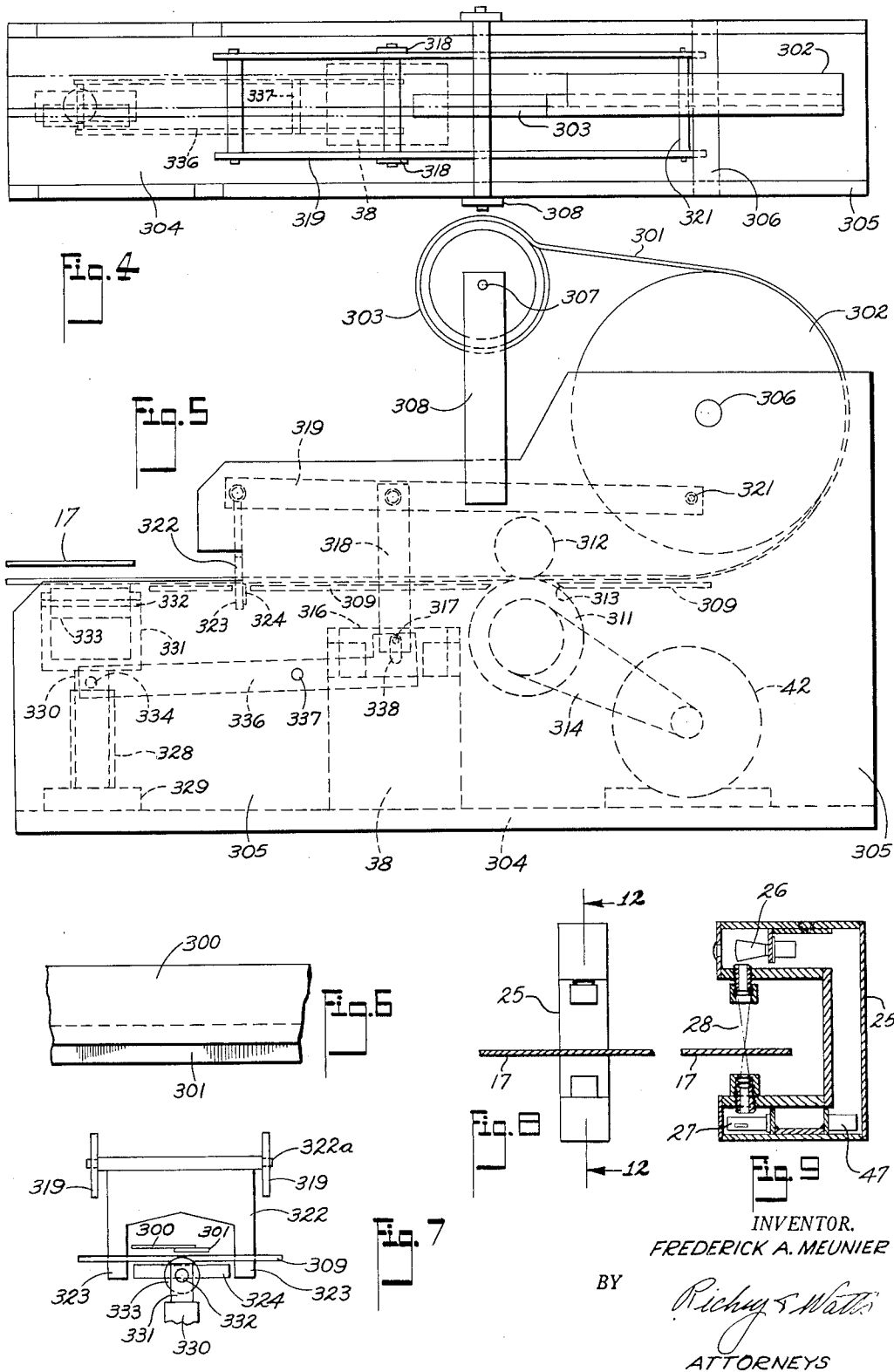
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## TEAR DETECTING AND INDICATING MEANS FOR SHEET METAL

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Application March 29, 1950, Serial No. 152,740

2 Claims. (Cl. 88—14)

This invention relates to the detection and indication or removal of defects in the marginal portions of webs of sheet metal.

In the manufacture of sheet steel, the steel stock is passed through rolls which reduce the gauge of the stock progressively to the desired thickness, the final product of the rolling operation being a long web of sheet metal which is coiled or rolled for further processing. After the rolling is completed, the strip or web is passed through a slitting line in which the edges of the stock are trimmed to provide stock of a standard width with straight edges. The stock may then be tin plated or galvanized, if desired, and may be cut into sheets.

During the rolling process the strip develops an uneven margin which is removed by the slitting operation. In addition, however, small tears or cracks extending inwardly from the edge of the strip frequently occur. If these cracks or tears are confined to the marginal portion which is removed in the slitting line they are not a matter of concern. However, frequently the tears extend into the usable portion of the strip which remains after the slitting operation. When stock with such marginal tears is fed through a plating line, the sharp corners of the tears sometimes catch on the machinery and cause the strip to be torn across its entire width. This is a serious hazard, since if the strip is torn in two in an electrolytic tin mill the result is a great loss in time, damaged material, and poorly plated stock.

This hazard can be eliminated by cutting out the marginal part of the strip where a crack occurs in such a manner as to eliminate the sharp corners as, for example, by removing an arcuate section from the edge of the strip so that no sharp corners are present to catch on equipment.

This invention is directed to the solution of the problem and the consequent elimination of losses due to severing of the strip by detecting tears which extend into the strip beyond the marginal part removed by the slitting operation, and either marking the strip so that these defects may be subsequently removed manually or otherwise, or cutting out the defective portions automatically as the strip is passed through the machine with which the tear detector is associated. There are, thus, two forms of the invention, one being an automatic machine to detect the tears and mark the strip in such a manner that the location of the tears is indicated and the other form being an automatic machine to detect and cut out the defective portions. The two embodiments of the invention may both be described as comprising means for feeding a strip, a device for detecting marginal defects which should be removed, and means for operating on the web in response to the presence of defects. The two forms differ, of course in the nature of the last-named means, since one form indicates defects in the strip and in the other form it removes the defective portions.

A brief description of the nature of the preferred embodiment of the invention may make clearer the nature

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of the invention and the problems involved in the detection and removal of tears in steel strip.

Preferably the invention is incorporated in or associated with the slitting line, which, as stated above, is a machine in which the edges of the web are trimmed. A tear detector is mounted at each edge of the web. The detectors are of a photoelectric type comprising a phototube which responds to light passing through the tears. The output of the phototube controls an amplifier of a type specially adapted to provide a reliable and positive response to the substantially instantaneous fluctuations in phototube current caused by the tears which pass the detectors and to deliver an output capable of energizing the ultimately controlled mechanism.

In the first form of the invention this mechanism is a device which I call a "tape shooter" which automatically feeds an adhesive tape, cuts off sections of the tape, and applies them to the strip so that they extend from the edge of the strip and are readily visible after the strip is coiled.

In the second form of the invention, the output of the amplifier is fed to a control circuit which actuates a cutting device which removes the defects. This form of the invention involves the solution of problems not present in the first form since the operation of the cutter must be so timed with relation to the detector that the cutter will operate at the right point on the rapidly traveling web. It involves the additional problem of providing a proper response to a succession of defects so that the cutter is not in an inoperative condition after removing one defect when a closely succeeding defect must be removed. The present invention solves these problems by the provision of a control circuit and cutter which are capable of removing all defects regardless of the spacing of the defects.

It is highly desirable from the practical standpoint that the invention be capable of use in actual machines in which the strip is processed, such as a slitting line, which greatly increases the difficulty of providing a workable solution to the problems solved by this invention. This is due to the fact that the strip may be moving at the rate of 2,000 feet per minute, and the defect must be detected and marked or removed with the strip traveling at this high speed, since the speed of the strip cannot be reduced for the marking or removing operation.

The principal object of the invention is to eliminate casualties in the processing of steel strip resulting from tears in the strip. A more specific object is to devise a machine capable of detecting and removing tears in metal strip. A further object of the invention is to provide a machine capable of detecting and marking or removing defects while the strip is traveling at high speed. Still further objects of the invention relate to the provision of instrumentalities for carrying out certain functions of the invention such as a detecting device, a device for applying a marking tape to the strip, a device for cutting defects from the strip, and appropriate control systems by which the marking and cutting device are actuated by the detecting device. A more specific object is to provide a cutting system which will be capable of cutting out an arcuate section of strip for a single defect or a longer part of the marginal portion of the strip in response to a succession of defects.

The manner in which these objects are realized and the preferred mode of carrying out the invention will be apparent to those skilled in the art from the description herein of the preferred embodiments of the invention.

Referring to the drawings, Fig. 1 is a schematic plan view of a slitting line with the tear detector and marking device; Fig. 2 is a vertical sectional view of the same on the line indicated in Fig. 1; Fig. 3 is a circuit diagram

of the control circuit for the tape shooter including the detector and amplifier circuits; Fig. 4 is a plan view of the tape shooter; Fig. 5 is an elevation view of the same; Fig. 6 is a plan view of a portion of the composite strip of tape; Fig. 7 is a detail partial elevation view of the tape shooter; Fig. 8 is an elevation view of the detector head; and Fig. 9 is a sectional view of the same on the plane indicated in Fig. 8.

Proceeding to a description of the form of the invention which marks the strip, illustrated in Figs. 1 to 9, and with particular reference to the schematic diagram of Figs. 1 and 2, these figures illustrate in a general manner the setup of the invention in combination with a slitting line. Since the details of the slitting line are immaterial to the invention, it will be described only generally.

The slitting line includes a feed roll 16 from which the web 17 is fed to a take-up roll 18, these rolls being coupled to motors 19 and 20. A slitting device 22 which trims the edges of the strip is located between the feed and take-up rolls and comprises a set of shearing wheels 23 at each edge of the strip, these shearing wheels being driven by a motor 24 and appropriate gearing as is fully understood by those skilled in the art. A detector head 25 is mounted at each edge of the strip in advance of the slit.

Each detector head (Figs. 8 and 9) is a U-shaped structure with arms extending above and below the web. A light source 26 is mounted in one arm of the head, preferably the upper arm, and a photoelectric cell 27 is mounted in the other arm. By an appropriate system of lenses a light beam 28 is projected from the light to the marginal portion of the strip and is normally prevented from reaching the photoelectric cell by the strip. When a tear passes through the beam the light reaches the photoelectric cell, which thus responds to the defect. The detector head includes a system of lenses for focussing the beam of light on the sheet 17 and concentrating the transmitted light on the phototube. Since the design of such structures is fully understood by those skilled in the art and the details thereof are not material to an understanding of the invention, they will be omitted from this specification in the interest of conciseness. The detector heads may be mounted so as to be movable transversely of the strip so that the position of the detector beams may be adjusted in accordance with the final width of the strip after passing through the slitters and so that tears of less than a predetermined extent will not be detected.

The detector head also preferably includes an amplifier tube 47 (Fig. 3), which boosts the output of the photoelectric cell. The output of the amplifier tube of each detector is connected to a common amplifier and relay circuit 30 which controls the operation of the tape shooter 32 which marks the location of defects. This control is effected through a control panel 34 through which the power supply for the devices is supplied and which contains additional relays and control devices, as will be described. A power supply 36 energized by the control panel provides the plate and filament supplies for the electronic circuits of the detector and the amplifier.

The control box energizes a solenoid 38 in the tape shooter which applies the marking tape to the web. Concurrently with the energization of the solenoid, the control box energizes a time delay device or holding relay circuit 40, which in turn energizes a motor 42 in the tape shooter to advance the tape, thus preparing the tape shooter for response to the next defect observed. The time-delay circuit maintains the motor in operation for a sufficient time to effect the feeding operation. A single tape shooter is sufficient, since a defect on either edge of the strip may be indicated by tape applied to one edge of the strip. The two detector heads are connected in parallel to the amplifier so that the tape shooter is ener-

gized in response to illumination of either of the phototubes 27.

The electrical system by which the tape shooter is actuated by the photoelectric cell is shown in Fig. 3. The heater circuits for the tubes and the source of plate supply are omitted from this diagram, since these elements may be conventional and illustration thereof is not essential to an understanding of the invention. The lamp 26 of the detector may be energized from the tube heater circuit or in any other suitable manner. The anode of the photoelectric cell 27 is energized by a voltage divider consisting of resistors 43 and 44 connected between the D. C. supply, indicated as B plus, and ground. The cathode of the phototube is grounded through 20 megohm resistor 46 and is coupled to the control grid of a pentode amplifier 47 by resistor 48. The cathode and suppressor grid of the pentode are coupled to ground in the usual manner by biasing resistor 49 and bypass condenser 51. The screen grid is energized from the plate supply through resistor 52 and bypassed to ground by condenser 53. The plate is energized through load resistor 54, decoupling resistor 56, and decoupling condenser 57.

The operation of the phototube amplifier circuit will be apparent to those skilled in the art. Bursts of light reaching the tube 27 increase the current through the tube, the resulting voltage drop in the resistor 46 driving the grid of the pentode more positive, increasing the plate current of the pentode, and driving the plate negative.

The plate of the pentode is coupled by condenser 58 to the succeeding circuits, the first element of which is a filter which rejects 120 cycle current. The filter thus makes possible the operation of the photocell unshielded from illumination around the machine energized from a 60 cycle supply, which tends to generate 120 cycle current in the output of the photocell. Since the amplifiers respond only to alternating current, they are not affected by constant illumination in the room in which the machine is located. The filter circuit comprises 0.1 mfd. condensers 59 and 61 connected in series in the line, 130,000 ohm resistors 62 and 63, connected between the input and output of the filter circuit and ground, and a 65,000 ohm resistor 64 and 0.2 mfd. condenser 65 connected between the junction of the condensers 59 and 61 and ground.

The coupling condenser 58 is connected to the input of the filter as is the corresponding coupling condenser of the other detector and first amplifier circuit, which is not shown in the circuit diagram since it is a duplicate of that just described.

The amplified photocell outputs from which 120 cycle components have been substantially eliminated are coupled to the succeeding amplifiers through a potentiometer or variable attenuator 66 connected between the output of the filter and ground. The variable tap of the potentiometer is directly connected to the control grid of a pentode 67 connected in a standard voltage amplifying circuit similar to that of the tube 47. The cathode and suppressor are energized through bias resistor 69 and bypass condenser 71. The screen grid is energized through plate decoupling resistor 74 and resistor 72 and bypassed to ground through condenser 73. The plate load resistor is 76 and the plate bypass condenser is 77. When the burst of light striking the photocell 27 drives the plate of the first amplifier 47 negative the control grid of tube 67 likewise goes negative and therefore the plate of 67 swings positive. The output circuit of tube 67 consists of coupling condenser 78 and resistors 79 and 81 in series to ground.

The center tap between the resistors is connected to the cathode of a clamper diode 82, the plate of which is grounded, and the control grid of the first triode 83a of a double triode trigger tube 83. The trigger tube operates only on positive signals from the output of the pentode 67, negative pulses being diverted by the clamper 82 which short-circuits negative pulses and thus prevents multiple operation of the trigger tube, assuring a single

output pulse for each defect. The cathodes of trigger tube 83 are connected together and energized through a common bias resistor 84. The plates are supplied through a decoupling circuit, comprising resistor 85 and condenser 86, and individual load resistors 87 and 88. The plate of triode 83a is coupled to the grid of triode 83b by condenser 89. This grid is also connected to the plate supply through 0.1 mfd. condenser 91 and 0.5 megohm resistor 92 in parallel. The plate of triode 83a is connected through coupling condenser 93 and resistor 94 to the plate of a clamper diode 96, the cathode of which is grounded so that the plate may swing negative but not positive. The plate of clamper 96 is coupled by resistor 99 to the grid of relay control triode 101, which is grounded through grid leak 97 and condenser 98 in parallel. The cathode of tube 101 is supplied through a 200 ohm resistor 102 which maintains a low bias on the tube so that the tube is normally conducting. The plate of the triode is connected through the normally energized coil 103 of relay R1 and resistor 104 to the positive supply. A large condenser 105 is connected between the relay and ground.

The operation of the trigger circuit is as follows: the grid of triode 83a is normally at ground potential, and the cathode is biased sufficiently that triode 83a is cut off. Triode 83b is conducting, since the grid is biased from the positive line. When pentode 67 responds to a defect, a positive pulse is transmitted to the grid of 83a, which fires, and, through coupling condenser 89, drives the grid of 83b negative to cut off 83b temporarily. When triode 83a returns to its normal cutoff condition, triode 83b again becomes conducting. The negative swings of the plate of 83a are transmitted by condenser 93 to the relay control tube 101, which temporarily de-energizes relay R1, closing the normally open back contacts 106.

The circuits so far described are preferably physically located in the unit 30, identified as the amplifier and first relay, and the output from the relay contacts 106 is supplied to the control panel 34 through which the tape shooter is energized. Although the control panel and time delay are indicated as separate units on the schematic of Figs. 1 and 2, they are preferably one unit in terms of structure and location. It will be apparent, of course, that the physical location of the components is not critical. The contacts 106 of the relay 103 are connected in a circuit extending from line 107 of an alternating current supply circuit through the relay contacts and coil 111 of relay R2 to the other side 108 of the A. C. line. Thus, when a defect is detected, closing of contacts 106 energizes relay R2, which is provided with two sets of normally open front contacts. Contacts 112 are connected in a circuit between lines 107 and 108 through an electromagnetic register 109 which counts the number of tears detected. Contacts 112 also energize the solenoid 38 of the tape shooter 32 which is connected in parallel with the counter to affix a strip of tape to the web 17. The structure of the tape shooter will be explained subsequently.

The normally open contacts 113 of relay R2 control the motor 42 of the tape shooter which advances the tape in preparation for a subsequent marking operation. This control is effected through a time delay or holding circuit which holds the motor in operation for a few seconds as necessary to feed the tape. The time delay circuit includes a pentode 115 and a diode 116 providing the plate supply for the pentode. Preferably these are included in one tube of the 117N7GT type. The diode is connected to a conventional filter circuit comprising 8 mfd. filter condensers 117 and 118 and resistor 119. The output of the filter is connected through the coil 121 of a relay R3 to the plate and screen grid of pentode 115. The cathode and suppressor grid of tube 115 are connected to the A. C. line 108 through 3,500 ohm resistor 122 and to the plate supply through 25,000 ohm resistor

123, these resistances provide a voltage divider establishing the desired cathode bias of tube 115.

The control grid of pentode 115 is connected to the front contact 113 of relay R2 through a 100 ohm resistor 124 and to line 108, which is effectively the ground for the circuit, through .005 mfd. condenser 126 and one megohm variable resistor 127 in parallel. Thus, when the relay contacts 113 close, a circuit is completed from the positive supply through contacts 113, resistor 124, and condenser 126 and resistor 127 in parallel, charging condenser 126. The control grid of the pentode goes positive, rendering the pentode conductive. Relay R3 in the plate circuit of the pentode is energized and closes front contacts 128, coupling 0.5 mfd. condenser 129 to the grid of the pentode. This condenser is normally charged from the output of the diode 116 through current limiting resistor 131 and the back contacts 132 of relay R3. When front contacts 128 close, the charged condenser 129 maintains the control grid of tube 115 positive until a sufficient part of the charge of the condenser has leaked off through the variable resistor 127 to make the potential of the grid of tube 115 sufficiently negative that relay R3 drops out. When the relay is deenergized condenser 129 is again charged through the circuit previously described.

While tube 115 holds relay R3, normally open front contacts 133 of this relay are closed completing a circuit from one side of the A. C. line to the other through coil 134 of motor relay R4. This relay closes its normally open contacts 136 completing an energizing circuit through the motor 42 of the tape shooter. The motor is thus energized for as long a time as the relay R3 is energized. The time of operation of the motor may be varied by adjustment of the variable resistance 127, which determines the rate of discharge of condenser 129.

The overall function of the system should be clear from the foregoing, but may be reviewed briefly. The very brief pulses of light striking the photocell cause an increase in photocell current which is amplified through the circuit comprising tubes 47, 67, 82, 83, 96, and 101 to provide a signal of sufficient strength and constancy to operate relay R1 which closes contacts 106 in response to the occurrence of each defect. Relay R1 directly operates relay R2 which, through contacts 112 immediately energizes the solenoid of the tape shooter and the register 109. Relay R2 also triggers tube 115, which energizes relay R3 and holds this relay energized for a time depending upon the discharge of condenser 129 through the variable resistor 127. Relay R3 energizes the tape shooter motor for the desired time through the intermediate motor control relay R4.

The tape shooter (Figs. 4, 5, and 7) feeds, cuts off, and applies to the web a tape particularly suited for this marking operation, which is illustrated in Fig. 6. It comprises a tape of kraft paper or other strong paper 300 and a pressure-sensitive adhesive tape 301. The two tapes are fed concurrently, with about-half the width of the adhesive tape adhering to one margin of the paper tape 300. The exposed gummed surface of the tape 301 serves to attach the composite tape to the moving web and the kraft paper tape imparts sufficient stiffness to the tape so that it may be projected into proximity to the web, is in general more manageable, and is more readily visible once it has been attached. While mechanical details of the tape shooter are capable of great variation and the specific arrangement of structure may be widely modified within the scope of the invention, the principles of a suitable tape shooter are illustrated in Figs. 4, 5, and 7. The tape shooter comprises a base 304 and upstanding side plates 305. A roll 302 of the kraft paper is rotatably mounted on a shaft 306 extending between the side plates. A roll 303 of pressure-sensitive adhesive tape is rotatably mounted on a shaft 307 extending between up-rights 308 fixed to the side plates. Appropriate spacers may be disposed on the shafts 306 and 307 to maintain

the rolls in proper alignment transversely of the device. The adhesive tape 301 is fed from the roll 303 with the gummed side down and over the roll 302 of kraft paper. One edge of the adhesive tape thus sticks to the kraft paper. The composite tape is fed between the side plates 305, supported by a platform 309, toward the front of the machine where the side walls of the machine and the tape project beneath the web 17 as illustrated in Fig. 5.

This feeding motion is accomplished by a feed roll 311 and pressure roll 312 mounted between the side walls in position to engage the non-adhesive surface of the strip, the roller 311 projecting through an opening 313 in the platform. These feed rolls are operated by motor 42 through suitable mechanical reducing gear, indicated schematically as a belt 314. The tape is severed and pressed into engagement with the web 17 by the solenoid 38 mounted on the plate 304. The movable armature 316 of the solenoid is coupled by a pin 317 and links 318 to a lever comprising two parallel arms 319 pivoted to the side members by a pin 321. A knife 322 is mounted between the outer ends of the arms by a cross pin 322a and normally bridges the tape, being formed with edge portions 323 which extend through a gap in the platform 309 to guide the knife. A fixed blade 324 mounted below the platform cooperates with the central portion of the knife 322 to sever the tape when the lever 319 is pulled downwardly by the solenoid.

A tubular guide member 328 is fixed to the base 304 by a flange 329. A tubular member 330 sliding in the column 328 is fitted with a clevis 331 in which is mounted a shaft 332 on which is rotatably mounted a roller platen 333. A rod 334 extending through the tubular member 330 couples it to two parallel levers 336 mounted on a shaft 337 extending between the side plates. The inner end of the levers 336 are formed with vertical slots 338 within which the pin 317 on the solenoid armature engages. When the armature is pulled down, it moves freely with respect to the lever 336 until the knife has severed the tape. Then, when the pin 317 engages the lower end of the slot 338, the levers 336 are actuated to project the platen 333 upwardly to force the tape into engagement with the web 17. The roller platen permits the tape to be carried freely with the web as soon as it is affixed. As previously explained, the solenoid 38 is energized by relay R2 (Fig. 3) and the motor 42 is energized through a holding circuit initiated by relay R2 and is continued in operation for a time sufficient to project an additional length of tape. Since the tape is severed some distance from the edge of the strip, the tape extends beyond the web and is readily visible after the web is coiled.

Subject-matter disclosed but not claimed in this application is being claimed in a continuation-in-part of this

application Serial No. 443,651, filed on July 15, 1954.

Having thus described the present invention so that those skilled in the art may be able to understand and practice the same, I state that what I desire to secure by Letters Patent is defined in what is claimed.

I claim:

1. In combination, a continuous strip mill including means for feeding a web of sheet metal; a winder for forming the web into a coil; a detector head including means for projecting a beam of light at an adjustably predetermined zone on the web and a light-sensitive device responsive to light passing through discontinuities of the web in the said zone; means for amplifying the response of the light-sensitive device; and means actuated by the amplifying means and positioned ahead of the winder for fixing a marking tape on the web adjacent the position of discontinuities discovered by the detector head so that the tape extends from the margin of the web and of the coil.

2. In combination, a continuous strip mill including means for feeding a web of sheet metal and means for taking up the web; a detector head including means for projecting a beam of light upon the web along a predetermined zone of the web on one side thereof; a light-sensitive device on the remaining side of the web and responsive to light passing through the defects of the web in the said zone for generating electric signals corresponding thereto; means for amplifying the signals from said light-sensitive means; a tape shooter positioned adjacent an edge of the web and between the detector head and the taking up means; the said tape shooter comprising a means for feeding an adhesive tape and means for pressing a portion of the tape so fed against the moving web, the remaining portion of the tape projecting beyond the edge of the web to mark the web; electric means including delay means for operating the said pressing means in response to signals from the said amplifying means so as to mark the web at a point adjacent the defects discovered by the detector head, and means responsive to the said electrical means for operating the said feeding means after the pressing means has been operated so as to ready the tape shooter for operation by a subsequent defect.

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