The invention relates to apparatus for cutting hot metal as it is received from a processing mill and, more specifically, to hot-saws for cutting rolled metal product, especially steel structural sections such as wide flange beams, as it is received from the finishing stand of a rolling mill. The invention, more particularly, is directed to the problem of determining the shrinkage that will take place as the product cools to atmospheric temperature after it has been cut and, as indicated, comprises improvements in an apparatus for gauging the shrinkage correction to be applied to the length of the product being cut. In a manner to be described the invention resides in part in the discovery that the shrinkage may be determined from the length of the time interval between discharge of the product from a processing mill and the cutting operation.

Many different forms of rolled steel product, such as plate, rails, and wide-flanged beams or other structural sections, are cut while hot as they are received from the finishing stand of a rolling mill, the cutting operation usually being performed by a hot-saw. In order that the cut product will have the desired length when it cools to atmospheric temperature, a shrinkage allowance must be made for thermal contraction from the temperature at which it is cut. Customarily, this shrinkage allowance is based on previous mill experience and is made on the assumption that the temperature of the product is always the same, usually about 1550°F, when the cutting operation is performed. Obviously, this practice results in an excessive shrinkage allowance if there is any delay and the product has cooled to a lower temperature when the cutting operation is performed. While the necessity of reducing the shrinkage allowance for lower cut temperatures has been recognized, attempts in practice to compensate for lower cutting temperatures have usually been less than required, since an excessive correction will result in a product that is too short and may require its being scrapped. As a consequence, the product is commonly cut with too large a shrinkage allowance and must therefore be trimmed to size by cutting or grinding after it has cooled to atmospheric temperature. One of the principal objects of this invention accordingly is to provide an improved shrink gauging apparatus that enables a more accurate determination of the shrinkage allowance and thus eliminates the costly size trimming operations heretofore required.

Another object of the invention is to provide a gauging apparatus in which the shrinkage is determined by the length of the time interval between the discharge of the product from a processing mill, a rolling mill in particular, and the cutting operation.

Other objects and advantages of the invention will become apparent from the following description and accompanying drawings, in which:

FIGURE 1 illustrates diagrammatically the requirements of an apparatus constructed in accordance with the principles of this invention; and

FIGURES 2 and 3 are graphs explaining the operation of the apparatus shown in FIGURE 1.

FIGURE 1 of the drawings shows the manner in which the invention is applied to a hot-saw 1 for cutting wide flange beams 2 as they are discharged from the finishing stand 3 of a rolling mill. A roller conveyor 4 delivers the beams from the stand 3 to a position controlled by an adjustable stop 5 for cutting by the saw 1. The stop 5 engages an end of the beam to limit its movement on the conveyor 4 and thus controls the length of the beam that is cut by the saw 1. The saw is driven by a motor 6 under the control of a switch 7 and has a support 8 that includes a drive (not shown) for movement transversely with respect to the conveyor 4 to cut a beam supported thereon.

The position of the stop 5 lengthwise of the conveyor 4 is controlled by a pair of carriages 9 and 10 that are supported for sliding movement in a direction parallel to the length of the conveyor 4. The carriage 10 has slide support on a stationary base 11 and is driven to a selected position of adjustment relative thereto by a motor 12 under the control of a reversing switch 13. The motor 12 through a worm gear drive 14 rotates a rack gear 15 that has meshing engagement with a rack 16 on the base 11. The rack gear 15 is mounted on the carriage 10 so that rotation thereof is effective to adjust the position of the carriage 10 relative to the base 11. The carriage 9 has a slide support on the carriage 10 and its position relative thereto is controlled by a reversible motor 17 through a drive that includes a threaded shaft 18 and a nut (not shown) secured to the carriage 9 and in which the shaft 18 has threaded engagement. Operation of the motor 17 is controlled by a null-balance potentiometric circuit 19 in a manner to be described. The reversing switch 13 is manually operated to position the carriage 10 according to the length of the beam 2 at atmospheric temperature, such length being indicated by the position of the pointer 20 along the scale 21. The carriage 9 operates to position the carriage 9 relative to the carriage 10 and thus move the stop 5 to a position that provides the required shrinkage allowance for the thermal contraction that will take place when the beam cools to atmospheric temperature.

A pivot shaft 22 supports the stop 5 on the carriage 9 for movement therewith. In addition, the shaft 22 provides for pivotal movement of the stop 5 from a position in an arbor engaging end of a beam 2 to an elevated position out of the path of movement of the conveyor 4 so that movement of the beam 2 over the conveyor 4 may be continued. Pivotal movement of the shaft 22 for this purpose is effected by a linkage 23 that is connected to the shaft 22 and is operated by a reversible motor 24.

The circuit 19 for the motor 17 is a self-balancing potentiometric circuit that includes a manually operable potentiometer 25, a balancing potentiometer 26, and a control potentiometer 27 and operates to adjust the position of the stop 5 to provide the required shrinkage allowance. The potentiometer 25 has a manually adjustable slide contact 28 and the potentiometer 26 has a slide contact 29 which is connected as indicated by the broken line 30 for actuation by the motor 17. Each of the potentiometers 25 and 26 includes a resistor 31 that is energized and calibrated according to the cold length of the beams to be cut, for example, 0 to 90 ft. The slide contacts 28 and 29 are connected by a balancing circuit 32 that includes the control potentiometer 27 and a tap-off lead 33 between a pair of resistors 34 and 35 to an amplifier 36 that controls the operation of the motor 17. When there is an unbalanced condition between the slide contacts 28 and 29, the motor 17 operates to drive the contact 29 to a position balancing the potential called for by the slide contact 28 and the control potentiometer 27. In operation, the slide contact 28 is adjusted to a position corresponding to the cold length of the beam to be cut, the potentiometer 27 introduces in a manner to be described the correction that will produce the required
shrinkage allowance, and the slide contact 29 is driven by the motor 17 to a corresponding balanced position along its resistor 31. This balancing operation of the motor 17 also moves the carriage 9 and stop 5 to a position providing the shrinkage correction required for the selected length of the beam.

As indicated generally above, the shrinkage allowance that is added to the length of the beam by operation of the motor 17 is regulated in accordance with the length of the time interval between discharge of the beam 2 from the finishing stand 3 and operation of the hot-saw 1 by closure of its control switch 7. For this purpose, the control potentiometer 27 comprises a slide contact 37 that is moved an angular distance corresponding to the length of time the beam 2 has been out of the finishing stand 3, and a non-linear resistor 38 that is wound to produce a potential corresponding to the shrinkage allowance to be added to the desired cold length of the beam 2. The potentiometer 27 is calibrated as shown in the drawings to provide a range of shrinkage allowances of from 1.2% to 0.6% of the length of the section that is set manually on the potentiometer 25, since this range covers the thermal contraction that will subsequently take place at the temperatures at which rolled sections are usually cut.

The drive for the slide contact 37 comprises a synchronous clock motor 39 that is under the control of the conventional load sensing device 40 which operates to start the motor 39 when the beam 2 leaves the finishing stand 3. The device 40 preferably includes a strain gauge attached to the housing of the finishing stand 3 and a relay contact in the energizing circuit for the motor 39 which is opened while the beam is moving through the finishing stand 3 and closes to start the motor 39 when the beam 2 is discharged from the finishing stand 3. The slide contact 37 is driven by the motor 39 through a speed change transmission 41 and a magnetic clutch 42. The speed change transmission 41 is a conventional mechanism, commonly referred to as a Reeves-type drive, providing an infinitely variable speed ratio of its input shaft 43, which is driven by the motor 39, with respect to its output shaft 44. It is shown diagrammatically as comprising a conical drum 45 connected to the input shaft 43 and a conical drum 46 connected to its output shaft 44, motion being transmitted between the drums 45 and 46 by a belt 47 which is shiftable axially with respect to the drums 45 and 46 to vary the speed ratio therebetween. By shifting the axial position of the belt 47, the angular distance through which the output shaft 44 is rotated in a given unit of time is varied for a purpose to be described. The output shaft 44 drives the clutch 42 which in turn moves the slide contact 37 an angular distance corresponding to the out-of-mill time of the beam 2. A relay 48 controls the energization of the clutch 42 and operates to deenergize it when the energizing circuit for the motor 39 is opened by the load sensing device 40 in response to a beam 2 moving through the finishing stand 3 and to thus permit resetting of the movable contact 37 by a resetting spring 49. The relay 48 also operates to energize the clutch 42 when the device 49 starts the motor 39 as explained above.

Before specific reference is made of the graphs shown in FIGURES 2 and 3 as a basis for explanation of the requirements of the control potentiometer 27 and its variable speed timing drive, mention will first be made of the fact that the data used in the preparation of such graphs was obtained from time-shrinkage measurements of bars of different sizes and shapes after they were discharged from the finishing stand of a rolling mill. Such measurements showed that the shrinkage of any steel section, expressed as a percentage of its change in length upon subsequent cooling to 60°F, could be determined without regard to temperature of the section from the length of the time interval after its discharge from the finishing stand of a rolling mill. These measurements further indicated that rolled sections of different sizes and shapes had different time-shrinkage characteristics that varied with their respective cooling rates. From the information thus obtained it was further determined that the cooling rate of each of the different sections could be expressed numerically as a constant or factor which for purposes of definition herein was established as the ratio of its weight per unit length (lbs. per foot) divided by its largest diagonal or transverse dimension (inches) and will be hereinafter designated the "cooling ratio" of the section to be cut. Stated in other words this diagonal dimension may be regarded as the diameter of a circle that will circumscribe the cross-sectional shape of the beam, and may be visualized as the internal diameter of a pipe that would just slip over the beam. Generally stated, the cooling ratio furnishes a numerical indication of the time required for the section to cool at a condition such that they will have a subsequent shrinkage of 0.7% of their total length upon cooling to an atmospheric temperature of 60°F. Similar time-cooling ratio curves for subsequent shrinkages of 0.8%, 0.9% and 1.0% were plotted and from these curves the graph of FIGURE 3 was prepared. This graph shows the relation of time out of mill to subsequent shrinkage for sections having the cooling ratios or constants indicated opposite each curve. For example, if a section having a constant of about 3.0, such as the CB-241 beam mentioned above, has an out-of-mill time of 6 minutes, FIGURE 3 shows that it will have a subsequent shrinkage of 0.8% upon cooling to atmospheric temperature. In such case, the required shrinkage allowance can be introduced manually in the apparatus shown in FIGURE 1, by operating the reversing switch 33 to move the pointer 20 to indicate the cold length of the beam, adjusting the slide contact 28 to a point indicating the same length, and then moving the slide contact 37 of the potentiometer 27 to the point at which it will provide a shrinkage allowance of 0.8% of the length called for by the potentiometer 25. The balancing potentiometer 29 and motor 17 will then take over and move the stop 5 to the position providing the required shrinkage allowance.

The apparatus shown in FIGURE 1 is however designed to perform the above operations automatically after the length settings have been manually made. For this purpose, the resistor 38 is non-linear as indicated above and more particularly is wound so that the potential developed by the potentiometer 27 will vary with changes in time and the angular position of the slide contact 37 according to the slope of any one of the curves shown in FIGURE 3. The transmission 41 then provides for operation of the potentiometer 27 in accordance with the cooling ratio or constant of the section to be measured and cut. This is accomplished by moving the belt 47 of the speed change transmission 41 to a position that will provide the proper change in the angular position of the slide contact 37 in a given unit of time for the section to be cut by the saw 1. This setting of the speed change transmission 41 will be best understood by noting, with refer-
ence to FIGURE 3, that the curves for the different cooling ratios are of the same shape and could be superimposed one on the other merely by scaling the time out of the ratio. Thus, the curve corresponding to a cooling ratio constant of 2.0 may be made coincident with the curve for a cooling ratio of 4.0 by multiplying the time out of the mill by a factor of about 2.25. In other words, the slide contact 37 is moved more slowly for a section having a cooling ratio of 4.0 than it is for sections having ratios of 3.0 or 2.0, and the transmission 41 operates to provide the speed of operation of the contact 37 that is required by the cooling ratio of the section being cut. The axial positions of the speed change belt 47 are calibrated as illustrated according to the cooling ratios of from 2.0 to 4.0 to provide the speed of operation of the shrinkage control potentiometer slide contact 37 that is required for the section being cut. In other words, if the section has a cooling ratio constant of 3.50, the belt 47 is shifted axially to a position midway between the calibration points 3.0 and 4.0.

In operation the reversing switch 13 is first operated to move the pointer 20 to a position indicating the length of the section of the beam to be cut, and the slide contact 28 of the potentiometer 25 is moved to a corresponding length indicating position. The speed change transmission 41 is then adjusted according to the cooling ratio of the section to be cut by moving the belt 47 axially to a position opposite the calibration indicating this ratio. After these adjustments have been made, and the load sensing device 40 operated to start the timing motor 39 and drive the speed change transmission 41 when the trailing end of a section 2 moves out of the roll finishing stand 3, the relay 48 will also operate to energize the clutch 42 to begin a timed movement of the slide contact 37. The potentiometer 27 preferably has a copper strip 59 over which the slide contact 37 travels during initial movement before it reaches the potential dropping resistor 38 to provide a time delay before any operation of the shrinkage allowance motor 17 takes place, this delay being dictated by the shape of the curves in FIGURE 3. In practice the time required to deliver a beam from the stand 3 to the saw 1 and cut an end from the beam will usually be such that the slide contact will have moved over the strip 50 and onto the resistor 38 before a section of a beam can be cut to length. This time will ordinarily be sufficient for the temperature of the beam to have cooled below the transformation range.

When the beam 2 moves into engagement with the stop 5, the switch 7 may be closed to operate the saw 1. Closing one of the switches 7 also closes a relay 51 in the circuit for the motor 17 to prevent any change in the position of the stop 5 while the section is being cut. After a cut has been made and the switch 7 is opened to stop the saw, the relay 51 operates to restore the energizing circuit for the motor 17. In the interim, out-of-mill time will have accumulated on the potentiometer 27 and will then operate to affect a further shrinkage allowance adjustment of this position of the stop 5 that may be required for the next length to be cut from the section 2.

Attention is directed to the fact that this invention contains only those components shown diagrammatically in the drawings and that different commercial forms thereof are available on the market. In this respect the potentiometer 27 has been described as having a non-linear resistor 38 and a slide contact 37 that is operated at a constant angular speed, it will be further understood that this arrangement may be modified by using a potentiometer having a linear resistor and a variable speed drive for its slide contact, the only requirement being that its voltage output must conform to the shape of the curves in FIGURE 3.

While one embodiment of our invention has been shown and described it will be apparent that other adaptations and modifications may be made without departing from the scope of the following claims.

We claim:

1. In apparatus for cutting elongated hot metal product as it is received from a processing mill, the combination with a device for cutting said product and adjustable means for controlling the length of the product cut by said device, of means for actuating said adjustable means in accordance with the length of time between discharge of the product from said mill and operation of said cutting device to provide for shrinkage of the cut product to a predetermined length upon cooling to atmospheric temperature.

2. In apparatus for cutting elongated hot metal product as its is received from a processing mill, the combination with a device for cutting said product and adjustable means for controlling the length of the product cut by said device, of means for timing the period between said product leaving said mill and operation of said cutting device, and means operated by said timing means for actuating said adjustable means to provide for shrinkage of the cut product to a predetermined length upon cooling to atmospheric temperature.

3. Apparatus as defined in claim 2 characterized by said last named means comprising a mill-balance control circuit including a slide contact operated by said timing means.

4. Apparatus as defined in claim 3 characterized by said circuit further including a second slide contact operated by said length adjusting means to a position in electrical balance with said first slide contact.

5. An apparatus as defined in claim 2 characterized by said timing means including a constant speed clock motor and a connecting drive rendering it effective to operate said length adjusting means.

6. Apparatus as defined in claim 5 characterized by a speed change transmission means in said drive rendering said motor effective to drive said length adjusting means at selectively different speeds corresponding to the respective cooling rates of the products being.

7. A shrinkage gauge for hot-rolled metal product such as wide-flanged beams and the like comprising, the combination with a hot-saw for cutting the product, a roller conveyor for delivering the product from the finishing stand of a rolling mill to a cutting position opposite said hot-saw, a stop for abutting engagement with the product to arrest its movement over said conveyor and determine the position of said product relative to said saw, and means for moving said stop to adjust the length of the product cut by said saw, means including a constant speed clock motor for timing the period between the discharge of said product from said finishing stand and operation of said hot-saw, and a length control means for operating said stop moving means to move said stop to a position in which the length of the cut product provides a shrinkage allowance such that it will contract to a predetermined length upon cooling to atmospheric temperature, and drive means connecting said length control means for actuation by said motor.

8. In apparatus for cutting hot-rolled metal product, the combination with a support on which the product is received from a rolling mill, a device for cutting the product on said support, and adjustable means for controlling the length of the product to be severed by said cutting device, of means operable in accordance with the length of time between discharge of the product from said rolling mill and operation of said cutting device for actuating said adjustable means to provide for shrinkage of the
product to a predetermined length upon cooling to atmospheric temperature.

9. In apparatus for cutting elongated hot metal product as it is received from a rolling mill, the combination with a device for cutting said product, and adjustable means for controlling the length of the product cut by said device, of means for timing the out-of-mill period between the discharge of said product from said rolling mill and operation of said cutting device, and means operable according to the length of said period for actuating said adjusting means to provide for shrinkage of the cut product to a predetermined length upon cooling to atmospheric temperature.

10. In apparatus for cutting elongated hot metal product, the combination with a conveyor for delivering the product from a processing mill to a cutting device and adjustable means controlling the length of the product cut by said cutting device, of means operable in accordance with the length of time between discharge of the product from said mill and operation of said cutting device for actuating said adjustable means to provide for shrinkage of the product to a predetermined length upon cooling to atmospheric temperature.

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