

June 20, 1961

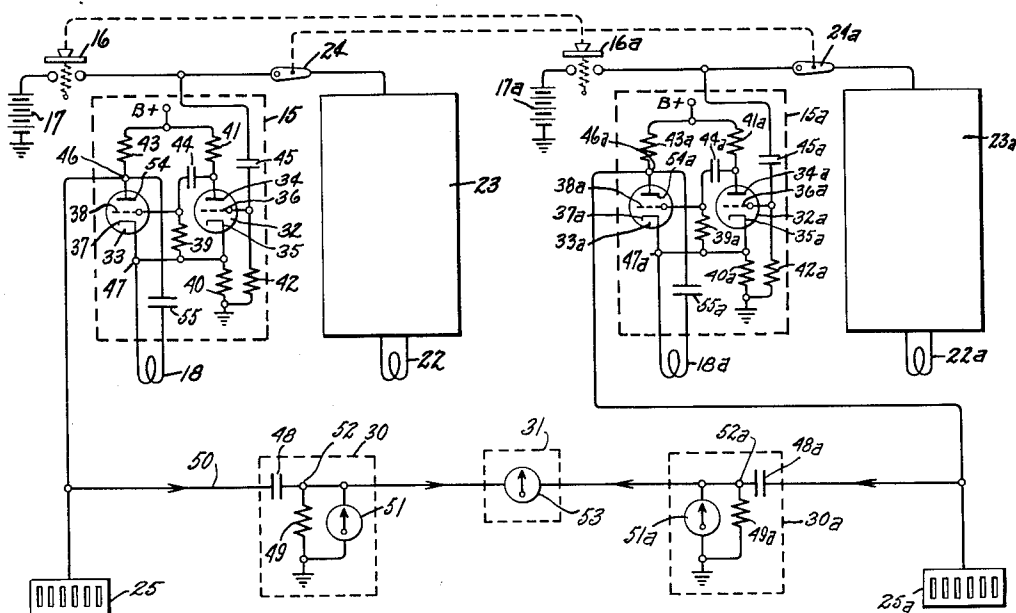
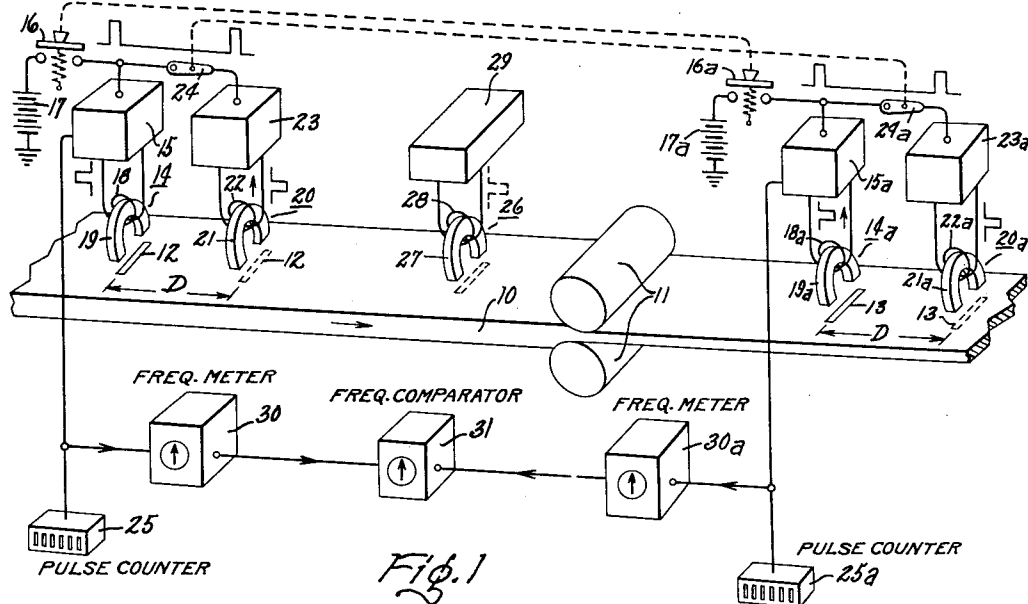
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2,989,690

ELONGATION, LENGTH, AND VELOCITY GAGE

Filed April 29, 1959

4 Sheets-Sheet 1



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June 20, 1961

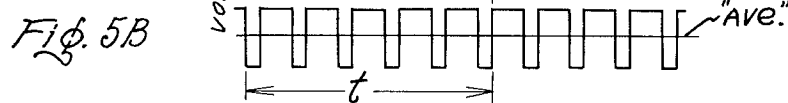
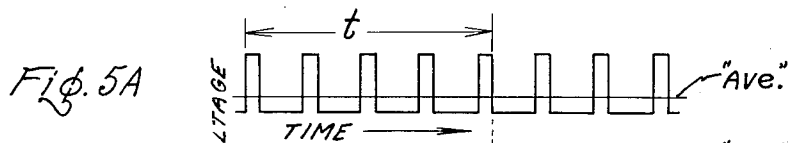
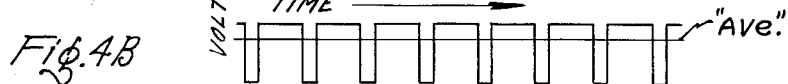
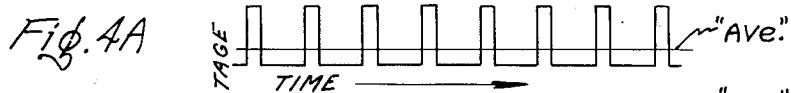
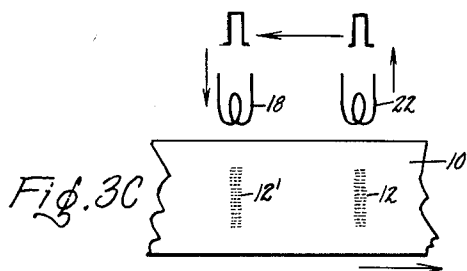
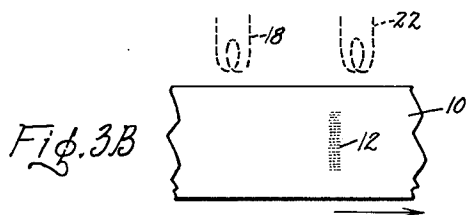
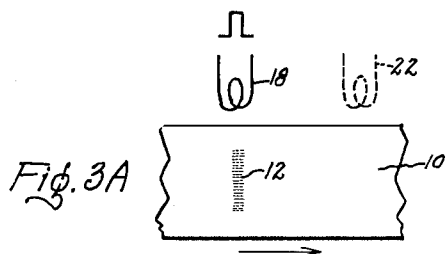
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ELONGATION, LENGTH, AND VELOCITY GAGE

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4 Sheets-Sheet 2



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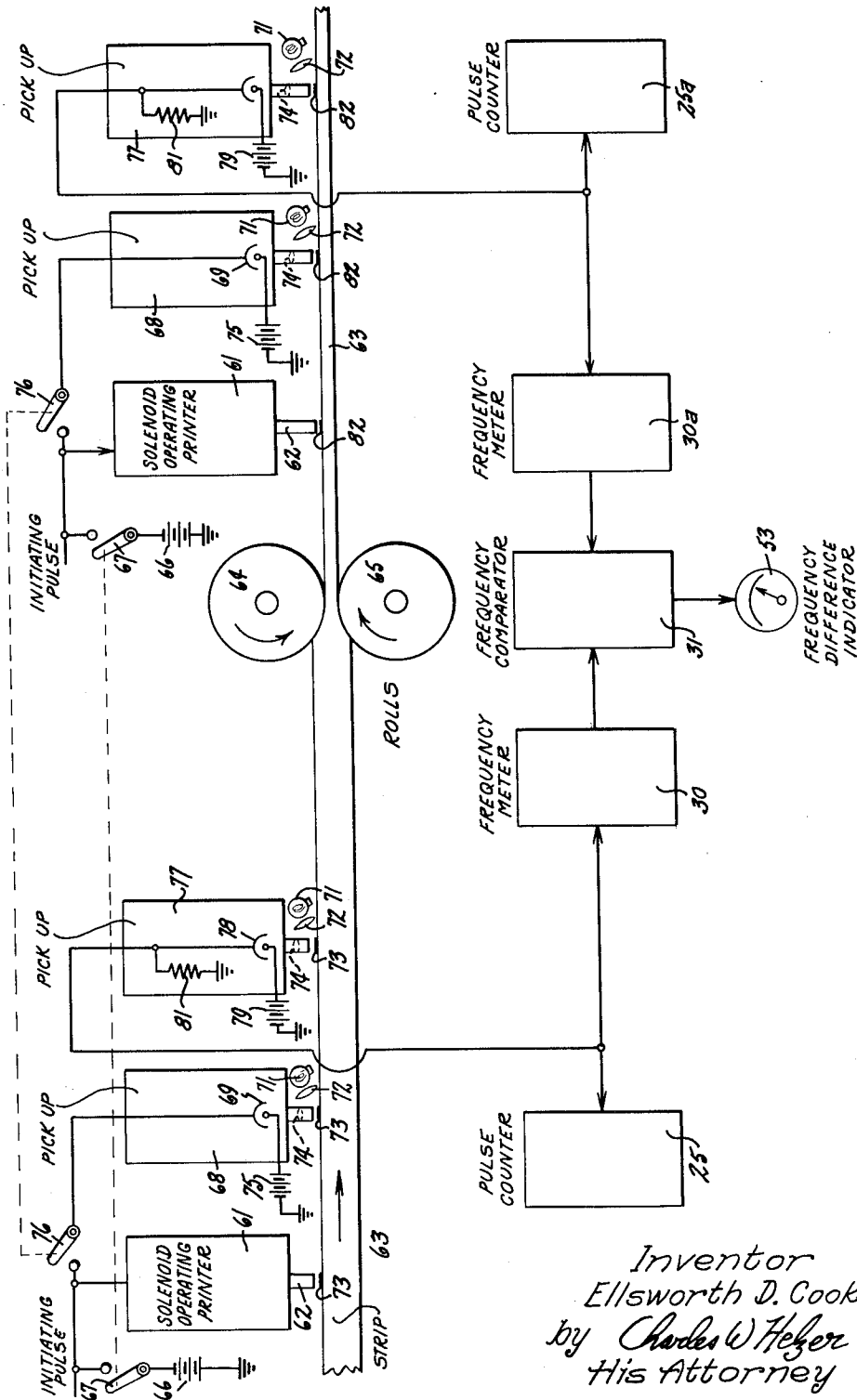
2,989,690

ELONGATION, LENGTH, AND VELOCITY GAGE

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4 Sheets-Sheet 3

FIG. 6



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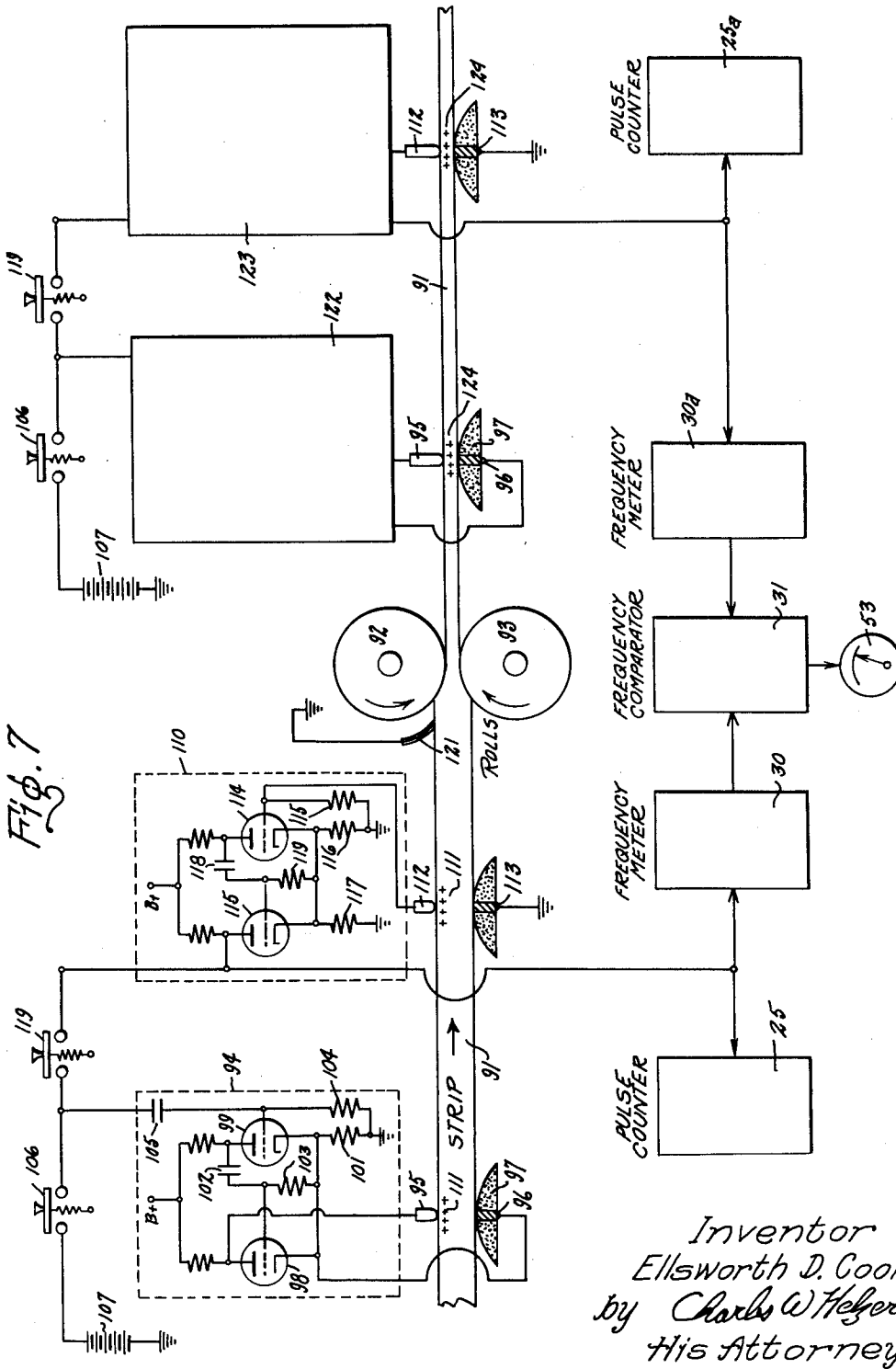
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ELONGATION, LENGTH, AND VELOCITY GAGE

Filed April 29, 1959

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2,989,690

ELONGATION, LENGTH, AND VELOCITY GAGE
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Electric Company, a corporation of New York
Filed Apr. 29, 1959, Ser. No. 809,882
10 Claims. (Cl. 324—34)

This invention relates to a method and means for determining velocity, length, and the change in length; i.e., the elongation of a strip of material which is reduced in cross section by some process such as rolling, drawing, or extrusion. The invention specifically relates to a method and apparatus for making such measurements while the piece undergoing reduction is in motion.

This application is a continuation-in-part application of United States patent application, Serial No. 640,698, filed February 18, 1957 and now abandoned—Ellsworth D. Cook, inventor—Elongation, Length, and Velocity Gage, assigned to the same assignee as the present application, the General Electric Company. While the detailed description set forth hereinafter is concerned primarily in connection with the measurement of elongation in the reduction of steel strips, it should be understood that the invention may be applied equally well in the measurement of elongation of other strips of material being rolled, such as paper, plastic, etc., as set forth in connection with the second species of the invention disclosed.

A temper mill is one where a strip of material such as steel is passed between at least one pair of rolls which reduce the thickness of the strip in order to obtain the desired tempering effect. When the cross section of the strip is reduced, an elongation results. It is important to be able to ascertain the elongation of a strip of steel in a temper rolling mill for a number of reasons. The main reason being that for a strip of steel having a given analysis, heat treatment, width, and gage, the temper is a function of the elongation. Generally speaking, the tensile strength (temper) obtained increases with the elongation; thus, if the elongation of the strip is monitored accurately, the temperature of the strip is also monitored.

One method which has been used to set the mill up so as to produce the desired elongation (which may be between 0% and 10%) has been to produce physical marks by some means, such as scribing, along the steel strip before it enters the reduction and measuring the change in distance between these marks after the strip has been reduced. In this manner the elongation of the strip may be accurately calculated. It will readily be seen, however, that this operation must be carried out at relatively low speeds (for example, 100 feet per minute or less) and considerable strip must be used in order to make the required adjustments.

Since factors such as front and back tensions (i.e., the strip tension before and after reduction), heating of the mill rolls, heating of the mill housing, and various other factors, effect the elongation it is impossible to make the necessary adjustments at low speed with a single pass. Consequently, when these adjustments are made at low speed it may be necessary to run a given strip through the mill several times before the desired elongation is imparted to the strip since the reduction process is generally carried out at relatively high speeds

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(for example, 3,000 feet per minute). In addition, methods which utilize physical marks scribed or placed on the steel strip before the strip undergoes reduction are generally not desirable for the reason that the reduction of the strip may obliterate the markings or the marks may cause flaws in the steel strip. Further, a scribed mark or a raised portion on the strip of material may mar and thus ruin a set of expensive reducing rolls. It is, of course, recognized that physical marks may not be considered disadvantageous for other applications.

Since the reduction in strip cross section results in an elongation of the strip leaving the reducing medium, it is axiomatic that the strip leaving the reducing medium must have a greater velocity than the entering (unreduced) strip. This fact has given rise to a number of elongation measuring systems which depend upon a comparison of the velocities of the strip before and after it is reduced. For example, it has been suggested that the velocity of the strip entering and leaving the reducing rolls may be obtained by utilizing a pair of tachometer generators, one driven by a drive wheel which contacts the steel strip on the front side of the reducing rolls and the other driven by a drive wheel which contacts the steel strip on the back side of the reducing rolls. The elongation of the strip may then be obtained by comparing the two velocities. This method has generally been considered unsatisfactory since the tachometer generators would be required to give an accurate indication over a speed range of approximately 100 to 3,000 feet per minute or a ratio of 30 to 1. Tachometers which will accomplish these results are not readily available. In addition, slippage between the drive wheels and the steel strip makes any arrangement which uses contacting drive wheels subject to errors of a magnitude which cannot be tolerated. The problem becomes more serious as greater accuracy is desired.

Placing magnetic marks on the material before it enters the rolls eliminates the possibility of the rolls being marred by the physical markings but the reduction process may obscure if not totally eliminate the magnetic marks. However, a magnetic mark on the strip can readily be sensed without actually contacting the strip. As a consequence, this approach is utilized in the present invention.

It is one object of this invention to provide an improved method and apparatus for accurately measuring the elongation of a moving strip of material which is reduced in cross section without contacting the moving strip.

Another object of my invention is to provide a non-contacting elongation gage which is accurate over a wide range of speeds and the accuracy of which is not affected by variations in speed of the elongated material.

A further object of this invention is to provide a non-contacting velocity gage for measuring the velocity of a moving strip of material.

Still a further object of this invention is to provide a method and means for simultaneously determining the length, velocity and elongation of a moving strip of material which is being subjected to a reduction in cross section.

In general, the invention is carried out by producing marks on a strip of material (in the embodiment illustrated, the marks are magnetized portions along the

length of the strip) a definite fixed distance apart and determining the rate at which these marks pass a given point adjacent to the strip before the material is reduced in cross section. The rate so determined is a direct measure of the velocity of the strip before its cross sectional area is reduced. Since the marks are placed on the strip at constant or fixed distances apart, the actual length of the strip before the reduction takes place is obtained by simply counting the marks which pass the given point. A series of marks are also produced a constant distance apart on the strip after the strip has been reduced (on the back side of the reducing rolls) and the velocity of the reduced strip is measured by ascertaining the rate at which these marks pass a given point adjacent to the strip. The actual length of the strip after reducing the cross sectional area thereof is determined by counting the marks which pass the given point on the exit side of the strip reducing means. The elongation is then determined by comparing the relative rates (the relative velocities) at which the marks occur. That is to say, the elongation is determined by comparing the rate at which the marks pass a given point after the cross sectional area of the strip is reduced with the rate at which the marks pass a given point before the reduction takes place. In this manner the effect of changes in speed of the strip driving means is entirely eliminated from the measurements.

The word "strip" when used in this application is not intended to denote any particular cross sectional configuration but may apply to a length of material having a cross section of any shape. The term "mark" or "marks" when used in this application is intended to include any distinguishing feature, the presence of which can be sensed. For example, the marks may consist of painted portions or the strip may be continuously magnetized with unmagnetized portions at fixed predetermined distances apart and the unmagnetized portions may be considered marks.

The novel features which are believed to be characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings in which:

FIGURE 1 is a perspective view illustrating a portion of a temper mill including in block form the components utilized in making the various measurements;

FIGURE 2 is a schematic diagram of the apparatus illustrated in FIGURE 1 which shows circuitry utilized in carrying out the present invention;

FIGURES 3A through 3C, inclusive, are schematic diagrams which illustrate the system used to place magnetic marks on the strip of material at a constant distance apart and which are further used in describing the principles of the present invention;

FIGURES 4A, 4B, 5A and 5B illustrate wave shapes which are utilized in describing the operation of the present invention;

FIGURE 6 is a functional block diagram of a second form of elongation gage constructed in accordance with the invention which employs a light modulating technique; and

FIGURE 7 is a functional block diagram of an elongation gage constructed in accordance with the invention which employs an electrostatic technique for measuring elongation of insulating materials being rolled.

FIGURE 1 illustrates the general type of application in connection with which the present invention was made. In this figure, a strip of magnetic material 10, such as steel, is shown moving between a pair of reducing rolls 11 which reduce the thickness of the strip 10.

In carrying out the present invention, it is necessary to place marks 12 on the strip of material at fixed predetermined distances apart before the cross sectional

area of the strip is reduced and another series of marks 13 at preset fixed distances apart after the cross section of the strip 10 has been reduced. Since the strip of material 10 passes through the reduction rolls 11 at a speed which is not constant and since it is desired to place the marks on the strip while the strip is moving at a relatively high rate of speed, for example 3,000 feet per minute, the problem of so placing the marks on the strip is relatively complicated. The speed at which the strip is moving virtually eliminates any contacting method of marking the strip. As a consequence, the actual apparatus used to place the marks on the strip 10 include magnetic record heads 14 and 14a energized by a pair of pulse generators 15 and 15a.

The manner in which the two record heads 14 and 14a are energized is identical and therefore only the system utilized to energize the record head 14 on the front side of reducing rolls 11 is described in detail below.

In order to start the operation of the strip marking system on the front side of the reducing rolls 11, a normally open push-button switch 16 is provided to connect a voltage source such as a direct current battery 17 to energize the pulse generator 15 whereupon the pulse generator supplies a substantially square pulse to the record head 14. The record head itself is illustrated as consisting of coil 18 wound around a magnetic core member 19 which core member is adjacent to the moving steel strip 10. Upon the occurrence of a pulse from the pulse generator 15 magnetic lines of force are generated in the core member 19 of the record head 14. The record head 14 is positioned near enough to the moving strip 10 to produce magnetic lines of force therein and thereby magnetize a portion of the strip 10 (for example, at 12). Since the push-button switch 16 which is used to connect the energizing source of voltage 17 in the circuit to initiate operation of the pulse generator is normally open, the pulse generator does not supply further pulses to cause other marks to be placed on the strip 10 unless some other means is used to energize the pulse generator.

In order to provide the energization required to place a series of magnetic marks 12 a preset distance D apart along the length of strip 10, a pick-up head 20 is positioned adjacent the steel strip the preselected distance D therealong in the direction of movement of the strip and ahead of the reducing rolls 11. The pick-up head 20 like the record head 14 includes a magnetic core member 21 having a coil 22 wound thereon. When a magnetized portion (a mark 12) of the steel strip passes under the pick-up head 20 it generates an electrical pulse therein by the well known principle of electromagnetic induction. As illustrated, the pulse from pick-up head 20 is amplified by conventional amplifier 23 and the output of the amplifier 23 is connected through a disconnect switch 24 to energize the pulse generator 15. When so energized, pulse generator 15 applies another magnetizing pulse to the record head 14. Thus, it is seen that as long as the disconnect switch which connects the amplifier 23 to the pulse generator is closed, each time a magnetic mark 12 passes under the pick-up head 20, the record head 14 is energized to record another magnetic pulse on the steel strip 10.

Since the record head 14 and the pick-up head 20 are a fixed predetermined distance D apart, the magnetized portions of the strip (the magnetic marks 12 on the strip) must occur at fixed predetermined distances D apart regardless of the speed at which the strip 10 is moving. This, of course, is true even if the speed of strip 10 varies. For example, if the strip 10 starts to slow down, it will take a recorded magnetic mark a longer interval of time to pass under the pick-up head and therefore a correspondingly longer period of time for the pick-up head to cause the subsequent recording pulse to be generated by the pulse generator and if the strip speed increases the opposite is true.

In view of the fact that the steel strip is to be marked

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along its length with marks which occur at fixed predetermined distances apart, it is apparent that the number of pulses which are picked up by the pick-up head 20 is a direct function of the length of steel strip which has passed thereunder. Since the number of pulses which are generated in the pick-up head 20 determines the number of pulses generated by the pulse generator 15, the number of pulses so generated is also a measure of the length of strip which has passed under the pick-up head 20. Therefore, in order to measure the length of steel strip which has passed under the pick-up head 20, a common pulse counter 25 is connected to receive the pulses generated by the pulse generator 15.

The particular pulse counter employed may be any one of a number of types which are available commercially such as the Pulse Counter, Model No. 5510, illustrated in Short Form Catalog C-701 "Instrumentation for Laboratory and Industry," published July 1955, by the Berkley Division of Beckman Instruments, Inc., 22 Wright Avenue, Richmond, California.

In order to measure the length of the reduced and elongated strip which leaves the reducing roll, a system is provided on the back side of the reducing rolls which is identical to that just described. Therefore, in order to simplify the present description, the apparatus which follows reducing rolls 11 is given reference numerals which are the same as the corresponding apparatus just described with the exception that the small letter "a" has been added to each reference numeral. Since the marks 12 which are placed on the strip before reduction are not used after the reducing process has been carried out, the marks are erased to make sure that they do not interfere with the marking process on the back side of the reducing rolls. This function is accomplished by an erase head 26 which is positioned between the pick-up head 20 and the reducing rolls 11. The erase head 26 may be of any conventional type but is shown as including a magnetic core member 27 and an energizing coil 28 wound thereon. The coil 28 is energized from a voltage source 29 which causes the erase head 26 to generate a magnetic field of sufficient strength to substantially remove the marks 12 placed on the strip but not to magnetize the strip in the opposite direction. The type of erase head used is not critical and it need not be used at all if the record head 14a and pick-up head 20a on the back side of reducing rolls 11 are laterally displaced so that the magnetic marks 12 would not pass under them even if these marks were not destroyed by the reduction process.

The action of the record head 14 and pick-up head 20 with regard to movement of the strip of material 10 being reduced may be seen more clearly by referring to FIGURES 3A through 3C, inclusive. In these figures only the coils for the record and pick-up heads and the steel strip are illustrated. In each of these figures the coils which are energized either by application of an electrical pulse or by magnetic induction due to the passage of a magnetized region on the strip are shown in solid lines and those which are not energized are shown in broken lines. Referring specifically to FIGURE 3A, it is seen that the coil 18 on the record head 14 is energized by a square wave pulse and as it is energized it places a magnetic mark 12 on the strip of material 10 which is travelling from left to right toward the coil 22 of the pick-up head. In FIGURE 3B, the strip has moved toward the coil 22 of the pick-up head 20 and the magnetic mark 12 thereon has moved almost under the pick-up head but not quite under it. Therefore, coil 22 of the pick-up head 20 is not energized and neither is the coil 18 of the record head 14. In FIGURE 3C the strip has moved on until the magnetic mark 12 is directly under the pick-up head 20. Therefore, an electric pulse is generated in pick-up head 20 which is transmitted to the pulse generator 15. Pulse generator 15 is fired by the received pulse and consequently energizes the record

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head 14 thereby recording a second magnetic mark 12' on the strip of material 10 while it is moving. The marks 12 and 12' are placed on the strip at a distance (D) apart which is equal to the distance between the record and pick-up head. The distance remains constant regardless of the speed at which the strip of material 10 is moving.

Since the magnetic marks 12 on the strip are a constant fixed predetermined distance apart it is seen that the number of such marks which pass a given point, such as the position of pick-up head 20, during any given unit of time, is a measure of the velocity of the strip. Since the record head 20 gives a pulse each time a mark 12 passes thereunder and since it further causes the pulse generator to fire at the same time, then it is apparent that the frequency of the electrical impulses which make up either the voltage wave output from the record head 20 or the output voltage from the pulse generator 15 is a direct measure of the strip velocity. Therefore, for determining the velocity of the strip before it enters the rolls a frequency meter 30 of any known variety may be connected to receive the output of the pulse generator and may further be calibrated directly in velocity in feet per minute or any other convenient measure. One way to measure this frequency is discussed subsequently with regard to the circuit diagram of FIGURE 2. In a like manner a frequency meter 30a may be connected to the pulse generator 15a on the back side of the reducing rolls 11 thereby to measure the velocity of the elongated strip of material 10.

The voltage waves of FIGURES 4A and 4B illustrate the output of the pulse generator on the front and back sides of the reducing rolls respectively. For the condition illustrated in these figures the record head 14 and pick-up head 20 on the front side of the reducing rolls 11 are spaced apart by the same distance as the record head 14a and the pick-up head 20a on the back side of the reducing rolls 11, and the condition illustrated is one where there has been no reduction in thickness of the strip and, therefore, no elongation thereof. Thus, it is seen from FIGURES 4A and 4B that exactly the same number of pulses occur or are generated by both the leading and trailing pulse generators in a given unit of time. For this condition the frequency meters 30 and 30a for each of the pulse generators indicate exactly the same frequency.

In connection with this figure, it is shown that the pulses supplied by both generators are in time phase, however, this does not necessarily have to be and, further, the record and pick-up heads do not have to be the same distance apart on the front and back sides of the reducing rolls. It will be explained later that it may even be desirable to have the record and pick-up heads spaced differently on the front and back sides of the reducing rolls 11 for the purposes of measuring deviations from the desired elongation.

The voltage waves of FIGURES 5A and 5B illustrate the condition for a 20% elongation of the strip. This is seen by the fact that during the period of time t when five pulses are being recorded on the front side of the reducing rolls, (FIGURE 5A) six pulses are being recorded on the back side of the reducing rolls (FIGURE 5B). For example, if the marks are spaced ten inches apart on the strip of material on both the front and back sides of the reducing rolls, 10 times 5 or 50 inches of strip is passing under the pick-up head on the front side of the roll while 10 times 6 or 60 inches is passing under the pick-up head on the back side of the reducing rolls.

Actually, the pulse generators 15 and 15a start at the same time in the embodiment of the invention illustrated in FIGURE 1 simply because the push-button switches 16 and 16a which energize them initially are illustrated as being mechanically connected together; however, there is no reason why this should be the case other than as a matter of convenience.

A measure of the velocity of the strip before it enters the reducing rolls and a measure of the velocity of the strip after it leaves the reducing rolls is obtained as described above. It is only necessary to compare these two velocities in order to obtain a measure of the elongation. This may be done by comparing the frequencies of the pulses produced by the pulse generators 15 and 15a on the front and back side of the reducing rolls. This can be done by utilizing any type of frequency comparator 31.

It is to be particularly understood that the measurements discussed above; i.e., the strip velocity and elongation, can be made by any number of conventional frequency meters or frequency comparators and the pulse generators referred to above can also be of any known and conventional type. However, in order to describe the invention completely, circuitry which has been found particularly suitable and which is considered to be simple and reliable is illustrated in FIGURE 2. In this figure the components which correspond to the components of FIGURE 1 are given the same reference numerals in order to simplify the discussion. The pulse generators 15 and 15a for the record heads 14 and 14a both before and after the reducing rolls are identical, therefore, only the operation of the leading record head 15 is described in detail. In addition, corresponding components of the pulse generator 15a for the record head 14a on the back side of the reducing rolls 11 are given the same reference numerals as those on the front side except that the small letter "a" has been added.

The pulse generator 15 on the leading side of the reducing rolls 11 is a conventional cathode coupled one-shot or monostable multivibrator. By this it is meant that upon the occurrence of an actuating pulse, the multivibrator generates a pulse of a given amplitude and a given pulse width and then returns to its initial state. The multivibrator includes two vacuum tubes 32 and 33 with one tube, the input tube, normally cut off (non-conducting) and the other normally conducting. Each of the vacuum tubes 32 and 33 is a three element tube. The input tube 32 (normally non-conducting) has a plate 34 connected to a source of positive direct current potential B+ through a plate resistor 41, a cathode 35 connected to ground potential through cathode resistor 40, and a control grid 36 connected to ground potential through a grid bias resistor 42. Output tube 33 also has a plate 54 connected to the unidirectional voltage source B+ through a resistor 43, a cathode 37 also connected to ground potential through the cathode resistor 40 of input tube 32, and a grid 38 connected to its cathode 37 through a coupling capacitor 44. The input to the pulse generator 15 is applied to the grid 36 of input tube 32 through a coupling capacitor 45 and the output voltage of the pulse generator 15 may be taken between the plate 54 (at terminal 46) and cathode 37 (at terminal 47) of output tube 33. A blocking capacitor 55 is connected in series with the coil 18 of record head 14 in order to prevent a unidirectional magnetizing voltage from being applied to the coil 18 of the pick-up head 14. If desired, additional shaping circuits may be used to perfect the squareness of the output wave but with the pulse generator illustrated this is not generally necessary.

A balance condition of the pulse generator 15 is established by the arrangement of biasing the tubes 32 and 33. This balance condition is, with output tube 33, fully conducting and input tube 32 cut-off (non-conducting). For these conditions the output voltage (the voltage across output tube 33) is substantially lower than when it is non-conducting.

Conduction of output tube 33 is insured under normal circuit conditions by fixing its grid 38 and cathode 37 at a common potential. This is done by connecting these two elements together through a biasing resistor 39 which is not normally conducting. The plate current of output

tube 33 therefore flows through the cathode resistor 40 for the input tube 32 and thereby establishes a positive potential at the cathode 35 of input tube 32 with respect to its grid 36 which prevents conduction therethrough.

In order to change the state of operation of the pulse generator 15 and thereby cause a pulse to be generated, a positive triggering pulse is applied to the grid 36 of the input vacuum tube 32 which pulse is of sufficient magnitude to cause the tube to conduct. Once the input tube 32 starts to conduct its plate voltage decreases. This plate voltage decrease passes through the coupling capacitor 44, which is connected to the grid 38 of output tube 33, and as the voltage across the capacitor cannot be changed instantaneously it appears on the grid 38 as a negative going voltage. The negative going voltage on the grid 38 decreases the plate current therethrough, thus reducing the voltage drop across the cathode resistor 40 and allowing more current to flow in input tube 32. Thus, the plate voltage of input tube 32 is further decreased causing the grid 38 of the output tube 33 to go still further negative as described above. This action continues until the output tube 33 is rendered non-conducting and the input tube 32 is fully conducting. This action is practically instantaneous.

When the output tube 33 is cut off its plate voltage rises to a potential which is approximately equal to the applied potential B+ and remains so while the coupling capacitor 44 discharges sufficiently toward the lower value of the plate voltage of the input vacuum tube 32 to allow the grid 38 of the output tube 33 to rise from its lowest value to cut-off voltage. At this time the output tube 33 begins to conduct and the plate current again starts to flow through the tube and the circuit, which includes cathode resistor 40, raising the cathode voltage of the input tube 32 thus reducing the current flowing therethrough. The decreased current through input tube 32 allows the potential at plate 34 of the input tube 32 to increase toward the B+ potential. This increase is coupled to grid 38 of the output tube 33 through coupling capacitor 44 still further increasing the current through the output tube 33 until it is again fully conducting and the potential at its plate 54 drops to its initial low value. This action is also substantially instantaneous.

Once the circuit is back to its original balanced state it remains so until another positive pulse arrives at grid 36 of tube 32 and causes the input tube 32 to pass current. Thus, every positive pulse supplied to the grid of the input tube 32, which is of sufficient amplitude to cause the first vacuum tube to conduct, results in a large positive pulse output from the plate 54 of the output tube 33. The length or duration of this positive output pulse is controlled by the value of the coupling capacitance 44 and the grid resistor 39. The circuit time constant is represented by the product of the magnitudes of the coupling capacitance 44 and grid resistor 39.

In view of the above explanation, it is seen that once the push-button switch 16 is closed to connect the source of direct current voltage 17 to the grid 36 of the input vacuum tube 32, it causes the pulse generator to put out a large positive pulse in the manner just described. As soon as the push-button switch 16 is released the pulse generator is no longer energized. However, as was previously described, the pulse generator 15 records or magnetizes a portion of the traveling magnetic strip passing thereunder and this magnetized portion passes under the pick-up head 20 which generates a voltage pulse in response thereto. This voltage pulse is then amplified by any conventional type of amplifier 23 such as the amplifier illustrated in FIGURE 5—5 on page 121 of the book entitled, Principles of Electron Tubes by H. J. Reich, published by McGraw-Hill Book Company, Inc., 1941. The pulse so generated is then applied to the grid 36 of input tube 32 of pulse generator 15 as a triggering or initiating pulse. Once this pulse is applied to the pulse gener-

ator 15, the pulse generator puts out a voltage pulse at the constant predetermined amplitude and pulse duration, thereby recording another magnetic mark on the moving strip of material 10 and the cycle repeats itself until there is no more material passing under the pick-up head 20 or the circuit is otherwise rendered non-operative.

Since the pulse generator 15 provides output pulses which are of constant amplitude and also a constant duration or width, it is a simple matter to obtain an indication of the frequency of the output voltage by integrating this output voltage wave. Any number of means can be provided for doing this. However, the frequency meter 30 which has been chosen represents one of the simplest known means.

As may be seen from FIGURE 2, the frequency measuring circuit of frequency meter 30 includes the combination of a capacitor 48 and a resistor 49 which are connected in a series circuit which may be traced from the output terminal 46 of pulse generator 15, conductor 50, capacitor 48 and resistor 49 to ground potential. This circuit passes square wave current pulses from the pulse generator 15 to ground. Thus, a voltage having the form of the pulses from the pulse generator is developed across the resistor 49 dependent upon the number of current pulses. A conventional low power consumption voltmeter 51 is connected directly across resistor 49. This meter reads the average value of the voltage wave built up across resistor 49. This average value is a direct measure of the frequency of the pulses and, consequently, of the velocity of the moving strip. In order to illustrate this point, reference should be had to FIGURE 4A which shows the pulsating voltage wave output of the pulse generator 15. Since a similar current wave flows through condenser 48 and resistor 49 and thereby develops a voltage wave of similar form across resistor 49, the pulsating voltage waves illustrated in FIGURES 4A and 5A and 5B may be considered as the voltage waves developed across the resistors 49 and 49a of frequency meters 30 and 30a respectively. The straight line marked "ave." which is above the minimum voltage level represents the average value of this pulsating voltage wave and also represents the reading which appears on the voltmeter 51 connected across resistor 49 as described. If the frequency of the pulses increase, the level of this line increases, and if the frequency of the pulses decrease, then the level of this line decreases. It is therefore seen that the reading or indication of meter 51 gives an indication of the frequency of the output voltage pulses from the pulse generator and consequently the velocity of the strip of material 10 before it passes through the reducing rolls 11.

The pulse generator 15a on the back side of the reducing rolls 11 operates in exactly the same manner as does that just described for the front side of the reducing rolls and the frequency meter 30a operates in exactly the same manner as the frequency meter 30 just described with reference to the output of the pulse generator 15 on the front side of the reducing rolls 11. Consequently, this description will not be repeated for this portion of the circuit. However, it will be noted that the pulsating wave of FIGURE 4B represents the output voltage of the trailing generator 15a and the straight line (marked "ave.") below the maximum value of voltage for this pulse generator represents the average value of this voltage wave across resistor 49a and consequently the reading of the voltmeter 51a for the frequency meter 30a for the trailing pulse generator 15a. The reason that the pulses for the two pulse generators are illustrated as being in opposite senses will be described in connection with the frequency comparison system.

In order to compare the velocity of the strip after its cross section has been reduced with the velocity before the cross section has been reduced, a means of comparing the frequencies of the voltage waves produced by the

leading and trailing pulse generators 15 and 15a is provided. The particular means of comparing these two frequencies consists simply of connecting a low power consumption voltmeter 53 between the terminal points 52 and 52a respectively on the two resistors of the frequency meters 30 and 30a, which terminal points are above ground potential. In this manner the average values of the voltage waves produced by each of the pulse generators is subtracted.

Since the average value of the potential developed across each of the resistors 49 and 49a of the frequency meters 30 and 30a is a direct function of the strip velocity before and after passing through reducing rolls 11, respectively, the difference of these two average values is a function of the relative velocities and, consequently, a direct function of the change in length (elongation) of the strip.

This may be seen by reference to the voltage waves illustrated in FIGURES 4A, 4B, 5A and 5B. The magnitude of the average values of the pulsating voltage waves of FIGURES 4A and 4B are equal as illustrated by the straight lines marked "ave." in both figures. The voltmeter 53 of frequency comparator 31, therefore, reads zero for this condition. This is true since the waves of FIGURES 4A and 4B were drawn to illustrate the condition where the strip 10 passes through reducing rolls 11 without having its cross section reduced. However, if any reduction in strip cross sectional area occurs, voltmeter 53 no longer reads zero. The voltage waves described with regard to FIGURES 5A and 5B illustrate the condition where the strip 10 is reduced in cross section by rolls 11. As was previously pointed out, the pulses are of equal amplitude and pulse duration but the frequency of occurrence of the pulses of FIGURE 5B is greater due to the strip elongation. Therefore, the average value of the voltage wave illustrated in FIGURE 5B is greater than the average value of the voltage wave illustrated in FIGURE 5A. As a consequence, the voltage comparator 31 (the voltmeter 53) connected between the positive terminal points 52 and 52a of the two resistors, and 51 and 51a respectively, will indicate the difference in potential; i.e., the difference in average value and therefore the elongation.

It is to be particularly understood that a number of alternative arrangements could be made which fall within the scope of the present invention. One such alternative would be to adjust the distance between the record head 14a and pick-up head 20a on the back side of the reducing rolls 11 in such a manner that the pulse generator 15a places its series of marks 13 on the strip 10 at a distance apart which is greater than the distance D between the marks 12 placed on the strip 10 on the front side of the reducing rolls 11. This may be done in such a way that the frequency comparator 31 is nulled (reads zero) when the elongation of the strip 10 is exactly the desired amount. For example, if the record head 14 marks the entering strip every 10 inches and it is desired to obtain as much as 20% elongation, the record and pick-up heads 14a and 20a on the trailing side of the reducing rolls 11 may be spaced 12 inches apart. In this manner the frequency of the recorded pulses on the front and back sides of reducing rolls 11 would be exactly equal when 20% elongation is obtained. Therefore, the frequency comparator meter would read zero for a 20% elongation. Under these conditions, the voltmeter 53 which compares the frequencies should be a zero reading type which gives a negative indication if the elongation is not as great as desired, zero indications if the elongation is exactly that desired, and a positive indication if the elongation is too great.

A second embodiment of a velocity elongation gage constructed in accordance with the teachings of the present invention is shown in FIGURE 6 of the drawings. The embodiment of the elongation gage shown in FIGURE 6 is particularly adapted for use in measuring elon-

gation of paper or plastic after being rolled, or any similar material where the placement of a small mark on the edge of the material will not impair its value. The elongation gage of FIGURE 6 includes a solenoid operated printing device 61 having a movable printing arm 62 adapted to contact a moving strip 63 of material such as paper or plastic whose elongation is to be measured after rolling through a rolling press indicated by the rolls 64 and 65. The solenoid operated printer 61 is initially actuated from a starting circuit formed by a battery 66 having one of its terminals grounded and the remaining terminal connected through a knife switch 67 to the input of the solenoid operated printer 61. To initially actuate the gage, the switch 67 is momentarily closed, and then opened, and results in causing the printing arm 62 to contact the moving strip of material 63 to place a small deposit of ink 73 or other similar contrasting material on the edge of the moving strip 63. The trip 63 then moves in the direction of the arrow to bring the printed mark under the view of a photoelectric pickup device 68 which includes a photocell 69 and light source 71. The light source 71 projects light through a focusing lens assembly 72 upon the mark indicated at 73. This light will be reflected up through a lens assembly 74 upon the photocell 69. The photocell 69 has its anode or collector electrode connected to the positive terminal of a source of energizing potential comprised by a battery 75 having its negative terminal grounded. The emitter electrode of the photocell 69 is connected through an actuating switch 76 back to the input of the solenoid operated printer 61. By this arrangement, it can be appreciated that light from the light source 71 will normally be reflected upward onto the photocell 69 until the occurrence of a printed mark which will absorb most of the light thereby resulting in the production of a sharp current pulse by the photoelectric cell. This current pulse is coupled back through switch 76 to trigger the solenoid operated printer 61. By this arrangement, it will be assured that the marks 73 placed on the moving strip of material 63 will be equally spaced apart.

In order to derive an output electrical voltage indicative of the marks 73 placed on the moving strips of material 63, a second pickup device 77 is provided which includes a photocell 78 having its collector electrode connected to a battery 79, and its emitter electrode connected through a load resistor 81 to ground and then to the battery 79. The load resistor 81 is connected through a suitable length of conductor to a frequency meter 30 and pulse counter 25 which are identical in construction and operation to the frequency meter, and pulse counter of the circuit arrangement shown in FIGURE 1 of the drawings. The frequency meter 30 has its output connected to a frequency comparator circuit 31 which likewise is identical in construction and operation to the frequency comparator circuit 31 shown in elongation gage of FIGURE 1 of the drawings. By this arrangement, upon a printed mark 73 passing under the view of the photocell 78, a voltage pulse will be produced across the load resistor 81 which is supplied to the pulse counter 25, and frequency meter 30. These devices then operate to derive an indication of the number of printed marks 73, and the frequency of repetition of the marks passing under the view of the photocell 78, respectively.

A second set of mark printing device 82 and photocell pickup devices 83 and 84 identical to that described with relation to the input side of the rolls 64 and 65, is located on the output side of the rolls. Because this arrangement is identical in construction and operation to the arrangement 61, 68 and 77 described with respect to the input side of the rolls, it will not again be described in detail, and the component parts of the arrangement have been given the same reference character. It should be noted, however, that the printed marks 85 placed on the strip of material by printing device 82 must be in a second line which is disposed from the line of the first

marks 73 so that no interference between the two lines of marks occurs. For this reason, it is anticipated that the mark printing and pickup arrangement on the output side of the rolls could be disposed on the side of the strip 63 opposite from that on which the mark printing and pickup arrangement on the input side of the rolls is located. To facilitate operation of the elongation gage shown in FIGURE 6, the starting switches 67 and the running switches 76 may be mechanically interconnected as shown by the dotted line, and the switches 76 likewise may be interconnected so that the two sets of mark printing and pickup arrangements on opposite sides of the rolls 64 and 65 are actuated simultaneously. The pickup 77 will operate to develop a pulsed output potential across the load resistor 81 which is representative of the count and repetition rate or frequency of the marks 85 passing within the view of the photocell 78. This pulsed output potential is then supplied to a pulse counter 25a, and to a frequency meter 30a. The pulse counter 25a and frequency meter 30a are identical in construction and operation to the pulse counter 25a and frequency meter 30a, respectively of the gage shown in FIGURE 1, and hence will not be again described in detail.

The two frequency meters 30 and 30a are connected to respective input terminals of a frequency comparator 31 where they will derive an output indication of any difference in frequency between the two pulsed wave form signal which is indicated on the frequency difference indicator 53. The magnitude of this frequency difference will then provide an indication of the elongation of the strip 63 produced by the rolls 64 and 65. Accordingly, by proper calibration of the frequency difference indicator 53, a readily observed output indication of the elongation of the strip 63 can be obtained. In place of the printed mark placed on the moving strip of material 63 by the printing head 61 it might also be possible to punch small holes in the material with a solenoid operated hole punching device. In this eventuality, should the material be opaque it would be possible to place a light source on the opposite side of the material in the pickup portion of the elongation gage so that as each mark or hole passes between the light source and the pickup photocell, an electrical signal pulse will be generated. As such an arrangement is believed to be obvious in the light of the description of the FIGURE 2 species of the invention, a further description is believed unnecessary. Additionally, with such an arrangement it might be possible to generate the desired frequency indicating electric signals with a pair of mechanical contacting wiping fingers which are allowed to close as they wipe across the punched holes, provided the strip 63 is of sufficient dielectric strength, and thin enough to allow the mechanical contacting finger arrangement to be used.

Still a third embodiment of an elongation gage constructed in accordance with the present invention is shown in FIGURE 7 of the drawings. The elongation gage shown in FIGURE 7 is designed for use with a moving strip of insulating material 91 which is to be rolled by a pair of rolls 92 and 93 from a first thickness to a second final thickness. The insulating material 91 may comprise a plastic such as one of the polyolefin plastics made up by polyethylene, polypropylene, polyisobutylene, or polyethylene terephthalate. If desired, one of the plastics known by its trade name such as Mylar, which is an oriented polyester, or Teflon or Saran wrap which is polyvinylidene chloride might be used. Another suitable plastic with which the gage could be used are the new aromatic polycarbonates which are sold under the trademark Lexan. From this list of materials it can be appreciated that there are a large number of plastic materials which when being processed are usually rolled from one thickness to another, and wherein it would be desirable to obtain a measurement of the percent elongation occurring by reason of the rolling. For this purpose

the elongation gage includes a capacitive charging circuit 94 which uses a capacitive charging head formed by a pair of opposed electrodes 95 and 96 to place an electric charge on the surface of the moving strip of insulating material 91. In order to effectively charge the moving material it is desirable that the opposed metallic electrodes 95 and 96 physically contact the moving strip of material 91. The metallic electrode 96 is disposed or sandwiched in between two insulating shoulders 97 which have their upper surfaces rounded to form a smooth pad to support the moving strip of insulating material 91. The upper electrode 95 which is disposed immediately over the electrically conducting portion 96 likewise has its lower surfaces which contact the moving strip of insulating material 91, rounded. The charge marking electrodes 95 and 96 are connected to the charging circuit 94 for providing a pulsed wave form electric signal thereto to effectively charge a small area or mark 111 on the moving strip of insulating material 91. It is desirable that this mark be anywhere between one-half inch and one-quarter inch long, and perhaps 10 mils wide, and that it be sharply defined for a period of time at least long enough to allow the strip of material to move the mark under the detecting circuit to be described hereinafter. The trigger circuit is formed by a pair of triode electron discharge tubes 98 and 99 which have their cathodes connected through a common cathode biasing resistor 101 to ground, and have the anodes connected through respective plate load resistors to a source of positive plate potential marked B+. Additionally, the anode of the triode 98 is connected to the charging electrode 95 through an isolating capacitor 100, and the cathode thereof is connected to the charging electrode 96. The anode of triode 99 is connected through a capacitor 102 and resistor 103 to the control electrode of the triode 98. The control electrode of triode 99 has an input triggering circuit connected which is formed by a grid resistor 104 and capacitor 105, and which is connected through a switch 106 to a battery 107.

In operation, upon the switch 106 being closed a positive voltage pulse will be applied to control grid of electron discharge tube 99. This voltage pulse causes tube 99 to be rendered conducting, and to feed back a negative pulse to the control grid of electron tube 98 resulting in cutting electron tube 98 fully off. Upon electron tube 98 being rendered non-conductive a large positive voltage pulse will be applied across the charging electrodes 95 and 96 causing a charge 111 to be built up on the surface of the strip of insulating material 91. Thereafter, the charge on capacitor 102 leaks off and returns the circuit to its normal condition wherein the electron tube 98 is conducting, and electron tube 99 is non-conducting. The resultant output signal at the anode electrode of electron tube 98 is a sharp, well-defined voltage pulse which results in a sharp, well-defined area of charge 111 produced on the surface of the insulating material 91.

After having the charge indicated by the plus marks shown at 111 placed thereon, the strip of insulating material 91 moves in the direction of the arrow to bring the charged mark 111 under a pickup head formed by a pair of opposed capacitive electrodes 112 and 113 which are identical in construction to the charging electrodes 95 and 96 shown in connection with the marking device 94. The electrode 113 is connected directly to ground, and the electrode 112 is connected across a grid resistor 115 to the control electrode of an electron discharge tube 114. The triode electron discharge tube 114 together with a second triode 115 forms a one shot trigger circuit. Both triodes 114 and 115 have their cathode electrodes connected through suitable cathode resistors 116 and 117 respectively to ground, and the anode electrodes thereof are connected to suitable plate load resistors to a source of positive plate biasing potential. Additionally, the anode electrode of electron tube 114 is connected through a charging network formed by capacitor 118 and resistor 119 back to the control electrode of electron tube 115.

By this arrangement upon the electron tube 114 being rendered conductive, triode 115 will be cut off producing a positive voltage pulse at its anode electrode which may be supplied back through a connecting switch 119 to the control electrode of triode 99 in the marking device 94. Additionally, the voltage pulse produced at the output of triode 115 is supplied to a pulse counting device 25 and frequency meter 30 which are identical in construction to the pulse counter and frequency meter 25 and 30 of the embodiment of the invention shown in FIGURE 1 of the drawings. By this arrangement, after the initial charge 111 has been placed on the strip of moving insulating material 91 by the marking device 94, the starting switch 106 may be released and the continuous running switch 119 closed so that the voltage pulses produced by the pickup device 110 are supplied back to trigger off the marking device 94 thereby assuring that the charged marks 111 will be spaced an equal distance apart along the length of the insulating material 91.

After passing under the pickup device 110 the strip of insulating material moves the charged marks 111 under a contact brush 121 which serves to discharge the mark on the insulating material prior to the material passing under the rolls 92 and 93. Thereafter, the material 91 passes through the rolls where it is elongated due to the action of the rolls.

A second charge marking device 122 and pickup device 123 are mounted over the moving strip of insulating material 91 at the output side of the rolls 92 and 93. The charge marking device 122 and pickup device 123 are identical in construction and operation to the charge marking device 94 and pickup device 110 described with relation to the input side of the rolls 92 and 93, and hence will not be again described in detail. It is believed adequate to point out that the charge 124 produced on the reduced thickness strip of insulating material 91 is a new electric charge, and that the spacing between the charges is identical to the spacing between the charges 111 placed on the strip at the input side of the rolls 92 and 93. The marks 124 will move between the charging heads 95 and 96 of the charging device 122, and the pickup heads 112 and 113 of the pickup device 123 at a greater velocity however due to the decreased thickness of the strip produced by the action of the rolls 92 and 93. This increased velocity will result in increasing the repetition rate or frequency of the pulses produced by the pickup device 123. These electric signal pulses are supplied in turn to a pulse counter device 25a and frequency meter 30a which are identical in construction and operation to the pulse counting device and frequency meter described with relation to the embodiment of the invention shown in FIGURE 1. Hence, these components will not be again described in detail. The two frequency meters 30 and 30a both supply output signals to a frequency comparator circuit 31 having a frequency difference indicator 53 coupled thereto. The frequency comparator 31 is identical in construction and operation to the frequency comparator described with relation to the embodiment of the invention shown in FIGURE 1 of the drawings, and hence it too will not be again described in detail.

It is believed to be adequate to point out that the frequency comparator compares the frequency signals supplied thereto from the frequency meter 30 and the frequency meter 30a and derives an output indication of the difference of the frequency which is indicated by the indicator 53. This difference in frequency then constitutes a measure of the elongation of the strip of insulating material 91 produced by passing through the rolls 92 and 93. Accordingly, by proper calibration of the frequency difference indicator 53, this elongation may be readily observed.

From the foregoing description it can be appreciated that the invention provides an improved method and apparatus for accurately measuring the elongation of a

moving strip of material which is reduced in cross section and which is not affected by variations in speed of elongated material. Further, it can be appreciated that the new and improved elongation gage may be used to provide an indication of the velocity of the moving strip of material both before and after passing through rolls for reducing the cross section thereof, and that the indication derived is both accurate and reliable and readily observed from indicating instrument comprising a part of the gage.

Having described several embodiments of a new and improved elongation gage constructed in accordance with the present invention, it is believed obvious that many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that changes may be made in the particular embodiment of the invention described which are within the full intended scope of the invention as defined by the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An apparatus for determining the elongation of a moving strip of material subsequent to rolling including in combination, first marking means for placing marks a predetermined distance apart on the strip of material prior to rolling, second marking means for placing marks on the strip of material a distance apart equal to the spacing of said first mentioned marks subsequent to rolling, first electric signal generating means spaced from said first marking means in the direction of travel of the moving strip for generating an electric signal upon each of the first marks passing a predetermined point prior to rolling, second electric signal generating means spaced from said second marking means in the direction of travel of the moving strip for generating an electric signal upon each of the second marks passing a predetermined point, and comparison means operatively coupled to both said first and second signal generating means for comparing the frequency of the signals generated thereby and deriving an output indication of the difference therebetween.

2. The combination set forth in claim 1 further characterized by a frequency meter operatively coupled to the output of each of said electric signal generating means.

3. The combination set forth in claim 1 further characterized by a frequency meter and a pulse counting device operatively coupled to the output of each of said electric signal generating means.

4. An apparatus for determining the elongation of a moving strip of magnetizable material subsequent to rolling including in combination, first magnetic marking means for placing magnetic marks a predetermined distance apart on the strip of magnetizable material prior to rolling, second magnetic marking means for placing magnetic marks on the strip of magnetizable material a distance apart equal to the spacing of said first mentioned magnetic marks subsequent to rolling, first electric signal generating means spaced from said first magnetic marking means in the direction of travel of the moving strip for generating an electric signal upon each of the first magnetic marks passing a predetermined point prior to rolling, second electric signal generating means spaced from said second marking means in the direction of travel of the moving strip for generating an electric signal upon each of the second magnetic marks passing a predetermined point, and comparison means operatively coupled to both said first and second signal generating means for comparing the frequency of the signals generated thereby and deriving an output indication of the difference therebetween.

5. The combination set forth in claim 4 further characterized by magnetic marks erasing means positioned intermediate the first signal generating means and the point at which the strip is rolled for removing magnetic marks placed on the strip of material prior to rolling.

6. An apparatus for determining the elongation of a moving strip of magnetizable material subsequent to rolling including in combination, first magnetic marking means for placing magnetic marks on the moving strip of magnetizable material prior to rolling, first pulse generating means for generating an electrical pulse upon each of the magnetic marks passing a predetermined point spaced from said first magnetic marking means in the direction of travel of the moving strip of material,

10 the output of said first pulse generating means being connected to said first magnetic marking means for actuating the same, first indicating means operatively coupled to said first pulse generating means for determining the number of pulses generated thereby in a given unit of time, second magnetic marking means for placing magnetic marks on said moving strip of material subsequent to rolling, second pulse generating means for generating an electric pulse upon one of the magnetic marks from said second marking means passing a predetermined point, said second pulse generating means being spaced from said second magnetic marking means in the direction of travel of the strip of moving material and being connected to said second magnetic marking means for actuating the same, second indicating means operatively coupled to said second pulse generating means for determining the number of electric pulses generated thereby in a given unit of time, and comparison means operatively coupled to both of said first and second indicating means for comparing the number of pulses generated by said first pulse generating means to the number of pulses generated by said second pulse generating means in a given unit of time.

7. A combination set forth in claim 6 further characterized by magnetic mark erasing means positioned intermediate the first pulse generating means and the point at which the strip is rolled for removing magnetic marks placed in a strip of material prior to rolling.

8. An apparatus for determining the elongation of a moving strip of material subsequent to rolling including in combination, first marking means for placing printed marks in a first line a predetermined distance apart on the strip of material prior to rolling, second marking means for placing printed marks in a second line disposed from the first line on the strip of material a distance apart equal to the spacing of said first mentioned marks subsequent to rolling, first photoelectric signal generating means spaced from said first marking means in the direction of travel of the moving strip for generating an electric signal upon each of the first marks passing a predetermined point prior to rolling, second photoelectric signal generating means spaced from said second marking means in the direction of travel of the moving strip for generating an electric signal upon each of the second marks passing a predetermined point, and comparison means operatively coupled to both said first and second signal generating means for comparing the frequency of the signals generated thereby and deriving an output indication of the difference therebetween.

9. Apparatus for determining the elongation of a moving strip of insulating material subsequent to rolling including in combination, first electric charge means for placing electrically charged marks in a first line a predetermined distance apart on the strip of insulating material prior to rolling, second electric charge marking means for placing electrically charged marks in a second line disposed from the first line on the strip of insulating material a distance apart equal to the spacing of said first mentioned marks subsequent to rolling, first capacitive electric signal generating means spaced from said first marking means in the direction of travel of the moving strip for generating an electric signal upon each of the first marks passing a predetermined point prior to rolling, second capacitive electric signal generating means spaced from said second electric charge marking means in the direction of travel of the moving strip for generating an

electric signal upon each of the second charged marks passing a predetermined point, and comparison means operatively coupled to both said first and second capacitive electric signal generating means for comparing the frequency of the signals generated thereby and deriving an output indication of the difference therebetween. 5

10. The combination set forth in claim 9 further characterized by electrically charged mark erasing means positioned intermediate the first capacitive electric signal generating means and the point at which the strip is rolled 10

for removing marks placed on the strip of insulating material prior to rolling.

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