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3,135,867

APPARATUS FOR INSPECTING A MOVING WEB

Filed May 31, 1961

4 Sheets-Sheet 1

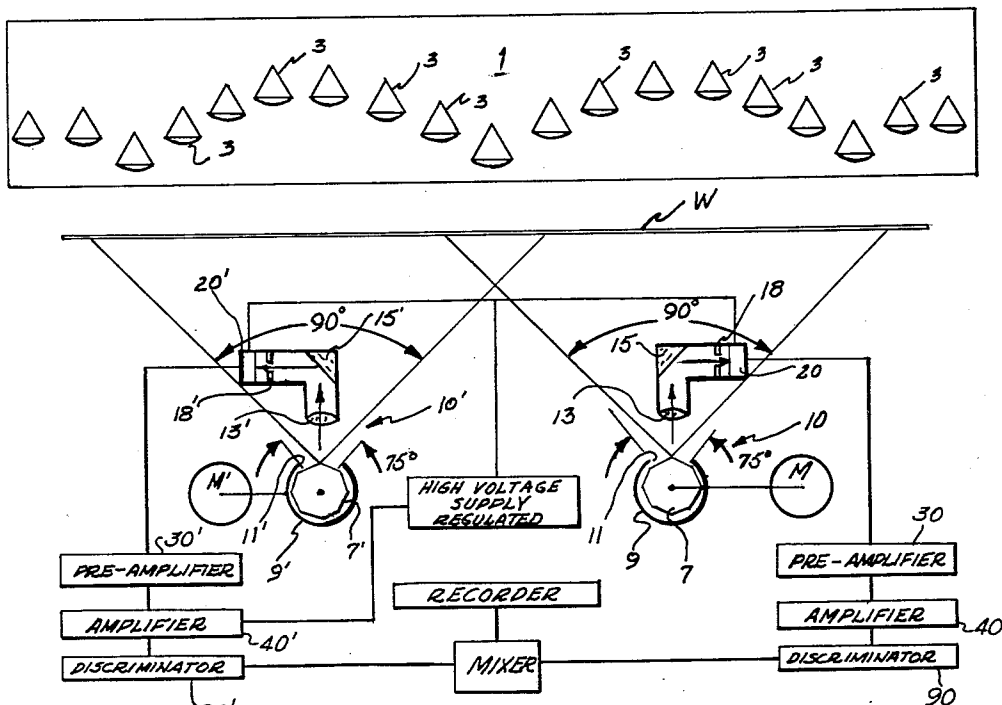


Fig. 1

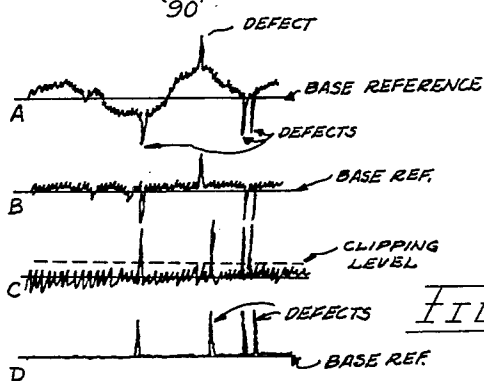


Fig. 2

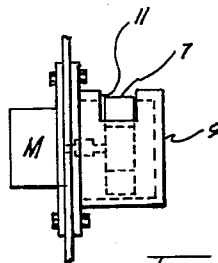


Fig. 3

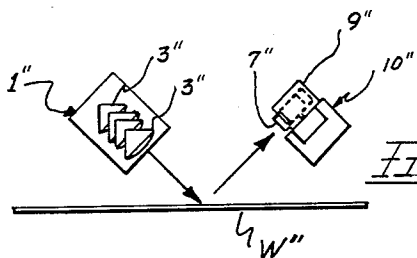


Fig. 4

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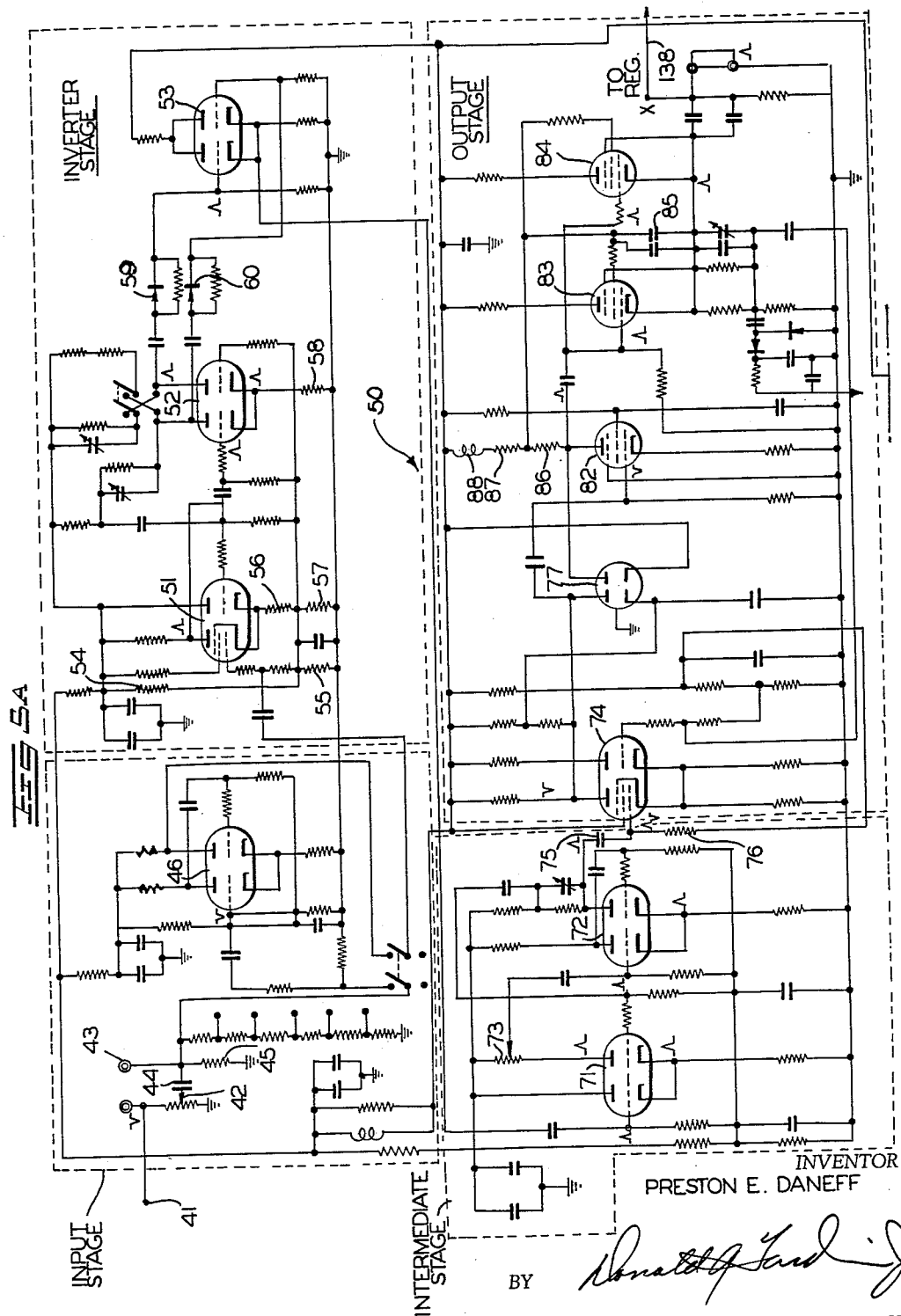
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4 Sheets-Sheet 2



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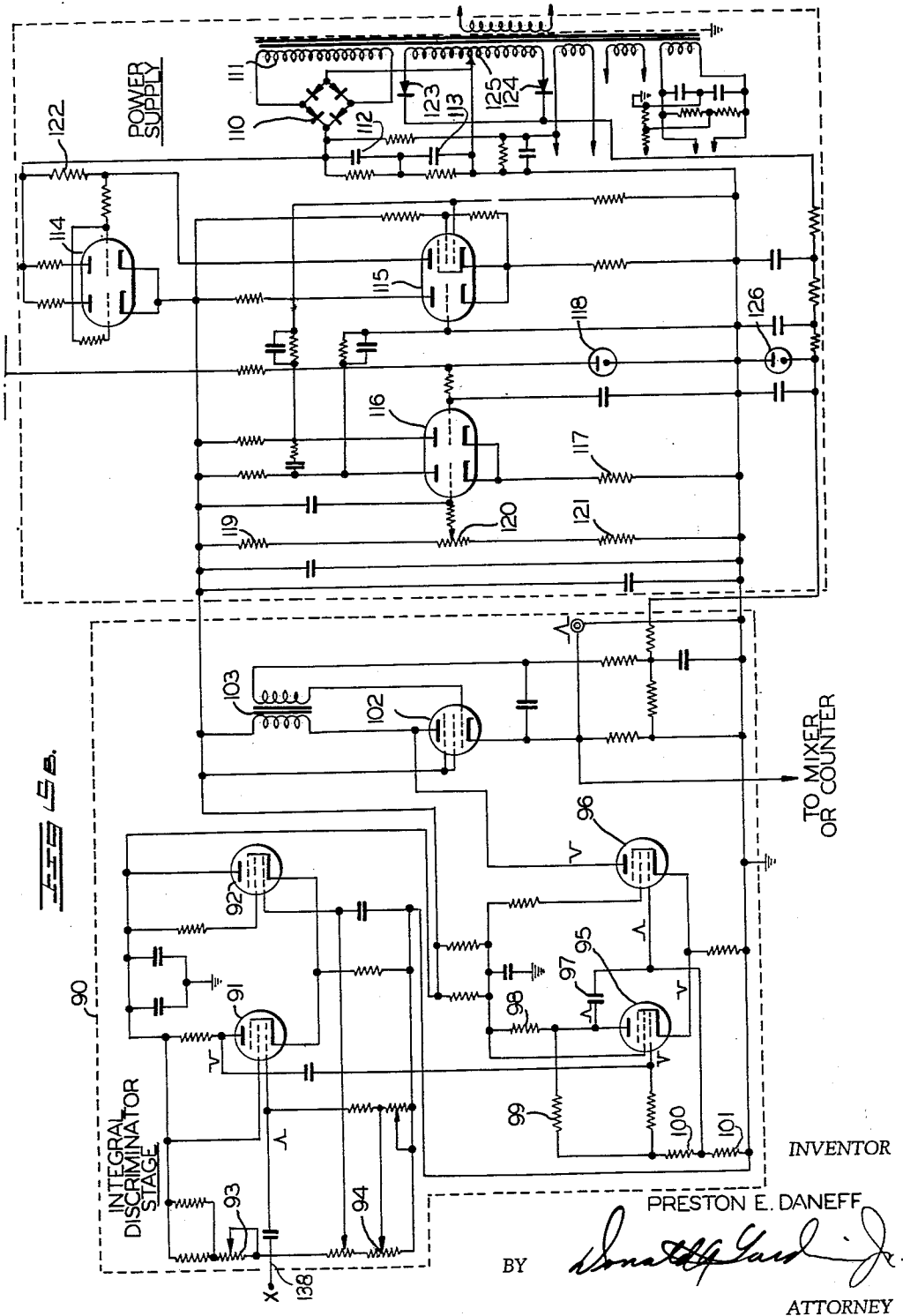
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APPARATUS FOR INSPECTING A MOVING WEB

Filed May 31, 1961

4 Sheets-Sheet 3



June 2, 1964

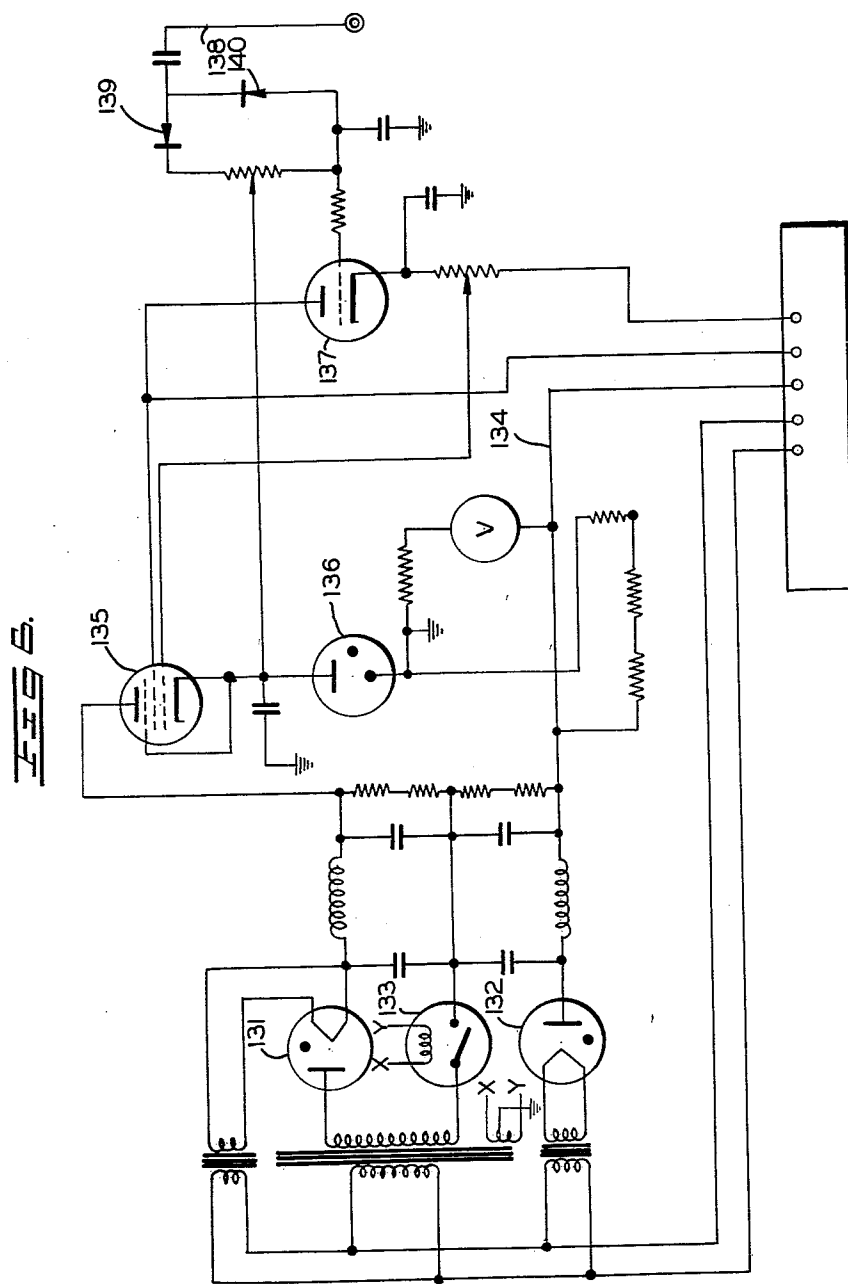
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APPARATUS FOR INSPECTING A MOVING WEB

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4 Sheets-Sheet 4



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3,135,867

APPARATUS FOR INSPECTING A MOVING WEB
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Papers Inc., a corporation of Ohio
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14 Claims. (Cl. 250-219)

This invention is concerned with an inspection device. More particularly, the invention is directed to a device for detecting defects in a moving web of material. The present invention is ideally suited for inspection and detection of defects in moving webs and may be used to scan both sides of such webs or sheets in particular paper of such basis weight as to be light permeable, or alternatively, may be used to scan one side of a material which is opaque.

Numerous devices have been proposed for the detection of defects, in moving webs, for example, in the manufacture of paper wherein such defects may comprise holes, slime spots, "tear outs," and the like. None of these devices has met with general acceptance for the reason that each has adherently created more problems than each has solved. In particular, reference is made to the excessive cost of many of the prior devices as well as extreme sensitivity to surrounding conditions and/or difficulties in proper installation and the like. In addition such units are limited in the width of web which they can effectively scan, requiring an inordinate number of individual devices to scan wide widths of material such as are formed in high output web manufacturing processes, for example the produce of a wide paper machine or the like.

The present invention defines an economical defect detector apparatus which may be conveniently installed on a variety of machines, for example a paper machine, cutter or the like, and which is reliable in operation and efficiently inspects a moving web or sheet for defects.

Accordingly, an object of the invention is to produce a reliable defect detector device for moving webs.

A further object of the invention is to provide an inspection device which is economical to manufacture, purchase and install.

Still another object of the invention is to produce an inspection apparatus which may have universal application to one or more of such other machines as may be used in a web manufacture process.

An additional object of the invention is to produce a wide scanning defect detection device having uniform sensitivity to defects at substantially any point on the web being scanned.

These objects and others not specifically referred to, may be attained by providing a constant light source geometrically associated with the web being scanned; a light sensitive means associated with said light source; means interposed between the two for scanning a moving web or sheet and for reflecting the light transmitted from the web to the light sensitive means, and means for translating the electrical signals generated by said light sensitive means into a discriminated signal for operation of indicator, recorder, alarm or the like, when a defect is sensed.

The function and operation of the device will become more apparent from the following description and reference to the drawing forming a part of the specification and schematically illustrating the general combination, wherein

FIG. 1 is a schematic layout of the invention utilizing light transmitted through a light permeable web for simultaneous inspection of both sides thereof, like parts being indicated by like reference numerals, the left hand numerals being primed,

FIG. 2 is illustrative of the type of signal and the manner in which the signal is modified and utilized in recording or otherwise indicating that a defect has been scanned by the equipment,

FIG. 3 is an enlarged elevational view of one of the mirror and shield assemblies shown in FIG. 1,

FIG. 4 is a schematic view of the apparatus as applied to the inspection of opaque materials,

FIGS. 5A and 5B illustrate in schematic form an amplifier system used in achieving the objectives of the invention, and

FIG. 6 is a schematic illustration of the regulated high voltage supply.

As may be seen in FIG. 1, the light source 1 may be comprised of a multiplicity of reflector type lamps 3 arranged in a line disposed transversely of the direction of movement of web W. Preferably, the lamps 3 are of the mercury vapor type, each having the interior thereof coated with a reflective substance except for the face in order that the maximum amount of light is reflected through the face and directed toward the object being illuminated. As will also be seen in FIG. 1, the lamps are disposed in the predetermined vertical relationship with respect to the web. The purpose of this arrangement will be subsequently apparent as the description proceeds.

The lamps 3 may be energized by either A.C. or D.C. energizing potential. However, it has been found that superior results may be achieved by utilizing mercury vapor lamps operated on 250 volts direct current through a 37 ohm series resistor which adequately limits the starting current yet provides proper operating voltage. Surprisingly enough, mercury vapor lamps are generally not considered as operable from a D.C. power source, yet in the present apparatus such operation has been highly successful, the lamps providing long life and reasonable efficiency.

Since it has been found that D.C. energization of mercury arc lamps is feasible, the present apparatus finds utility in the inspection of webs traveling at extremely high speeds because among various other variables, there is no phase problem created as is the case where these lamps or their equivalent are operated from an A.C. power source and thus supply intermittent light which, of necessity, limits the speed at which the prior art devices may adequately inspect a moving web.

While, the use of mercury vapor lamps energized from a D.C. power source is preferred, because of the match between spectral response of these lamps and the multiplier photo tube, it has also been found possible to provide a constant light source from an A.C. powered illuminating arrangement. This can be accomplished by proper split phasing of groups of high wattage incandescent lamps having a large or heavy filament possessed of considerable thermal inertia such that as the A.C. current cycles in the usual manner and the filament is de-energized, the thermal inertia of the filament is such that the light energy is not completely dissipated in the period of time required for reversal of the power cycle.

Thus, on normal 60-cycle A.C. current, two or more groups of lamps arranged as will be described, each group operating on an alternative or split phase of the A.C. cycle, can be used such that the total cumulative light energy developed by the whole assemblage approximates a substantially constant value.

While mercury arc lamps D.C. powered are preferred as a light source, it is singularly important that regardless of source the illumination of the web must be constant to enable inspection of webs at high speeds.

In FIG. 1 of the drawing illustrating one use of the invention, two inspection devices 10, 10' are shown as they might be used to scan wide webs of material for example

over one hundred (100) inches. It will be appreciated that any number of such devices 10 may be combined depending on the width of the material being inspected and the degree of sensitivity required for adequate inspection. For example, as will be apparent hereinafter, in some instances only one such device 10 may be necessary where the width of the web being scanned is such that the scanning angle of a single scanning means enables inspection thereof from approximately edge-to-edge and the defects are usually of a substantial size.

As illustrated, the scanning devices, 10, 10¹ are mounted on a common beam or other support (not shown) in such a manner that they may be adjusted toward and away from one another as circumstances may dictate. Each scanning device is comprised of a rotating mirror 7 mechanically coupled to the driving motor M. Each motor M is conventional and is of the type such that it provides a constant speed of rotation; in this particular arrangement the speed is 24,000 r.p.m. The rotating mirror 7, in the particular embodiment of the invention illustrated, is octagonal in shape and thus is provided with eight highly reflective surfaces of generally rectangular form as may be apparent from an inspection of FIGS. 1 and 3. The mirror is so positioned in this case that transmitted light from the web falls on the mirror surface and as the mirror rotates each successive reflective surface reflects light to the light sensitive means 20. Thus as the web moves, successive elementary areas thereof are viewed by each mirror face, with the result that the combination of web movement and transverse scanning effectively breaks up the web into narrow successive strips as it passes over the scanning device 10.

Of particular importance is the relationship between the mirror 7, the light sources 1 and the mirror housing 9 provided with a window 11. As seen in FIG. 3 the window is so dimensioned that it effectively controls the included angle of view which may be scanned by the moving mirror faces. Thus it may be seen that as the mirror 7 is rotated each of the reflected surfaces is in turn exposed to light transmitted through a given area of the web from the light source 1. To this end, since the incidence angle of light is equal to the reflectance angle, the mirror may be disposed at a very slight angle with respect to the web such that the photo-sensitive system will not interfere with scanning. Of course this angle will vary depending on the distance of the lens 13 from the mirror, this distance being a matter of convenience, i.e. the compactness of the overall installation.

It is particularly important that the window 11 in the shield 9 be dimensioned such that, as an individual mirror face moves from beneath the one edge of the window 11 in shield 9 through its scanning arc and beneath the opposite edge of the window and is preceded and followed by its next adjacent mirror face, the sum total of light reflected to the light sensitive means 20 regardless of the position of or number of mirror faces so acting in any one instant, is a substantially constant value. Thus the housing acts to cut off the light reflected to the light sensitive means as any given mirror face completes its particular scanning function. This relationship thus eliminates any pulses from being generated during the moment of transition from one exposed face to the next exposed face to thus prevent generation of a pulse except by a defect sensed in the web. Further the housing 9 shields the mirror from stray light thus eliminating any errors which could result from variations due to light transmitted from other than the web W.

It must also be noted that the scanning is confined to the web and that no extraneous or stray pulse is generated by the sudden drop off that will occur if scanning beyond the edges of the web is attempted.

The light which impinges upon the rotating surfaces is then reflected from the mirror through an optical system comprised of a lens 13, a right angle prism 15 and an aperture plate 18 such that the reflected light covers the

photocathode of a multiplier phototube 20 which converts the light into an electrical output. An excellent multiplier phototube for use in the system is identified commercially as a type 931A multiplier phototube such as is manufactured by the Radio Corporation of America.

The electronic circuits of the amplifier, discriminator, regulator are illustrated and described hereinafter in some detail in connection with FIGS. 5A, 5B and 6. However, for ease of understanding the broad functional aspects of the circuits will be discussed at this stage of the description.

The output of the phototube is fed through suitable conducting means to a preamplifier 30 indicated in the diagrammatic illustration of FIG. 1. Referring to FIG. 2A it will be seen that the output signal from the phototube 20 includes high and low frequency components as is diagrammatically represented as an erratic line of high frequency pulses following a low frequency base. The output signal from the preamplifier 30 is fed through a coupling network having a small time constant to attenuate the low frequency component and flatten out the base of the high frequency component of the signal before it is passed into the input stage of an associated amplifier 40. This signal is illustrated at FIG. 2B. It is to be understood that a defect in the web being sensed produces a clearly defined pulse or "spike" in the high frequency component as is clearly illustrated. The less pronounced high frequency pulses are caused by variations in the web due to its formation or light permeability characteristics while the low frequency pattern of stage A is produced by variations in illumination and basis weight, i.e., thickness or profile across the width of the web.

As may also be apparent from FIG. 2, there may be both positive and negative pulses indicating defects. This is due to the fact that, for example, a defect may be a dark spot or a hole. Obviously, if the former, the light transmitted to the phototube is reduced, if the latter, the light is increased. Thus after the signal passes from the preamplifier 30 to the amplifier 40 the signal includes both positive and negative pulses. By the inclusion of inverted circuitry, inverter stage 50 illustrated in FIG. 5A, in the amplifier 40, one series of the pulses caused by defects may be so inverted that both light and dark spots or defects produce the same positive pulse. Thus, as seen at illustration FIG. 2C the signal is amplified and modified such that definitive defects produce clearly definitive positive pulses. Therefore a clipping level can be established such that extraneous "noise," high frequency pulses due to irregular sheet formation, etc., are screened out by a discriminator 90 and a standard pulse is generated for each defect for transmission to the mixer 70 as indicated in FIG. 2D. The output of the mixer 70 is transmitted to a recording device 80, which may typically comprise a counter or alarm indicating the presence of a defect in the web being sensed by the apparatus. It will be noted that the noise level may vary as the optical properties of the web W vary. To assure that the sensitivity of the system is relatively constant despite variations in formation, opacity, etc., the "noise level" is used to control the high voltage applied to the phototube by means of a voltage regulator system shown in schematic form in FIG. 1. To accomplish this result the high frequency signal or "noise" signal is rectified and filtered in a conventional manner and the resultant signal is impressed upon a voltage regulation means which in turn controls the high voltage applied to the multiplier phototube 20 of the type defined which, of course, is extremely sensitive to variations in voltage impressed upon it.

In many instances the apparatus may be coupled to a sorting apparatus if desired, wherein sheets of material embodying defects may be sorted from those free of defects. As has been previously mentioned, one or more detection units 10 may be used in concert as the circumstances of use may demand. FIG. 1 then is illustrative of the use of multiple units to scan an extremely wide web.

5

Turning now to FIGS. 1 and 3 the relationship between the light source 1, and the scanning mirror will be considered. It is obvious that for the apparatus to perform its function it must not produce false indications of non-existent defects and must exhibit uniform sensitivity to defects at any position across the scanning angle. To this end the arrangement of the light source is such that the level of light received at the scanning mirror is substantially constant for any point on the web being scanned. The light level to the scanning mirror varies inversely as the square of the distance from the light source. In order to maintain this level constant at the phototube when scanning the web, it is necessary to arrange the lamps in an arc, so that the light path from each lamp normal to the web and thence to the phototube is constant. Thus the individual mercury arc lamps 3 are mounted such that the optical distances from each one of the lamps vertically through the web (and from any point on the web) to the scanning mirror are approximately equal. With this arrangement, then, there is no area of the web being scanned, where the illumination falls off to the point where the sensitivity of the system would be affected regardless of the point across the width of the web being scanned at any given moment.

Having explained the broad operative function of the apparatus consideration may now be given of a typical embodiment of the invention illustrated in FIGS. 5A, 5B, and 6.

The preamplifier 30 may typically comprise a pentode-triode amplifier tube such as a 6U8A capable of amplifying the electrical signal received from the phototube 20. Typically, the input signal may be developed across a low resistance load resistor to maintain the high frequency response. The pentode section of the preamplifier tube functions as a low gain amplifier with the triode section as a cathode follower for coupling the signal into a low impedance coaxial line for transmission to the main pulse amplifier 40. The overall gain from the preamplifier is approximately 2.

Amplifier

Referring specifically to FIGS. 5A and 5B, the amplifier 40 is shown to have an input stage having an input 41 to receive the output of the preamplifier stage 30. Due to the non-uniformity of gain in the multiplier phototube 20 of the type used in this apparatus, it is necessary to adjust the output from each scanner unit so that all the outputs thereof are equal going in their respective amplifier. This is accomplished by a potentiometer 42 and the signal potential may typically be visually observed on a cathode ray oscilloscope connected to the front input coaxial connector 43.

The input coupling network comprised of a capacitor 44 and a resistor 45 has a very small time constant (2.2 microseconds) to attenuate the low frequency noise caused by unequal lamp output, 60 cycles per second pickup, etc.

The input signal is then fed to the grid of a dual triode tube 46 (12BZ7) with an overall gain of about 25.

Phase Inverter

The output of the input section of the amplifier 40 is fed to the phase inverter stage 50 which consists of a pentode triode 51 (6U8A), a dual triode 52 (6BQ7), and a dual triode 53 (5670). The control grids of the tubes 51 and 52 are connected to a point having a potential of about 180 volts positive with respect to ground. This potential is determined by a voltage divider network consisting of resistors 54 and 55. Cathode current established through resistors 56 and 57 act to establish a negative grid-cathode quiescent bias for tube 51.

The grids of the tubes 51 and 52 are operated well above ground potential in order to permit large negative excursions in the grid voltage without cutting off the tubes. At the same time, the unbypassed cathode resistors

6

56 and 57, as well as a resistor 58, permit large positive swings of grid voltage without grid current flow.

Positive or negative pulses, determined by the polarity of the input signal are coupled from the plate of the pentode section of the tube 51 to the grid of the left-hand section of the tube 52.

A positive pulse at this grid of tube 52 is coupled to the cathode thereof, giving rise to a positive pulse at the plate thereof. A silicon diode 59, which is forward-connected for a positive signal, permits the pulse to pass to the grid of the tube 53. A negative pulse appearing at the plate 52 will not pass through the silicon diode 59, which is reverse-connected for this polarity.

A negative pulse at the grid of the tube 52 gives rise to a positive pulse at the plate thereof. A silicon diode 60, which is forward-connected for a positive signal, permits this pulse to pass to the grid of the tube 53. As before, a negative pulse appearing at the plate of tube 52 will not pass through silicon diode 60.

The positive pulses occurring at the grids of the tube 53 are mixed and appear as positive output pulses at the cathodes thereof. Thus, the phase inverter 50 automatically provides a positive output signal to the next succeeding stage of the amplifier regardless of the polarity of the pulse at the grid of the tube 51.

Pulses occurring at the plate of tube 52 are attenuated and fed back to the grid of the tube 51. This section of the tube 51 is a cathode follower and couples the feedback signal to the cathode of the input pentode section thereof. Feedback is employed in this instance to achieve gain stability, independent of the tube or parameter variations.

Intermediate Stage

The intermediate stage consists of tubes 71 and 72, both 12BZ7 dual triodes connected as a long-tailed pair. The cathodes of each pair of these dual triodes are connected to a common impedance. This arrangement has the advantage of extreme stability regardless of tube condition, filament voltage, or circuit parameter changes. In addition, the output of the tube 72 is fed back to the tube 71, resulting in further stability. A variable resistor 73 is coupled between the tube 72 and the tube 71 and functions as a fine gain control for the entire amplifier.

The signal output of the tube 72 is coupled to a pentode-triode tube 74 (6AN7) through a small time constant (3.5 microseconds) network consisting of a capacitor 75 and a resistor 76. This network effectively attenuates the low frequency noise and any 60-cycle per second pickup.

Output Section

Because of the small time constant coupling network mentioned above, differentiation of the pulse occurs, producing both a positive and a negative pulse at the grid of tube 74. When these pulses are amplified by the pentode section of this tube, they appear reversed in polarity at the plate thereof. One section of a dual diode 77 (6AL5) is used as a clamp to prevent the positive component of the pulse from drawing grid current in pentode tube 82 (6197). The negative component of the signal after amplification by the tube 82 is coupled to pentode tubes 83 and 84 (6194) as a positive pulse. Tubes 83 and 84 are paralleled cathode followers having a gain of unity. A large capacitor 85, between the cathodes of the tubes 83 and 84 and the junction between resistors 86 and 87 (plate resistors of the tube 82) cause the voltage across the resistor 86 to be maintained at approximately a constant value during the rise in potential of the plate of the tube 82. This circuit is known as a "bootstrap circuit." The effect of this circuit, as well as the use of an inductance 88 in the plate circuit of the tube 82, is to cause the plate voltage of the tube 82 and also the output voltage to rise very rapidly upon the application of a negative pulse to the grid of the tube 82. Because of the inductance 88, it is possible for the plate voltage of the tube 82 to rise to a value greater than the

300 volt supply. To prevent this, the other half of the dual triode tube 77 is cathode clamped to the B+ voltage.

The output stage of the amplifier 40 is coupled to the integral discriminator 90 and the regulated high voltage supply through an output conductor 138 (FIGS. 5A and 5B) as will be explained in detail hereinafter.

Integral Discriminator

Referring now to FIG. 5B which shows remaining sections of the amplifier 40, the integral discriminator 90 consists of three sections, namely, a pulse height selecting amplifier, Schmitt trigger, and an output pulse amplifier.

Pentode tubes 91 and 92 (6AK5) comprise the pulse height selecting amplifier and are connected to the output stage of the amplifier 40 at X also indicated on FIG. 5A. A potentiometer 93 adjusts the voltage that is impressed across a potentiometer 94. Thus, if a voltage of about 100 volts is established across the potentiometer 94, a slightly larger voltage is impressed on the grid of the tube 92. This causes the cathodes of both of the tubes 91 and 92, which are tied together, to be approximately 100 volts. The grid of the tube 91 is returned or coupled to the arm of the potentiometer 94, and thus is at a lower potential than the cathodes thereof. As a result, the tube 92 conducts heavily while the tube 91 is cut-off.

The potentiometer 94 can be so adjusted that the bias on the tube 91 will allow only the upper portion of the incoming pulse to bring the tube 91 into a conductive state. When tube 91 conducts, a negative pulse of a few volts amplitude is developed at its plate and this voltage is coupled to the grid of a pentode tube 95 (6AK5).

The tube 95 and another pentode tube 96 (6AK5) comprise the Schmitt trigger circuit. The cathodes of these tubes are coupled together and, in addition, the plate of the tube 95 is coupled through a capacitor 97 to the grid of the tube 96. Because of a voltage divider consisting of resistors 98, 99, 100, 101, the grid potential of the tube 96 is lower than the grid potential of the tube 95. Thus, the tube 95 is normally conducting and establishes a cathode voltage high enough for the tube 96 to be normally cut-off. When an incoming negative pulse arrives at the grid of the tube 95, it is coupled by the grid cathode capacitance to the cathode causing tube 96 to approach the conduction region. At the same time, the negative pulse at its grid causes the tube 95 to conduct less, raising its plate voltage. This positive swing is coupled through a capacitor 97 to the grid of the tube 96 driving this tube rapidly to conduction. Because of the cathode coupling, the tube 95 is driven rapidly to cut-off. Thus, a sharp positive pulse is developed at the plate of the tube 95 which is coupled through the capacitor 97 to the grid of the tube 96, and appears as a fast negative pulse at the output of the tube 96.

A pentode tube 102 (6197) comprises the output pulse amplifier which is a monostable blocking oscillator circuit. The tube 102 is biased below cut-off and is non-conductive until triggered by the negative pulse from the tube 96, which is introduced across the plate winding of the transformer 103. The resultant positive output pulse is then fed to a mixer circuit (when two or more of the amplifier circuits 40 are employed) or in the event only a single amplifier circuit is employed this pulse may be fed directly to a counter system.

Power Supply

The power supply for the amplifier 40 consists basically of two sections: a positive section and a negative section. The positive section utilizes a fullwave selenium bridge rectifier 110 operating from a 348-volt transformer winding 111 to develop a D.C. potential of about 450 volts across a filter capacitor network comprised of capacitors 112 and 113. This voltage is fed through a

dual triode regulator tube 114 (6080) to the output terminal. Both halves of the tube 114 are tied together and the effective resistance of the tube is varied by means of a D.C. amplifier network consisting of a pentode triode tube 115 (6AN8) and a dual triode tube 116 (12AX7). The tubes 115 and 116 operate to control the grid voltage of the tube 114, the series regulator tube.

The tube 116 is connected as a difference amplifier, the cathodes being coupled together with a common cathode resistor 117. The grid of the tube 116 is held constant at -85 volts by a voltage reference tube 118 (8582), while the other grid of the tube samples the output voltage through a voltage divider network consisting of resistors 119, 120 and 121. Variations in the output potential cause changes in the grid voltage at the grid of the left-hand section of the triode tube 116 and similar changes reversed in phase at the associated plate terminal thereof. These plate voltage variations are coupled to the grid of the triode section of the tube 115 through suitable conducting means. The tube 115 is also connected as a difference amplifier. Variations at the grid of the triode section of the tube 115 produce changes in the cathode potential which are amplified by the pentode section of the tube. The output which appears at the plate of the pentode section of the tube 115 is coupled to the grid of the tube 114 and to a plate load resistor 122 and acts on the grid to control the effective resistance of the series regulator tube 114. The amount of feedback from the supply output can be varied by the variable resistor 120 which forms a portion of the above described voltage divider network to control the positive output voltage which is normally set at in the order of positive 300 volts.

The negative section of the power supply consists of a full wave rectifier which includes rectifier elements 123 and 124 and operated from a transformer winding 125. The fullwave rectifier is associated with a capacitor resistance filter stabilized by a voltage regulator tube 126 (0A2) to deliver negative 150 volts.

Regulator-High Voltage Supply

Referring now to FIG. 6, there is shown the regulator-high voltage supply network which consists of two half-wave rectifier tubes 131 and 132 (866A) in a conventional voltage doubler circuit with a condenser input filter to provide approximately 2000 volts to the series regulator. A thermal time delay 133 is provided to allow for a warm-up period of approximately 30 seconds before the application of high voltage.

The dynodes of the phototube 20 used in the scanning apparatus derive their potential from the high voltage supply through a voltage divider network and an electrical conductor 134. This potential is controlled by a regulator system consisting of a series regulator tube 135 (6BQ6), a voltage regulator tube 136 (0A3), and a cathode follower triode tube 137 (6SF5). The control signal for the regulator is derived from the noise level present in the output signal of the tube 84 of the amplifier circuit shown in FIG. 5A through a conductive means 138. This noise level caused by formation and wildness in the web being scanned is rectified by diodes 139 and 140 and applied to the grid of the tube 137.

The action of the regulator system shown in FIG. 6 is such that with increasing light level or wildness in the sheet or web being sensed, the A.C. component of the phototube current tries to increase. This increases the noise level of the output signal from the output stage of the amplifier 40 sensed through conductor 138 shown in FIG. 5A. This output signal which is received by the regulator shown in FIG. 6 is rectified and gives rise to a negative voltage on the grid of tube 137. This negative signal is fed to the grid of tube 135 causing the current through the series regulator tube to decrease, thereby lowering the voltage across the phototube dynode. With decreasing dynode voltage, the sensitivity of the

multiplier phototube is reduced and the phototube output current decreases.

In this manner the feedback around the loop tends to maintain a constant anode current regardless of the input light level. With the amount of gain present in the loop, the D.C. anode current is kept at approximately 5.5 microamperes. Such action results in minimization of phototube fatigue and at the same time renders the entire detector system independent of variation in lamp output, tube parameters, dirt on scanner window, and other variable factors.

It will be appreciated from the above description of the regulator system and its associated feedback arrangement that the sensing device of the invention in addition to sensing defects in the web could also be employed as an indicating device to indicate the optical property of the paper or other material being sensed by the invention.

Having explained a typical amplifier and regulator network for effectively carrying out the inventive concept of the system, consideration will now be given to an embodiment of the invention as applied to a given set of conditions.

For example, let it be assumed that the web to be scanned is paper of such basis weight as to be light permeable, the speed of the web is about 1000 feet per minute and the width of the web is about 100 inches.

Initially we must consider the fact that the sensitivity of the device as well as the width of web which can be scanned are both correlated in that they are both affected by the distance of the web W from the scanning mirror 7. If then the size of the aperture in plate 13 in the device is maintained constant then as the apparatus is moved further away from the web W, the size of defect which can be detected increases. Simultaneously as the scanning device 10 is moved further from web W, the width of web which can be scanned increases as a function of distance in the ratio of about 2:1. Therefore as a compromise to effect efficient scanning with a minimum of equipment, yet to pick up defects of a reasonable size, one-sixteenth to one-eighth of an inch in a 100-inch web under the prescribed conditions the scanning devices 10, 10¹ of FIG. 1 are positioned about 25-27 inches below the web W. By positioning the scanning devices at the greater distance there is a slight overlap at the center of the web W.

Since the web is to move at about 1000 feet a minute, if the mirrors 7 are octagonal in shape, i.e., have eight scanning faces, rotation of these mirrors at 24,000 r.p.m. will result in 100% scanning of the web W to detect defects of the size selected. Thus the web W is scanned at the rate of 3200 scans per second. If the web is thus moving at 1000 feet per minute it will be apparent that the web will advance one-sixteenth of an inch per each scan. Thus a defect as small as one-sixteenth of an inch in diameter will be detected.

It will be noted that this arrangement is schematically illustrated in FIG. 1, while FIG. 4 is an elevational schematic showing the devices as they might be arranged for one side scanning of a web of opaque material W¹ such as a heavy basis weight paper or board, it being understood that like reference numerals indicate like parts, the numerals being double primed to correspond with like components illustrated in FIG. 1.

In this particular arrangement, the regulator system previously described in FIG. 6 responds to the surface reflectance characteristics of the web being scanned, rather than formation because there is no transmission of light through the sheet and, hence, no variation in light permeability due to formation. However, there will be and are variations in surface characteristics due to variables such as gloss, smoothness, etc. These variations which result in variations in reflected light which can be used to control or regulate the sensitivity of the multiplier phototube via the output stage of amplifier 40

sensed through conductor 138 and the variations of negative voltage applied to the grid of tube 137 in the manner of and for the purpose previously described. Thus the sensitivity of the multiplier phototube is always regulated in accord with the conditions which may be encountered within or on the surface of the web being scanned.

It should be noted also that the particular application of the invention shown, using an octagonal mirror having eight scanning faces, revolving at 24,000 r.p.m., it has been found that the scanning window should embrace an included cut-off angle of about 75° and that because the mirror faces are spaced from the center of rotation the apparatus will scan an included angle of approximately 90° across the web W.

By combining the light source and the scanning shield with the scanning mirror as taught herein a practical, reliable, defect detecting apparatus has been developed. It will be understood that various modifications may be made therein within the spirit and scope of the invention, which is limited only as defined in the following claims.

This application is a continuation-in-part application of applicant's copending application Serial No. 28,476 entitled "Apparatus" filed May 11, 1960 now abandoned.

What is claimed is:

1. Apparatus for detecting imperfections in a moving web comprising a light source positioned to illuminate a portion of the web to be inspected, photoelectric light sensitive means disposed adjacent said web, a multi-faced mirror disposed adjacent to said web and mounted for rotation about an axis lying in a plane which would intersect said web normal to the width of said web and extend parallel to the direction of movement of the web to scan the illuminated portion of the web, shield means surrounding a major portion of said mirror, said shield means being provided with a scanning window embracing a defined angle from edge to edge in the direction of rotation of said mirror, said mirror being positioned to scan said web from edge to edge and to reflect the light transmitted via said web to said light sensitive means, a signal translating circuit connected to the output of said light sensitive means for translating the electrical output thereof into a series of pulses indicating imperfections in said web, and indicating means coupled to said circuit and responsive thereto upon the occurrence of pulses due to imperfections in said web, regulator means impressing a potential on said light sensitive means, said regulator means being responsive to the high frequency signal component generated by said scanning means due to variations in the characteristics of said web, to maintain the sensitivity of the scanning system constant.

2. An apparatus as defined in claim 1 wherein said light source is disposed adjacent one surface of a light permeable web, and said scanning means is disposed adjacent the opposite side of said web to receive light transmitted through the moving web.

3. An apparatus as defined in claim 1 wherein said light source and said scanning means are disposed on the same side of an opaque web and said scanning means receives reflected light from said web.

4. Apparatus for detecting imperfections in a moving web comprising a light source spaced from a side of said web to be detected and illuminating a portion of said web, photoelectric light sensitive means disposed adjacent said web, a multi-faced mirror disposed adjacent to said web and mounted for rotation about an axis lying in a plane intersecting and extending substantially parallel to the direction of movement of said web, shield means surrounding a major portion of said mirror, said shield means being provided with a scanning window embracing a defined angle from edge to edge in the direction of rotation of said mirror, said mirror being positioned so as to scan said web from edge to edge at the illuminated portion and to reflect the light so received to said light sensitive means, signal translating means connected to the output of said light

sensitive means for translating the electrical output thereof into a series of pulses indicating imperfections in said web, and indicating means coupled to said signal translating means and responsive to the signal received upon the occurrence of imperfections in said web, said light source being disposed on the opposite side of the web from that being scanned and being comprised of a series of identical high output lamps arranged in linear relationship transversely of the moving web and varying in distance from the web in normal direction such that the optical distance from each lamp vertically through said web and to any point on said scanning means is approximately the same regardless of the point on the web being scanned by said rotating mirror.

5. An apparatus as defined in claim 4, wherein said high output lamps are mercury vapor lamps, and further including a source of direct current for energizing said lamps.

6. An apparatus as defined in claim 5 wherein each of said lamps is a high wattage incandescent lamp energized from a source of alternating current, the thermal inertia of the filaments thereof being such as to be non-extinguishing during the cyclic fluctuations of said source.

7. A scanning apparatus for detecting defects in a moving web comprising a light source for illuminating the web to be scanned, an optical scanning means disposed adjacent the web and having a movable element positioned to scan the web from edge to edge in the area illuminated by said light source, a defect indicating means coupled to said scanning means for translating signals generated thereby to said defect indicating means, said light source being comprised of a series of high energy output lamps arranged in linear relationship transversely of the web being scanned, said lamps being arranged transversely of the web in a common plane transversing the web and wherein the optical distance from each lamp to the web and from the web to the scanning means is varied so as to give a constant value of intensity to said movable element.

8. An apparatus as defined in claim 7 wherein said light source is comprised of a series of mercury vapor lamps energized from a direct current power source.

9. An apparatus as defined in claim 7 wherein each of said lamps is a high wattage incandescent lamp energized from a source of alternating current, the thermal inertia of the filaments thereof being such as to be non-extinguishing during the cyclic fluctuations of said source.

10. A scanning apparatus in accordance with claim 7 wherein said movable element includes a multi-faced mirror rotatable about an axis lying in a plane intersecting said web normal to the width of said web and extending parallel to the direction of movement of the web whereby each of said faces is exposed to light transmitted from said light source via said web.

11. A scanning apparatus for detecting defects in a moving web comprising

a light source for illuminating the web to be scanned, a scanning means disposed adjacent the web and positioned to scan the web in the area illuminated by said light source, said scanning means including a light sensitive means for responding to light received from the light source via the web, and further comprising a regulator means for impressing a potential on said light sensitive means responsive to the high frequency signal component generated by said scanning means due to variation in formation and opacity of said web being scanned to thereby maintain the sensitivity of the scanning system substantially constant,

a defect indicating means coupled to said scanning means for translating signals generated thereby to said defect indicating means,

said light source being comprised of a series of high energy output lamps arranged in linear relationship

transversely of the web being scanned, the distance of each lamp from the web varying in a normal direction such that the optical distance from each lamp to the scanning means is substantially constant regardless of the point on the web being scanned at any instant.

12. Apparatus for detecting imperfections in a moving web comprising a light source for illuminating that area of the web to be inspected, and scanning means for scanning the illuminated area thereof, said last mentioned means comprising photoelectric light sensitive means disposed adjacent said web, a multi-faced mirror disposed adjacent to said web and mounted for rotation about an axis lying in a plane intersecting said web and extending longitudinally in the direction of movement thereof, shield means provided with a scanning window embracing a defined angle from edge to edge in the direction of rotation of said mirror, said mirror arranged to scan said web from edge to edge and to reflect the light transmitted from said light source via said web to said light sensitive means, signal translating means connected to the output of said light sensitive means for translating the electrical output thereof into a series of pulses indicating imperfections in said web, indicating means coupled to said translating means and responsive thereto, and regulator means impressing a potential on said light sensitive means, said regulator means being responsive to the high frequency signal component generated by said scanning means, due to variations in formation and opacity of said web being scanned, to maintain the sensitivity of the scanning system constant.

13. Apparatus for detecting imperfections in a moving web comprising a light source for illuminating that area of the web to be inspected and scanning means for scanning the illuminated area thereof, said last mentioned means comprising photoelectric light sensitive means disposed adjacent said web, a multi-faced mirror disposed adjacent to said web and mounted for rotation about an axis lying in a plane intersecting said web and extending longitudinally in the direction of movement thereof, shield means provided with a scanning window embracing a defined angle from edge to edge in the direction of rotation of said mirror, said mirror arranged to scan said web from edge to edge and to reflect the light transmitted from said light source via said web to said light sensitive means, signal translating means connected to the output of said light sensitive means for translating the electrical output thereof into a series of pulses indicating imperfections in said web, indicating means coupled to said translating means and responsive thereto, and wherein said signal translating means includes a pre-amplifier for receiving both low and high frequency signals from said light sensitive means, means for attenuating the low frequency signal only, such that a high frequency signal only having a substantially straight line base, is generated; an amplifier, said high frequency signal passing to said amplifier and means associated with said amplifier to establish a clipping level discriminating between minor pulses and abnormal major pulses generated by detection of a major variation in the light transmittance over the web, and signal mixing means for integrating said pulses to actuate a recording apparatus.

14. Apparatus for detecting imperfections in a moving web comprising a light source for illuminating that area of the web to be inspected and scanning means for scanning the illuminated area thereof, said last mentioned means comprising photoelectric light sensitive means disposed adjacent said web, a multi-faced mirror disposed adjacent to said web and mounted for rotation about an axis lying in a plane intersecting said web and extending longitudinally in the direction of movement thereof, shield means provided with a scanning window embracing a defined angle from edge to edge in the direction of ro-

tation of said mirror, said mirror arranged to scan said web from edge to edge and to reflect the light transmitted from said light source via said web to said light sensitive means, signal translating means connected to the output of said light sensitive means for translating the electrical output thereof into a series of pulses indicating imperfections in said web, indicating means coupled to said translating means and responsive thereto, and regulator means for impressing a potential on said light sensitive means in response to high frequency components of the signals sensed by said light sensitive means wherein the high frequency component is representative of variations in the amplitude and frequency of light variations being transmitted to the scanning means, thereby to automati-

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cally maintain the sensitivity of the scanning system substantially constant.

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