

Sept. 24, 1963

P. NASH

3,105,151

PHOTOELECTRIC INSPECTION AND SORTING MACHINES

Filed April 14, 1959

7 Sheets-Sheet 1

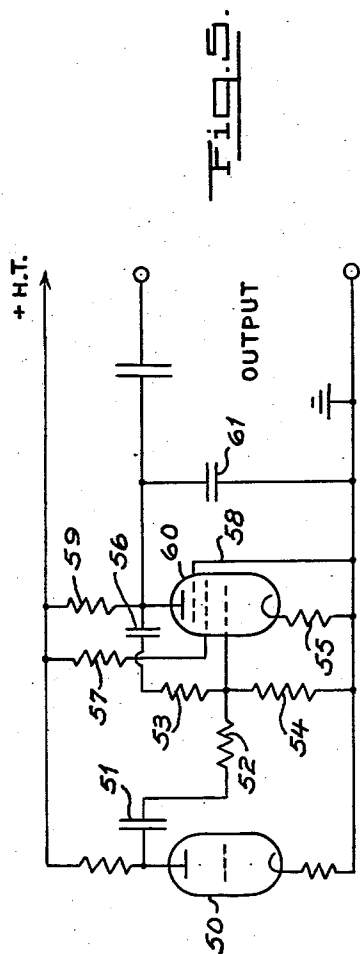


Fig. 5.

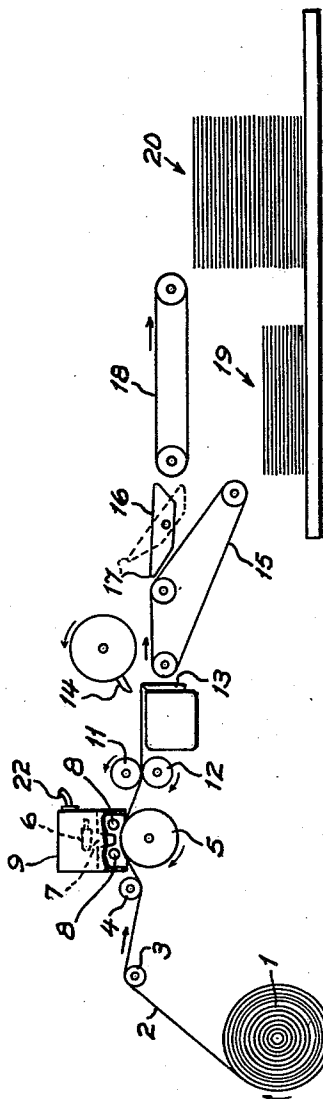


Fig. 1.

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7 Sheets-Sheet 2

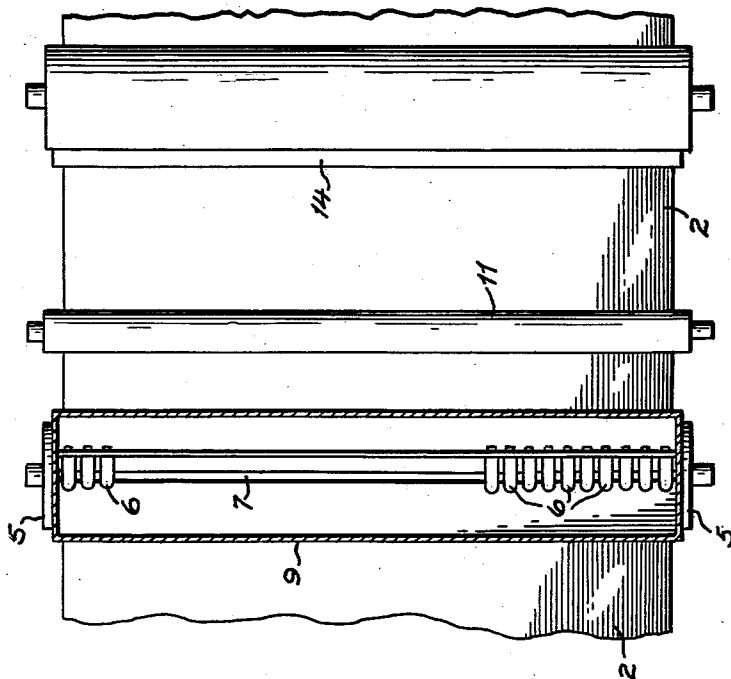


Fig. 3.

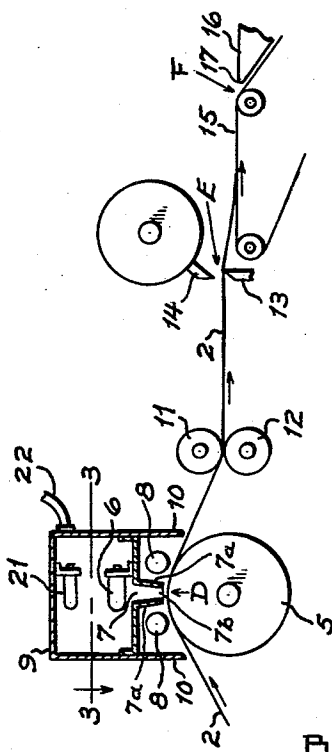


Fig. 2.

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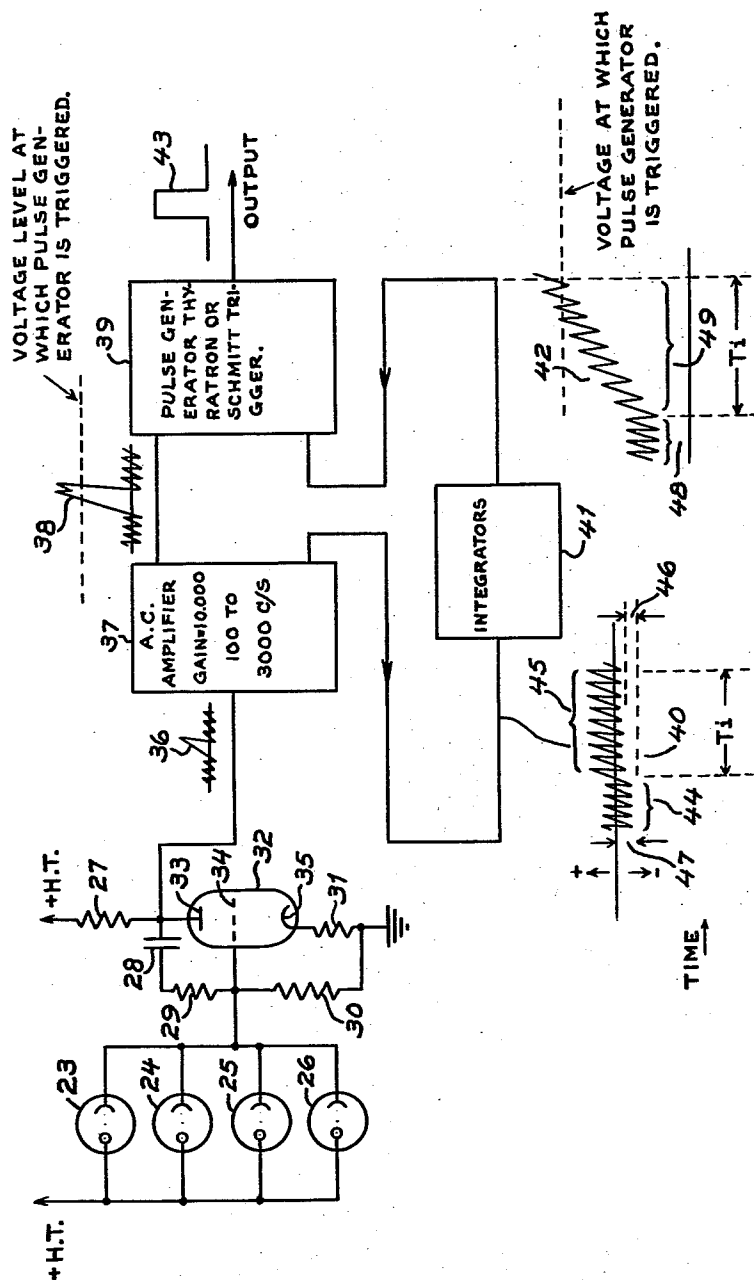
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PHOTOELECTRIC INSPECTION AND SORTING MACHINES

Filed April 14, 1959

7 Sheets-Sheet 3



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3,105,151

PHOTOELECTRIC INSPECTION AND SORTING MACHINES

Filed April 14, 1959

7 Sheets-Sheet 4

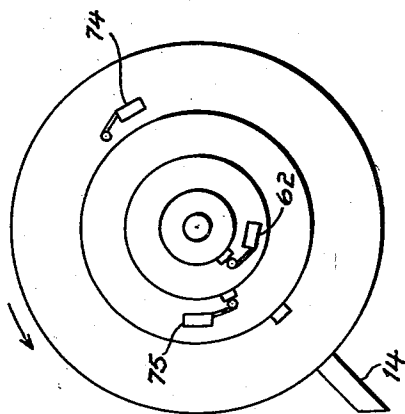


Fig. 7.

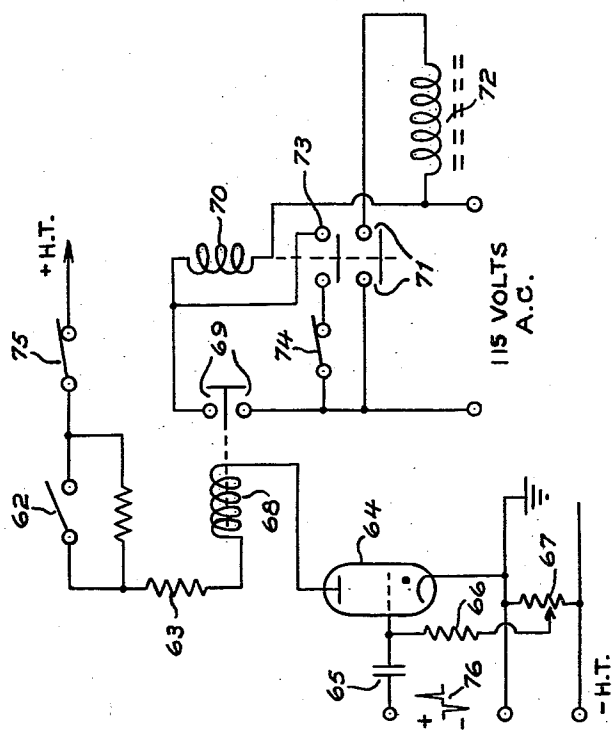


Fig. 8.

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PHOTOELECTRIC INSPECTION AND SORTING MACHINES

Filed April 14, 1959

7 Sheets-Sheet 5

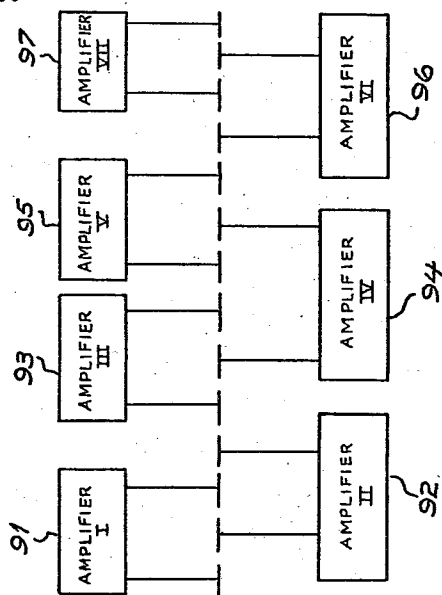


Fig. 9.

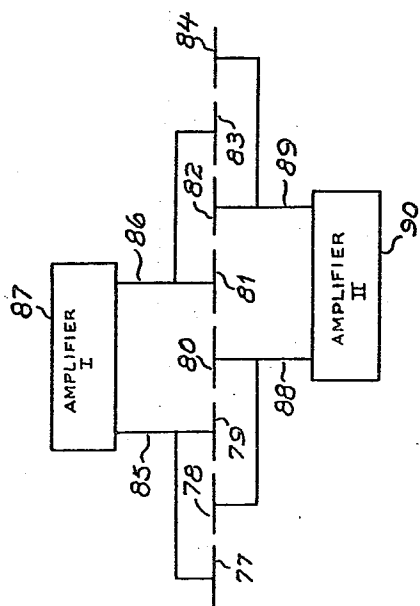


Fig. 8.

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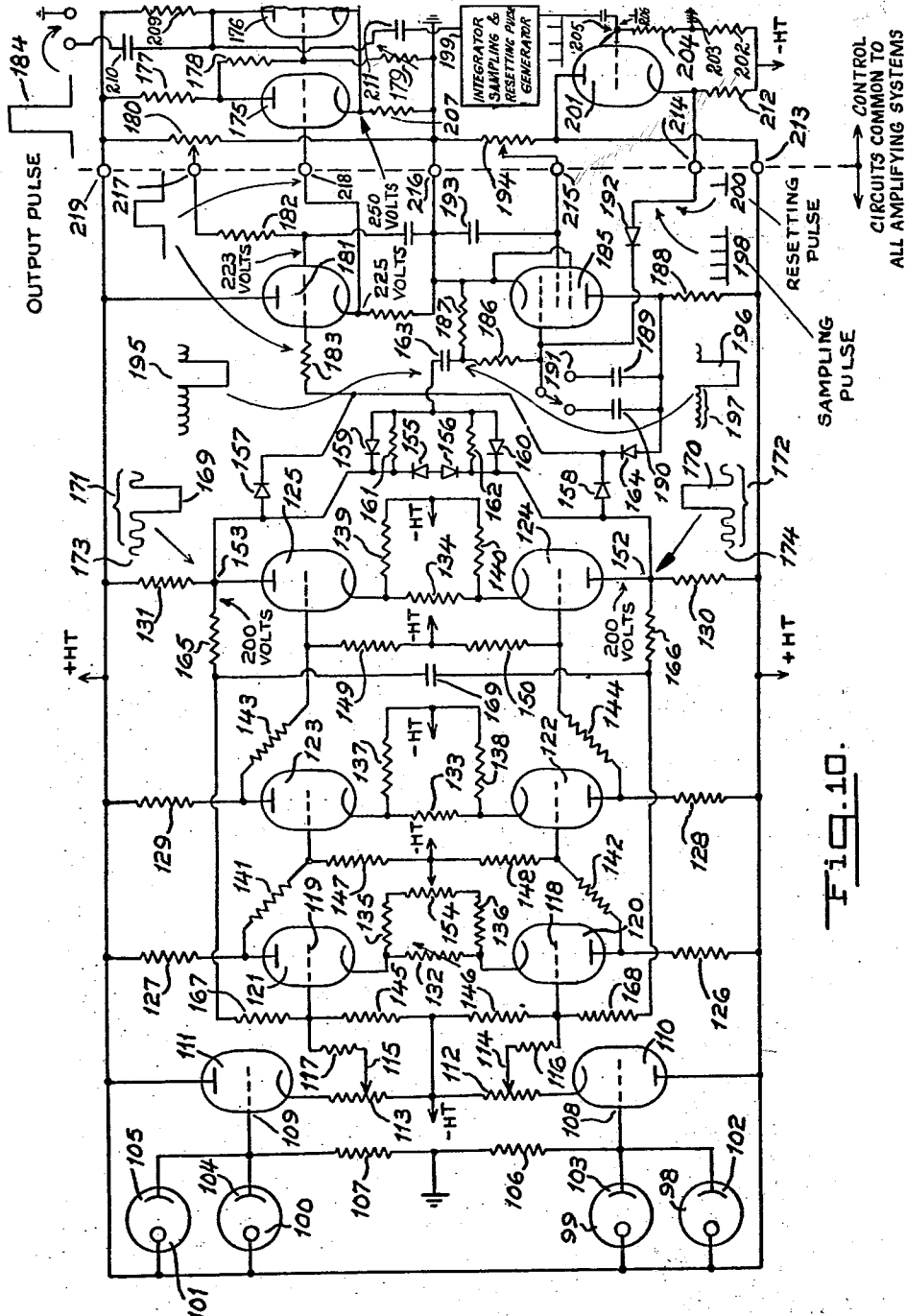
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3,105,151

PHOTOELECTRIC INSPECTION AND SORTING MACHINES

Filed April 14, 1959

7 Sheets-Sheet 6



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PHOTOELECTRIC INSPECTION AND SORTING MACHINES

Filed April 14, 1959

7 Sheets-Sheet 7

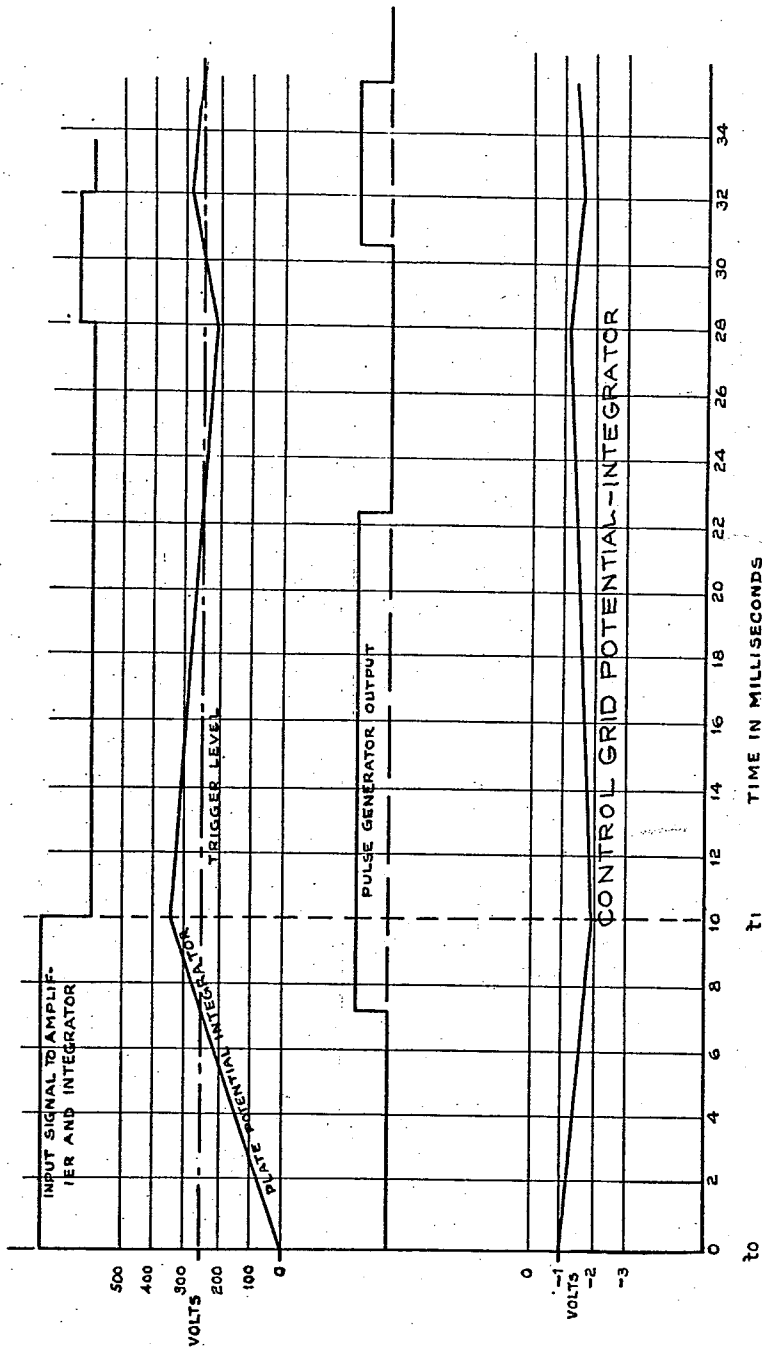


FIG. 11.

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3,105,151 PHOTOELECTRIC INSPECTION AND SORTING MACHINES

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Filed Apr. 14, 1959, Ser. No. 806,349

Claims priority, application Canada Apr. 9, 1957

33 Claims. (Cl. 250—219)

This invention relates to new and useful improvements in photo electric apparatus for inspecting sheet materials and the method of examining sheet materials for the detection and separation of defective parts thereof and is a continuation-in-part of my application Serial No. 726,920, filed April 7, 1958, and now abandoned.

The present invention is more particularly useful in the manufacture of high quality paper. When associated with a paper cutting machine, the defects of the paper are detected on the uncut and continuously moving paper sheet as it enters the cutting machine. The paper is then cut into sheets of the required size and with the aid of a deflector or grading switch, actuated by the output of photoelectric means and associated electrical devices, is sorted into two compartments. In one compartment only the first grade sheets without defects are stacked, while in the other compartment the defective, second grade sheets are stacked.

Defects in first grade paper consist of dark discolorations, starch spots, holes, folds, tears and similar inclusions and discontinuities. Defects may also consist of intensely small spots or larger areas of faint discolorations and may extend in the direction of the travel of the paper or at right angles to the direction of the travel of the paper. The photoelectric means and associated circuits must therefore have different characteristics for the reliable detection of defects.

In contradistinction to prior proposals, the present invention will detect and grade all types of discolorations. The prior art discloses rotating, fast moving scanning means or electronic "flying spot" scanning type cathode ray tube for scanning and detecting the light intensity of elementary areas of a travelling paper sheet. In such scanning methods, the photoelectric means is modulated by the scanning device itself, such modulation being present when the paper sheet under observation is without defects. As the said device scans the elementary areas from the start of the selected paper section to it end, the intensity of the reflected light picked up by the photoelectric means changes. In order to eliminate such unwanted modulation of the photoelectric means, filters must be employed which do not pass this basic scanning frequency component of the signal. When the paper sheet is discolored the entire length of the scanned paper section, the defect signals produced have the same frequency content as the scanning frequency and therefore the defect in the paper can not be detected.

Scanning means or methods may be employed wherein modulation of the phototelectric means due to the scanning action itself is not present. For example, adjacent elementary areas of the sheet paper can be scanned simultaneously by two scanning devices in conjunction with two photoelectric pickup means with their outputs connected in "push-pull," each scanning device being associated with one of the two photoelectric means. The combination of such a double, push-pull scanning system does not respond to light intensity changes which are in phase. Such systems however cannot detect discolorations which extend in the sheet in the direction of the travel of the paper and at right angles to the scanning motion. In the foregoing description, it was assumed that the elementary areas scanned simultaneously are adjacent in the direction of movement or travel of the

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paper. When the simultaneously scanned elementary areas are adjacent in any other direction relative to the direction of the travel of the paper, then faint defects which extend in the same direction as the adjacent elementary areas cannot be detected. For example, the elementary areas may be adjacent in the direction of scanned motion and at right angles to the direction of the travel of the paper.

Further, some high grade papers, such as for example bond paper, have non-uniform textures. When such paper is scanned by the illumination of an elementary area, the photoelectric means is modulated according to the intensity changes of the bond paper texture. Such modulation is termed the "noise level" of the particular paper. Investigations on bond paper samples have shown that paper noise can result in a percentage modulation of the photoelectric means as high as three parts in one hundred. As a result, faint defects extending over large areas of bond type paper sheets and detracting from the quality of the paper, cannot be detected against the paper noise level.

According to the objects of this invention all types of discolorations and defects in sheet paper are reliably detected, the noise level of the paper is reduced as observed by the photoelectric means which are positioned close to the paper in a line and preferably at right angles to the direction of motion of the paper sheet and such photoelectric means are not associated with mechanical or electronic scanning means.

For purposes of simplicity in description, the material under inspection is paper, the invention however is applicable to the sorting of other types of sheet materials uncut or already cut and of substantially uniform reflection characteristics when unblemished. The invention is also applicable to rewinding machines, machines which manufacture the sheet materials, sorting machines and cutting machines.

When the present invention is applied to cutting machines, the sheet paper is fed from a generally large roll via auxiliary rollers which eliminate flutter and folds in the material moving to an inspection surface or roller above which the travelling sheet is examined by photoelectric means. The line of photoelectric means may consist of a number of photoelectric cells placed side by side in such a manner that each photoelectric cell observes a narrow strip of the paper through an aperture. For example, the strip of paper observed is $\frac{1}{32}$ of an inch in the direction of movement of the paper and is 1.5 inches at right angles to the direction of movement of the paper. The paper sections observed by adjacent photoelectric cells overlap so that the row of photoelectric cells views and inspects the entire width of the paper sheet. The paper is flooded by strong light, for example by two D.C. fluorescent lamps placed close to the inspected section of the paper. The axes of such tube shaped lamps are arranged parallel to the line of photoelectric cells. The said photoelectric cells are enclosed in and supported by a light-tight housing the lower side of which is provided with an aperture forming structure. The construction and arrangement of the aperture is such that only the diffused light reflected from the inspected paper can reach the photoelectric cells. The fluorescent lamps are also surrounded by a housing which serves as a light shield against external illumination and light intensity changes of the inspected paper section due to changes in external illumination which could simulate defects and cause rejection of non-defective sheets.

One or more of the photoelectric cells, for example a group of 10 cells, feed a common cathode follower in adder type circuit arrangement. Light intensity changes due to defects in the paper modulate the output current of one or more photoelectric cells of the group. Such

modulation appears as a voltage variation (defect signal) at the output of the common cathode follower stage. Such defect signal is amplified in a constant-gain amplifier, the output of which operates via two channels a pulse producing stage, one for example, a Schmitt trigger stage, which is well known in the art.

The first of the two said channels is a direct link between the amplifier and the trigger stage and uses the signal amplitude levels, proportional to the modulation of the photoelectric cells, for the initiation of the output pulse. The second channel consists of one or more integrating stages the output of which can build up to a critical voltage level which can also initiate the trigger action.

The two said channels are used for the detection of faint defects in the paper. When a faint defect extends at right angles to the direction of movement of the paper, the first channel is effective because the percentage of modulation of the photoelectric cell increases with the size of the defect and a signal is produced which is above the noise level of the paper.

When a faint defect on the paper is in the direction of movement of the paper, the percentage of modulation of the photoelectric cell is low and substantially constant and is not proportional to the extent of the defect. Such a weak unidirectional signal can be built up to the required voltage level by the integrating stage of the second channel which will operate the trigger stage, even though such unidirectional signal is of the order of the paper background noise. In one embodiment of the invention the noise signal being of alternating polarity does not raise the output of the integrating stage. Several integrating stages with various time constants can be used to respond to defects of various sizes and intensities.

After a required delay, the output trigger pulse operates the grading switch by means of relays and actuators, the grading-switch deflecting the cut and defective sheets into a second grade compartment. The required delay between the instant a defect is detected and the instant the grading-switch must operate is determined by the construction of the paper cutting machine. Having passed the inspection roller, the paper sheet usually travels between draw-rolls, past a circular cutter and then by means of carrier tapes moves to the grading-switch. Thus the delay is defined by the characteristics of the particular machine to which the photoelectric inspecting means and the sorting apparatus is attached.

Further, the percentage modulation of the photoelectric cells associated with one amplifier is low when a full-black $\frac{1}{32}$ " diameter defect passes under the inspection head. Interfering disturbances to the system which can modulate the photoelectric cell currents by only a fraction of one percent must therefore be avoided.

The embodiments of my invention as hereinafter disclosed serve the elimination of the said disturbances and enhance the reliability of the subject inspection or sorting machine. In particular there are two critical requirements of the inspection head and the surface above which the inspection takes place which must be satisfied in order to avoid the production of interfering signals which can simulate defects which are not present on the sheet material inspected.

When inspection takes place above the inspection roller, eccentricity of the roller increases or decreases the diffused reflected light reaching the photoelectric cells through the aforementioned aperture. When fluorescent lamps are employed, such lamps can flicker or oscillate, even when the D.C. supply potentials are highly regulated.

In order to substantially reduce modulation of the photoelectric cells due to the said effects, one or more cells are connected to one common load resistor or impedance and the same number of photoelectric cells (one or more) are connected to another common load resistor or impedance. The value of the load resistors are equal. The two sets of photoelectric cells are matched

to give substantially equal output. Ideal matching can be accomplished by slightly adjusting the width of the aperture associated with one set of cells relative to the width of the aperture associated with the second set of cells, so that the voltages developed across the two said load resistors due to the currents in the photoelectric cells are equal. Such load resistors are then connected through cathode or anode followers to the two control grids of a symmetrical push-pull amplifier. Alternately, the resistance values of the load resistors (or impedance values when load net-works are used consisting of resistors, capacitors and coils) at the input or output of the cathode or anode followers, can be adjusted relative to each other to give identical in-phase output voltages.

The amplifying stages of the push-pull amplifier consists preferably of cathode coupled, longtailed pairs of amplifying means which are well known in the art. In such amplifiers in-phase signals simultaneously reaching the two said control grids are not amplified, while the signal reaching only one of the two control grids or anti-phase signals reaching both grids are amplified. Signals due to the eccentricity of the inspection roller or due to intensity changes of the lamps are in-phase signals and are not amplified. Signals due to defects of the sheet material are not in-phase signals and therefore are amplified. Well balanced cathode coupled long-tailed amplifiers differentiate as much as 10,000 to 1 between in-phase and anti-phase signals.

The cathode coupled long-tailed pair type amplifiers will convert the signal reaching only one grid into two symmetrical anti-phase push-pull signals at the two control grids and plates of each amplifying stage.

Further, the light source can extinguish momentarily, but such an amplifier will not respond even to such a major disturbance in the system.

According to the invention, the row of photoelectric cells in the inspection head are paired and connected in such a manner that substantially all defects of the sheet material are detected, while interference signals being of the same or greater magnitude than the defect signals, are not amplified.

Having regard to the foregoing and other objects and advantages which will become apparent as the description proceeds and the details become known, the invention consists essentially of the novel combination and arrangement of parts hereinafter described in more particular detail and illustrated in the accompanying drawings in which:

FIG. 1 is a diagrammatic illustration of the present invention which is shown in association with a paper cutting machine.

FIG. 2 is an enlarged diagrammatic view showing the photoelectric inspecting means together with the paper cutting and grading means.

FIG. 3 is a section taken on the line 3—3 of FIG. 2.

FIG. 4 is a schematic representation of a circuit arrangement for the photoelectric cells and in block diagram form, of the double channel feature of the invention, as used between the photoelectric cell amplifier and the output pulse generator.

FIG. 5 is the circuit diagram of an integrating stage as used between the photoelectric cell amplifier and the output pulse generator.

FIG. 6 is a circuit diagram of a thyratron controlled solenoid actuator as used between the pulse generator and the grading switch.

FIG. 7 is a schematic view of the rotary cutting blade and operating switches shown mounted on a disk support.

FIG. 8 is a block diagram representation of photoelectric cells connected to two amplifiers.

FIG. 9 is a block diagram representation of photoelectric cells connected to more than two amplifiers.

FIG. 10 is a circuit diagram of the amplifying system and of the control circuit common to all amplifiers.

FIG. 11 represents waveforms of the integrator channel of the amplifying system.

Referring now to the accompanying drawings wherein the present invention is illustrated and wherein like numerals and characters of reference designate corresponding parts in the various illustrations, the numeral 1 indicates a roll upon which the continuous paper sheet 2 is wound and stored. As observed in FIG. 1, the sheet paper moves over and under idling feed rollers 3 and 4 respectively and then, after moving over inspection roller 5, passes between draw-rolls 11 and 12 to the cutting station where stationary cutting blade 13 and rotary cutting blade 14 are located. After the sheets of paper are cut, they are moved by carrying tapes 15 to a grading switch 16 which deflects the defective sheets onto a layboy in the second-grade compartment 19 while the sheets of paper without blemishes or defects pass over grading switch 16 and are carried by tapes 18 onto a layboy in the first-grade compartment which is indicated by the numeral 20.

In structure, inspection housing 9 is elongated as illustrated in FIG. 3 and has mounted therein multiple photoelectric cells 6 and cathode or anode follower thermionic tubes 21 as seen in FIG. 2. Directly beneath the photoelectric cells, the lower wall of the housing is formed with a narrow aperture 7 which extends from end to end of the housing. Walls 7a extend downwardly from aperture 7 and terminate in the form of aperture 7b which also extends the full length of the housing and forms an important feature of the invention. Additionally, the lower outer walls 10 of housing 9 extend downwardly from the body of the housing and provide spaced, individual compartments within which fluorescent lamps 8 are mounted on opposite sides of aperture 7b all of which will be later referred to.

By again referring to FIG. 1 it will be seen that idler roller 4 is so positioned that by being close to yet below the level of inspection roller 5, it eliminates flutter and folds in paper sheet 2 and directs the paper in such a manner that it follows the curvature of a substantial segment of the inspection unit 5. Thus, lamps 8 can be positioned close to the surface of the paper and will not interfere with the optimal position of aperture 7. The draw rollers 11 and 12 are also so positioned that the latter purpose is served.

The rotating inspection roller 5 is not an essential feature of the present invention since a similar stationary, polished surface can replace the rotatable inspection roller. The former type of inspection roller has the advantage of minimum friction between the moving paper and the surface above which the inspection of the paper takes place but it also has the disadvantage of causing error signals when the axial symmetry of the roller is imperfect.

A non-rotating polished inspection surface is free from the aforementioned disadvantages, however, friction between the paper and the inspection surface can build up high static charges upon the paper, but such static electricity can be eliminated by the use of radiating isotopes preferably located below the inspection surface.

The inspection surface of the member 5 is preferably dark and non-reflecting in order to detect the transparent defects or "shiners," and such surface is well suited for certain types of relatively heavy, white and light coloured papers. When light weight and transparent sheets are being inspected, a white, polished metallic or gray surface with high reflection co-efficient will minimize the lack of uniformity of the unblemished paper texture due to transparency, while the detection of "shiners" is still possible. Various grades of paper of various thickness and colour require different coloured light or darker inspection surfaces in order to detect, with optimal efficiency, all types of defects and in order to minimize the inherent paper background noise. The inspection mem-

bers 5 can be made removable in order to give best performance with various grades of paper.

The photoelectric inspection means consists of a number of photoelectric cells one of which is indicated by the numeral 6 in FIGS. 1 and 2. Aperture 7 is formed between parts of the housing 9 and 10 while lamps 8 illuminate the paper sheet 2. The lower section 10 of the housing is positioned close to the paper in order to exclude external light, while the light illumination of the inspected section of the paper is kept constant in the frequency response range of the amplifying system to which the photoelectric cells 6 are connected, otherwise, changes of external illumination or of the light output of lamps 8 could initiate false defect signals which would result in deflecting unblemished paper sheets into the second grade compartment. The lamps 8 are preferably D.C. fluorescent lamps which have the form of elongated tubes which extend the entire width of the paper 2 and such lamps are fed from a regulated D.C. power supply. Regulation and peak to peak ripple of such supplies is better than a 0.5 part in a hundred for plus and a minus 10 part in a hundred line input voltage variation.

In FIG. 2, I have illustrated a cathode or anode follower thermionic tube 21 which is fed by an optimum number of photoelectric cells 6. The line of photoelectric cells illustrated in FIG. 3 shows them close to one another for viewing the entire width of the inspected sheet. As an example, if there are sixty photoelectric cells, groups of ten cells may be joined to one cathode follower 21 so that there will be six cathode followers mounted inside housing 9 and each cathode will be connected to a separate amplifier.

Connections between the cathode followers 21 and associated amplifiers may take the form of shielded cable members 22 and the amplifiers may be positioned any convenient distance from the photoelectric means. The shielded cables carry the cathode follower signal output lead as well as leads for the D.C. supply to the cathode follower and the photoelectric cells. As previously mentioned, the photoelectric pickup means herein consists of a row of photoelectric cells which will reliably detect all blemishes present on paper sheets which have substantially uniform reflection characteristics.

Upon investigation of various types of high grade bond paper, it has been shown that if such paper is scanned by the illumination of an elementary area 0.25 inch x 0.25 inch equals $\frac{1}{16}$ of a square inch, the percentage modulation of the reflected, diffused light can be as high as three parts in one-hundred. When the illuminated elementary area is reduced, the modulation due to the unblemished paper texture usually increases and the light intensity is reduced. Thus, for purposes of the following consideration, it is reasonable to assume a practical elementary spot size of $\frac{1}{16}$ of a square inch area.

When it is required to detect a small black spot of say $\frac{1}{32}$ inch x $\frac{1}{32}$ inch dimensions, that represents an area of approximately $\frac{1}{1000}$ of a square inch. Therefore, the percentage modulation, that is the defect signal, obtained when a blemish of $\frac{1}{1000}$ of a square inch area is scanned by an illuminated elementary area of $\frac{1}{16}$ of a square inch is 1.6 parts of one-hundred so that the defect signal is below the noise level of the paper (three percent) and can not be detected. For reliable detection, the defect signal should be at least twice the value of the noise signal.

Further investigations on a wide selection of bond type papers have shown that when a narrow section, say $\frac{1}{32}$ of an inch wide by 1.6 inches long is illuminated, the noise modulation is a maximum of one part in one-hundred or less. When the length of such section of paper is increased, the maximum noise modulation is reduced to less than one part in one-hundred. The reduction of noise modulation is due to the averaging out of the modulation caused by the small size of the distinct areas of the texture having different shades or different reflective properties.

When a black spot having a 0.001 square inch area enters an inspection section of $\frac{1}{32}$ inch by 1.6 inches, which equals 0.05 square inch area, the resulting percentage modulation is 0.001/0.05, that is to say, two parts in one-hundred. Therefore, such blemish is detected over the one percent paper background noise modulation.

When the outputs of several photoelectric cells are connected to the control grid of a cathode or anode follower stage, the modulation due to the paper background noise is reduced while the modulation due to the blemishes is added. For example, it is practicable to connect ten photoelectric cells of the 1P39 type to a common anode follower.

In what follows, it is shown that the inherent noise of the photoelectric cells due to the current passing from the photocathodes to the anodes caused by the reflected illumination of the unblemished paper and collected by the photocathodes is by order of magnitudes smaller than the paper background noise. Inherent noise in high vacuum photoelectric cells, such as for example in type 1P39 cells used for investigation, is caused mainly by the "shot" effect which is the generic term given to current fluctuations in a beam of electrons arising from the randomness of emission of the photocathode. The mean square fluctuation of the photoelectric current $\overline{di^2}=2eIdf$, where di =instantaneous fluctuation of current from its mean value I , e =electron charge= $1.6 \cdot 10^{-19}$ coulombs, df =frequency interval in which $\overline{di^2}$ is observed. Therefore, the mean noise voltage $\overline{dv}=\sqrt{2eIdf} \cdot R$, where R =the load resistance of the photoelectric cell.

A $\frac{1}{32}$ inch by 1.6 inch illuminated aperture gave, in each photoelectric cell, a current $I=3.3 \cdot 10^{-8}$ amperes. The load resistance R was 1 megohm. The frequency response range of the photoelectric cells, anode follower and amplifier system $df=3 \cdot 10^3$ c./s. for a paper velocity of two-hundred inches per second. Therefore, in ten cells

$$\overline{dv}=\sqrt{2 \cdot 1.6 \cdot 10^{-19} \cdot 3.3 \cdot 10^{-8} \cdot 3 \cdot 10^3 \cdot 10^6 \sqrt{10}}=18$$

microvolts. Measurements have confirmed such theoretical noise levels. The highest paper background noise peak voltage v corresponding to a modulation of one percent of I is $v=1 \cdot 10^{-2} \cdot R=330$ microvolts. This is the paper background noise voltage pickup by one cell only, so that the inherent noise of ten type 1P39 photoelectric cells can be neglected against the basic paper noise.

In FIG. 3, the plan view illustrates the housing 9 with aperture 7 extending lengthwise from end to end thereof and the relative position of the multiple photoelectric cells 6 with respect to the aperture 7. It will also be observed that the housing 9 extends the entire width of the sheet paper 2 so that in operation the entire width of the sheet 2 is subject to inspection.

As illustrated in FIG. 4, photoelectric cells 23, 24, 25 and 26 are paralleled by connecting their cathodes to the grid 34 of triode 32. For purposes of simplicity only four photoelectric cells are shown. The number of photoelectric cells thus paralleled may be ten or more as long as the inherent noise of such a group is below the paper background noise and as long as the paper background noise is half or less than half of the signal produced by the smallest defect to be detected. Additionally, instead of the triode 32, a pentode or other type of amplifying devices may be used. The anode follower stage consists of tube 32, anode-grid feed-back resistor 29, grid-leak resistor 30, cathode bias resistor 31, coupling capacitor 28 and anode resistor 27, and is the preferred form of coupling, but could be replaced by a cathode follower stage which is well known in the art.

When the paper under inspection has a uniform texture, without blemishes, the amount of light reflected from the illuminated paper sheet falling upon the photocathodes of cells 23, 24, 25 and 26 is constant and the current in the photoelectric cells 6 is also constant. When however a paper defect such as a dark area is viewed by one or

more photocathodes, the steady current of the cells is less. Without feed-back resistor 29 such current decrease would produce a voltage decrease at the grid 34 as defined by the current change and the value of resistor 30. Due to the amplification of tube 32 and feed-back impedance 28 and 29, substantially all the change of the photoelectric cell currents is flowing to the anode 33 and the potential of grid 34 remains substantially constant so that the effective load resistance of cells 23, 24, 25 and 26 is resistor 29.

The grid potential of the triode 32 remains substantially constant during modulation hence the limiting effect upon the high frequency response of the large circuit capacitance between the photocathodes and ground and photocathodes and the photoanodes is substantially eliminated. Due to the wiring and paralleling of many photocathodes to the common grid 34, such capacitance can be as high as 100 micromicrofarads.

It can be shown that when the tube 32 is a pentode with an open loop gain of 150 and when the highest frequency component of the photo-signal modulation is 3 kilocycles, when the modulation due to a black spot of 0.001 square inch area is $6.6 \cdot 10^{-10}$ amperes, the resistor 29 can be 6.8 megohms, so that the peak signal at the anode 33 is approximately 5 millivolts.

Such minimum signal shown at 36 in FIG. 4 is amplified to a 50 volt level by a conventional amplifier 37 in order to operate the trigger generator 39. In order to raise the 5 millivolts minimum input signal to the required 50 volt level, amplifier 37 has a voltage gain of 10,000 and is conveniently an R.C. coupled A.C. amplifier wherein the gain is constant and is stabilized against tube changes and ageing by limiting the stage gain of each stage of a total of four stages to ten. This is conveniently arranged by the use of anode follower type feed-back networks for each stage.

The output signal of the amplifier 38 shown in FIG. 4 initiates the output pulse 43 of the pulse generator 39 for which various conventional pulse producing circuit arrangements may be employed. For example, a biased off grid controlled gas-filled triode, known in the art as a thyratron can be switched into conduction by signal 38 which has a positive polarity or similarly, a Schmitt trigger circuit may be employed.

The cut-off bias applied to the control grids of the said devices is such that the paper noise level is safely below the trigger voltage level so that only the defect signal will initiate the output pulse which, in turn, actuates the grading switch.

When the defect to be detected is a $\frac{1}{32} \times \frac{1}{32}$ inch square black spot or is a weaker blemish extending at right angles to the direction of travel of the paper, an amplitude sensitive direct input channel between amplifier 37 and pulse generator 39 is effective. For example, defects which are $\frac{1}{32}$ inch wide and have the following intensities and dimensions at right angles to the paper motion will produce identical output signals.

Size of defects in inches		Intensity of defect expressed in fractions of full black
In the direction of paper motion	At right angles to paper motion	
$\frac{1}{32}$	$\frac{1}{32}$	1
$\frac{1}{32}$	$\frac{1}{16}$	$\frac{1}{2}$
$\frac{1}{32}$	$\frac{1}{8}$	$\frac{3}{8}$
$\frac{1}{32}$	$\frac{1}{4}$	$\frac{1}{2}$
$\frac{1}{32}$	1	$\frac{1}{32}$
$\frac{1}{32}$	10	$\frac{1}{320}$

It is pointed out however that when a weak blemish extends in the direction of travel of the paper and is narrow at right angles to the paper travel, integrating links are used between amplifier 37 and pulse generator 39, one such link being shown at 41 in FIG. 4. Section 45 of

the signal 40 shown in FIG. 4, is such an amplified defect signal.

Amplitude 46 of the unidirectional defect signal is smaller than the peak amplitude 47 of the paper background noise signal. In spite of this, the level of the defect signal 49 is raised above the voltage level at which the pulse generator 39 is triggered by an integrator network or stage 41. The simplest form of this network consists of a capacitor C_i and resistor R_i . When the time constant C_i-R_i is of the order of the duration T_i of the defect signal, the triggering voltage level is safely reached within the time interval T_i as shown by the signal 49.

The statistical average of the noise signal 44 consists of equal positive and negative voltage excursions so that its integrated mean level 48 is constant and is below the triggering voltage level. When the extent of the faint defect in the direction of the paper travel varies, the required integrating time constant T_i is changed in proportion.

Advantageously, an amplifying integrating stage is used as shown in FIG. 5. The output stage 50 of the amplifier 37, as shown in FIG. 4, is connected by coupling capacitor 51 and resistor 52 to the control grid of the integrator-amplifier pentode 60. The cathode bias resistor 55, grid-leak resistor 54, screen feed resistor 57 and plate load resistor 59 all have such values that the gain of this pentode stage is several hundred when the feed-back resistor 53 is disconnected. By connecting the plate to the grid by means of the coupling capacitor 56 and feedback resistor 53, the gain of the pentode stage is set at approximately 20. At the same time, the linear amplification of any one frequency component is improved. The integrating time constant is defined by the plate load resistor 59 and capacitor 61. The integrator capacitor 61 has such value that it builds up the unidirectional defect signal amplitude 46 while the noise signal consisting of peaks of alternating polarities and having a higher frequency content, is not integrated and is attenuated. The inputs of several such integrating amplifiers with various time constants may be connected to the plate of tube 50 and the outputs connected by adder resistors and an adder amplifier to the control grid of the pulse generator.

The output pulse produced by a defect located at position D, see FIG. 2, is delayed until the leading edge of the continuous sheet material 2 has approached position F where the deflector edge 17 of grading switch 16 is located. Meanwhile, the sheet 2 has been cut by blades 13 and 14 at the position indicated by the letter E. The aforementioned delay consists of a constant part and a variable part. The constant part of the delay is defined by the time required for the defect in sheet 2 to move from the position D to the position E. For example, when the velocity of travel of the paper is 200 inches per second and the distance from D to E is twenty-five inches, such constant part of the delay is 25/200 which equals 0.125 part of a second. The variable part of the delay is defined by 3 parameters, namely the angular position of the rotating cutter member 14 at the instant the defect arrives at position E, the distance from E to F and the speed at which the cut sheet is carried by the tape 15.

In what follows, it will be seen that a thyatron 64, see FIG. 6, associated with microswitches 62, 74 and 75 together with relays 68 and 70 and grading switch actuating solenoid 72 will satisfy the conditions set by the said parameters for reliable sorting.

Initially, microswitches 74 and 75 are closed, microswitch 62 is open, thyatron 64 is biased to cut-off by having its control grid connected by resistor 66 to adjustable potential divider 67 which is connected between ground and a negative supply rail while coils 68, 70 and 72 are not energized and contacts 69, 71 and 73 are open. Thyatron 64 is fired by a positive pulse delayed relative to the instant of the leading edge of pulse 43 by the constant part of the delay. See FIG. 4.

By using a phantatron delay generator which is well

known in the art, pulse 43 starts the plate voltage run-down of a normally cut-off phantatron which bottoms at the end of the constant delay and then returns to its initial cut-off condition. The differentiated screen voltage jump at this instant is the positive pulse 76 which fires thyatron 64. See FIG. 6.

The variable second part of the delay is introduced by synchronizing the instant of operation of the solenoid of the grading switch 16 with the rotating cutting blade 14. When the cutting blades 13 and 14 meet, microswitch 62 closes and the increased current through relay coil 68 closes contacts 69 which energizes relay coil 70 which, by closing contacts 71, connects solenoid 72 which actuates grading switch 16. Contacts 73 close simultaneously with contacts 71 holding coil 70 energized until microswitch 74 momentarily opens. The momentary opening of microswitch 74 is synchronized with the rotating cutter blade, thus, for example by placing microswitch 74 diagonally opposite microswitch 62, it initiates the cycle of operation. By this means then, the grading switch 16 is retained in the desired position for the passage of half a length of the cut sheet in the desired position. The edge 17 of the grading switch 16 is so shaped and its movement is such that it does not interfere with the passage of the cut sheets once they are deflected toward either the second grade compartment 19 or the first grade compartment 20. Further, thyatron 64 is prepared for the reception of some other defect pulse by the momentary opening of microswitch 75 which interrupts the HT supply to thyatron 64. The angular position of switch 75 is displaced a few degrees clockwise relative to the position of switch 62 while switches 62, 74 and 75 are operated by one or more shaped disc members attached to the mechanism of the rotating cutter 14. The rotation of the cutting blade 14 is anticlockwise. In FIG. 7, three shaped disc members are shown together with microswitches 62, 74 and 75, however, other switches such as the commutator type with brush pick-ups may be employed.

When the distance between the cutting position E and point F of the grading switch is greater but is of the order of the length of the cut sheets, the hereinbefore described method and means for producing the required delay is satisfactory. Other and more complex means may be employed when the speed of the carrying tapes 15 is not constant or when the distance between points E and F is much greater than the length of a cut sheet. In all cases, the delay must be such that the grading switch is deflected just before the leading edge of a defective sheet approaches the edge 17 of the grading switch 16.

In the operation of the invention thus far described, sheet paper 2 is fed from a large roll to auxiliary rollers 3 and 4, such rollers eliminating flutters and folds in the paper sheet. The paper then passes over inspection member 5 after which, by means of draw rollers 11 and 12, the paper sheet is moved from the inspection member 5 to the point E where it is cut into sections or lengths by means of cutting members 13 and 14. Immediately above inspection member 5, the paper 2 is flooded with strong, uniform light by means of the fluorescent lamps 8. The lamps 8 are arranged close to the paper surface and on opposite sides of the long, narrow aperture 7 so that the light rays therefrom are directed downwardly on to the surface of the paper on the inspection member 5 and are then reflected upwardly through aperture 7 to the photoelectric cells 6.

As the sheet paper moves over the inspection member 5 and a defect appears in that portion of the paper beneath the aperture 7, the diffused, reflected light rays falling upon the photoelectric cells 6 will increase or decrease the current of the photoelectric cells according to the nature or characteristics of the defect and such changes in the current produce a corresponding voltage change such as signal 36 at the input of amplifier 37. The amplified signal 38 produced by the direct channel, or

signal 42 produced by the integrator 41, passes the generator 39 and produces output pulse 43 which, in turn, actuates grading switch 16.

At the instant the defect in the paper appears beneath aperture 7, output pulse 43 is produced. This output pulse is then delayed by a time period which is defined by the time period in which the said defect moves from beneath aperture 7 to the stationary cutting blade 13. The grading switch 16 moves upwardly at the instant the stationary and rotary cutting blades 13 and 14 meet to cut the defective sheet of paper. The defective sheet of cut paper is then carried to compartment 19 by tapes 15. When the cut sheets of paper are without defect, the deflector 16 remains stationary and such first grade paper is carried to the first grade compartment 20 by tapes 18.

Referring now to FIG. 8 of the drawings, the lines numbered 77, 78, 79, 80, 81, 82, 83 and 84 represent the photoelectric cells shown in FIG. 2 and FIG. 3, such lines also give visual representation of the aperture 7 also shown in FIGS. 2 and 3. In practice, lines 77 through 84 meet and represent a part of the continuous aperture 7. The lines 77 through 84 also indicate equal sections of the sheet material under inspection, each such section being viewed by one, two or more photoelectric cells. The number of photoelectric cells viewing each section from 77 to 84 are equal.

The cathode of the photoelectric cells, as for example seen at numerals 23 to 26 in FIG. 4, viewing sections indicated by numerals 77 and 79, are connected together and are connected by link 85, which may be a cathode or anode follower stage, such as is indicated by numeral 32 shown in FIG. 4, to one of the input control grids of amplifier 87 which consists of the heretofore described long-tailed pair stages.

Similarly, photoelectric cells viewing sections 81 and 83 are connected together and are connected by link 86 to the other input control grid of amplifier 87.

Sections 78, 80, 82 and 84 are interleaved with sections 77, 79, 81 and 83 and the photoelectric cells viewing sections 78, 80 and 82, 84 are connected by links 88, 89 to the two input control grids of amplifier 90. Amplifier 90 is identical in all its characteristics to amplifier 87.

According to my invention, the main rule of connections is that adjacent sections such as 77, 78 or 79, 80 and so on, are connected to different amplifiers and that to each control grid of such amplifiers the same number of photoelectric cells are connected and thus view sections of equal lengths. The number of amplifiers used can be two or more, however, the number of sections used must be an even number. As an example of this, an alternative arrangement satisfying the aforementioned principle of connection is shown in FIG. 9.

When the number of the equal interleaved aperture sections is n , the maximum number of amplifiers which can be connected according to the stated rule is $\frac{1}{2}n$, and the minimum number of amplifiers is 2 when $n/2$ interleaved sections are connected to one amplifier and the other half to the second amplifier; n must be an even number in order to preserve the symmetry of the system and should preferably be equal to $4m$, where m can be any number. As an example, when m equals 1, 2, 3, 4, or 5 n equals 4, 8, 12, 16 or 20.

Adjacent aperture sections are connected to different amplifiers in order to eliminate blind spots in the viewing aperture 7 shown in FIGS. 2 and 3. To serve the same purpose, the photoelectric cells associated with one section also view bordering parts of both adjacent sections. If adjacent sections, as for example n and section $n-1$, were connected to the two control grids of the same amplifier, and if a defect then passes under the dividing line of the said sections, the amplifier would receive two identical inphase signals and such signals would not be amplified.

An amplifying system such as block 87 or 90 seen

in FIG. 8 or one of blocks 91 to 97 seen in FIG. 9, is shown in the circuit diagram of FIG. 10. This amplifier system performs all the basic functions which are specified in the amplifying system shown in FIG. 4 and is immune to in-phase interference signals, amplifies and detects defect-signals brighter or darker than the mean intensity of the sheet material under inspection. It is not sensitive to supply and heater voltage variations. While it is also an A.C. amplifier it is substantially free from blocking effects, i.e., it reliably detects small defects which follow large and intense defects, its integrator channels do not respond to the basic paper noise and are sensitive to unidirectional weak defect signals which extend in the direction of travel of the sheet material. Additionally, the output cathode follower stages of several such amplifying systems are paralleled and connected to the output pulse producing stage common to all amplifying systems such as block 39 seen in FIG. 4, in such a manner that undesirable interaction between the amplifying systems, does not occur.

Photoelectric cells 98 and 99 represent the cells which view one aperture section, e.g. section $n-2$ of FIG. 9. Photoelectric cells 100 and 101 view another aperture section, e.g. n seen in FIG. 9. For purposes of description only, two pairs of photoelectric cells shown in FIG. 10 view equal interleaved aperture sections. The number of photoelectric cells which view each such aperture may be one or more.

The cathodes 102 and 103 of cells 98 and 99 are connected to load resistor 106 as well as the control grid 108 of the cathode follower 110. The photocathodes 104 and 105 of photoelectric cells 100 and 101 are connected to the load resistor 107 as well as control grid 109 of a second cathode follower 111. The resistance of resistor 106 is equal to that of resistor 107.

The D.C. voltages developed across the load resistors 112 and 113 of the cathode followers 110 and 111 are proportional to the diffused reflected light from the sheet material viewed by photoelectric cells 98, 99 and 100, 101. The output of the photoelectric cells 98, 99 and 100, 101 are matched to be equal by adjusting the variable arms 114 and 115 of cathode follower load resistors 112 and 113. Thus, the in-phase output signals of the inspection head are matched and are applied to both input control grids 118 and 119 of the amplifier.

The amplifier proper consists of long-tailed coupled triode stages, three such stages being shown in FIG. 10. Triodes 120 and 121 represent the first long-tailed pair, triodes 122 and 123 the second pair and triodes 124 and 125 the output stage. The number of stages used will vary according to the gain and stability requirements of the amplifier. The plates of the triodes are connected to the positive supply line +HT by resistors 126, 127, 128, 129, 130 and 131. Such load resistors belonging to the first, second and output stage have equal resistances, e.g. the resistance of member 126 equals the resistance of member 127.

The cathodes of the paired triode stages are connected by resistors 132, 133 and 134 to each other and are connected by the "long-tail" resistors 135 to 140 to the negative supply line -HT. The cathode resistors have equal resistance values for each paired stage. Thus the resistance of resistor 135 is equal to the resistance of element 136, the resistance of element 137 is equal to the resistance of element 138 and the resistance of element 139 equals the resistance of element 140.

The gain of the first stage is mainly defined by the resistance ratio of resistors 126/132 or 127/132 giving an identical number, the second stage gain by 128/133. The third stage gain is by 130/134. Therefore, the gain of the whole amplifier is defined by the value of these resistances and is substantially independent of the triode characteristics as well as aging loss of electron emission from the cathodes and heater voltage changes in these tubes. It is an essential feature of my invention that

when a particular defect is sensed by one or more photoelectric cells 98 to 101 and is amplified to some well defined level by the "constant gain" amplifying system shown in FIG. 10, all other amplifying systems associated with the rest of the photoelectric cell row 6, shown in FIGS. 2 and 3, must have the same gain and characteristics as the amplifying system shown in FIG. 10, raising the defect signal to the same well defined level. According to the present invention and in order to make all the amplifier systems identical with each other, precision resistors are employed and such resistors define the "constant gain" of the amplifiers. All amplifiers therefore are made to provide the same gain so that the differences in tube characteristics will have only a second order effect upon such gains and the gain frequency characteristics of all amplifiers will be identical. Discrepancies of the nominally identical precision resistors are compensated for by a slight adjustment of the variable resistor 132 which equalizes the gain of all the amplifiers.

The amplifying stages herein are direct-coupled to each other by resistors 141 through 144. The resistance of element 141 equals that of element 142 and the resistance of element 143 equals that of element 144.

The control grids of the amplifying stages are connected to the negative supply line —HT by resistors 145 through 150. The resistance of element 145 equals that of element 146 and the resistance of element 147 equals that of element 148 while the resistance of element 149 equals that of element 150. The values of resistors 141 through 150 are so selected that the voltage levels of the control grids 118 and 119 and the control grids of tubes 122 through 125 are close to ground potential.

By equalizing the values of all the resistors attached to triodes 111, 121, 123 and 125 with the values of the corresponding resistors of triodes 110, 120, 122 and 124, the amplifier is made insensitive to variations of the supply potentials +HT and —HT. Supply voltage variations are reduced to in-phase signals at the control grids, the cathodes and the plates of the triode-pairs, hence such signals are not amplified.

The frequency response of the amplifying system should be constant from 1 cycle per second to 9 kilocycles. The low frequency limiting response of 1 cycle per second is defined by the requirement of the system to be able to integrate information on the sheet material when it travels slowly. When the slowest velocity of the sheet material is 20 inches per second, information present in the section of sheet material 20 inches in length can be integrated. The limit of high frequency response is defined by the requirement of amplifying without attenuation of the smallest defect of $\frac{1}{32}$ inch by $\frac{1}{32}$ inch at the fastest sheet velocity. When the velocity of the sheet is 200 inches per second the high frequency limit must be 3 kilocycles per second and at a sheet velocity of 600 inches per second the high frequency must be 9 kilocycles per second.

The amplifier must also respond without blockage to small signals which follow high amplitude signals, for example, when a $\frac{1}{32}$ inches diameter full-black spot follows a defect of a much larger area.

In order to satisfy the low frequency requirements, the amplifier shown in FIG. 10 is D.C. coupled from the photoelectric cell cathodes to the output plates of the triode pair indicated by numerals 124 and 125. It is a further essential requirement of the output triode pair 124 and 125 that the steady state potentials of such output plates 152 and 153 shall be equal. These potentials are made exactly equal by balancing potential divider 154. The plate potentials must, of course, be equal in order that the coupling diode network, which consists of diodes 155 through 160, will function satisfactorily.

As is well known in the art in D.C. coupled high gain amplifiers, it is difficult to achieve the stated balance of the output potentials for long periods of time without rebalancing such systems. Therefore, according to my in-

vention, the D.C. amplifier shown in FIG. 10 is converted into an A.C. amplifier by a feed-back network consisting of resistors 165, 166, 167, 168 and capacitor 169. Substantially all the D.C. output at plates 152 and 153 is fed back to the input grids 118 and 119 by this network while the useful signal frequencies from one cycle per second to 9 kilocycles per second are decoupled by capacitor 169 and consequently are not fed back from the output to the input. As a result the system amplifies without the feed-back attenuation of such frequencies.

Blockage of the amplifier previously mentioned may be avoided by Zener diodes 155 and 156 connected to the output plates 152 and 153, or, alternatively, a neon tube could replace diodes 155 and 156. Further, the gain of the amplifier is such that the smallest defect signal is amplified to say a 50 volt level. The voltage breakdown of the Zener diodes or the neon tube is so chosen that any output signal above the 50 volt level can not raise the potential of plates 152 and 153 due to the discharge in such diodes or neons. As a result the A.C. negative feed-back pass does not receive signals above the minimum defect level and can not induce blockage.

Additionally, the steady state D.C. levels of the output plates 152 and 153 are substantially defined by the precision resistors 165, 167, 145 and 166, 168 and 146, when the supply voltages +HT and —HT are regulated and have the long-term stability of plus or minus one volt, the output plate potentials are defined with an accuracy of approximately plus or minus a volt and are equal, assuming, of course, that the resistance of resistor 165 equals that of element 166 and 167 equals that of element 168 while element 145 equals element 146.

When a black defect in the sheet material reduces the light collected by the photoelectric cells 98 or 99, a positive signal indicated by numeral 170 is produced at the output plate 152. Simultaneously, the cathode coupled pairs shown in FIG. 10 produce an identical negative output signal indicated by numeral 169 at the output plate 153, such signal is negative only relative to the plate mean potential. It will be seen therefore that signals due to any defect result in two output signals which are equal and are not in-phase. When a defect viewed by any of the photoelectric cells 98 through 101 is brighter or darker than the mean intensity of the sheet material, one of the output plates 152 or 153 is always positive while the other is negative. Signals indicated by the numerals 171 and 172 represent such push-pull anti-phase signals; the negative section of the output signals 169 and the positive section 170 are due to the defect and sections 173 and 174 are due to the basic noise of the sheet material.

Each of the output signals just mentioned are fed by two channels to the output pulse generator which may be a Schmitt trigger generator which is well known in the art and which consists of double triodes 175 and 176.

Channel one of the invention is the amplitude differentiating channel and its operation is described in what follows. The potential of the cathodes of the triodes 175 and 176 is defined by potential divider chain 177, 178 and 179. Adjustable resistor 179 sets this potential to say 250 volts; triode 175 is normally cut off so that the conducting triode 176 acts as a cathode follower. Potential divider 180 defines the potential of the cathode of the output cathode follower 181 of the amplifying system and is, for example, set at 225 volts. The 25 volt difference between the cathode potential of triodes 175 and 176 and the cathode potential of cathode follower 181 is sufficient to cut off triode 175.

The potential of the control grid of triode 181 is defined by the potential divider 180 through the grid-leak resistor 182 and is close to the potential of the cathode of triode 181 for the reason that triode 181 is a cathode follower. For purposes of description, the grid potential is assumed to be 223 volts. This potential of 223 volts is also applied through resistor 183 to the junction of the

output plate coupling diodes 157 and 158. The anodes of the diodes 157 and 158 are connected to the output plates 152 and 153 while the cathodes are connected to the grid of the output cathode follower 181 through resistor 183. Therefore the cathodes of the said diodes are biased 23 volts positively relative to the steady state output plate potentials which are set at 200 volts by the previously described feed-back network. The peak values of the defect signals 169 and 170 are limited to plus or minus 50 volts relative to the mean output plate potentials by the Zener diodes 155 and 156. Therefore, the peak level of the output signal 169 is +150 volts and that of the output signal 170 is -250 volts. Peak values of the basic noise signals 173 and 174 are less than plus or minus 10 volts relative to the mean output plate potential so that the noise signals do not pass through the biased coupling diodes 157 and 158 while a portion of the defect signal 170 will pass through coupling diode 158 and will appear at the cathode of the cathode follower 181 and at the grid of the trigger generator triode 175. Such a defect signal is approximately 50 volts minus 23 volts which equals 27 volts and its peak level at the grid of triode 181 is +150 volts and at the cathode of triode 181 it is +252 volts. Thus the control grid of the normally cut-off triode 175 of the trigger generator is raised above the potential level of 250 volts of its cathode and the output pulse 184 is produced. The relative potentials of the cathodes of the trigger generator triodes and the cathodes of the coupling diodes are thus so arranged that defect signals raising the potential of one of the output plates to about +250 volts will produce an output pulse of constant amplitude (184), while the noise content of the output signals do not effect the output trigger generator.

The second channel of the amplifying system shown in FIG. 10 consists of coupling diodes 159 and 160, paralleled by resistors 161 and 162 with capacitor 163 coupling the junction of the anodes of diodes 159 and 160 to the control grid of the Miller integrator 185 through resistor 186. The following components associated with the Miller integrator are the grid-leak resistor 187, plate load resistor 188, the plate to grid feed-back capacitors 189 and 190 which are coupled to the control grid by switch 191, the integrator output coupling diode 164, the plate resetting diode 192 and the screen grid de-coupling capacitor 193.

The principle of the Miller integrator is well known in the art and its main function as illustrated in FIG. 10 is the production of a linearly increasing plate potential. The rate of increase of the plate potential

$$\frac{dV}{dT} = \frac{v}{CR}$$

where v is the potential applied to the resistor 186 at the junction of resistors 186 and 187 and capacitor 163, C is the capacitance of the capacitors 189 or 190 and R is the resistance of resistor 186. The control grid and the cathode of the Miller pentode 185 are at substantially the same potentials while the resulting plate current is such that the plate potential of tube 185 will be only a few volts, say ten volts, above ground level (cathode potential). By applying to the screen grid of this Miller integrator a high enough potential by divider 194, such "bottomed" condition of the plate can always be attained.

Now when a negative potential is applied to R (186), the current of the tube is reduced and its plate potential will linearly increase toward the positive line potential +HT set at say +350 volts. When the plate potential reaches +223 volts, that is the level to which the grid of the cathode follower output tube 181 is set, coupling diode 164 conducts and the further rising plate potential of the integrator 185 appears at the output of the amplifying system producing an output pulse similar to signal 184, the duration of which is equal to the time period during which the integrator plate potential remains above 250 volts.

This second integrator channel of the amplifying system senses defect signals which are below the trigger level of the output pulse generator and which can be of the same order of magnitude or smaller than the basic noise level (173, 174) of the sheet material under inspection and which are due to defects which are extended in the direction of travel of the sheet material. For example, the integrator constant CR may be set to have such value that the input signal v specified in the table below raise the integrator plate potential to the hereinbefore defined trigger level of 250 volts for defects specified in the following table.

Dimension of the defects at right angles to the direction of travel of the sheet material equal $\frac{1}{32}$ of an inch.

Intensity of defect, 100 percent full black in percentage	Dimension of defect in the direction of travel of the sheet material in inches	Input signal amplitude v in volts	Time interval $T=CR$ in millisecond during which plate of integrator rises to +250 volts sheet velocity equals 100 inches per second
50	$\frac{1}{16}$	25	0.625
25	$\frac{1}{8}$	12.5	1.25
12.5	$\frac{1}{4}$	6.25	2.5
6.25	$\frac{1}{2}$	3.125	5.0
3.13	1	1.56	10.0

For defects extending in the direction of travel of the sheet material, the integrator response is the same as that of the amplitude differentiating channel, channel 1, for defects extended at right angles to the direction of travel of the sheet material. In both channels the output signal peak is proportional to the product of the intensity and the area of the defects. This law corresponds quite well to the mental effect whereby the human eye senses the magnitude of a defect.

The dimensioning of the time constant CR of the integrator in the above described manner is given only as an example. The time constant can be chosen to satisfy other integration requirements. For example, to integrate a defined number of minute defects (each less than $\frac{1}{32}$ inch diameter) falling within a certain area of the sheet material. One or more integrator stages satisfying several programmes can operate simultaneously and can be coupled via capacitors such as 163 and diodes such as 164 to the output cathode follower 181.

When the defect signal is smaller than the amplitude of the noise signals such as are indicated at 173 and 174, it is desirable that the integrator shall not respond to the noise signals. According to my invention this is accomplished by coupling the output plates 152 and 153 by diodes 159 and 160 as well as capacitor 163 to the input of the integrator. The cathodes of the diodes 159 and 160 are connected to the output plates while the anodes are connected to the capacitor 163. The mean potential of the output plates is fed to the anodes of the diodes 159 and 160 by two equal resistors 161 and 162 so that the coupling diodes are not biased and only the negative excursions of the noise signals 173 and 174 pass through the coupling diodes and appear at the junction of the capacitor 163 and diodes 159 and 160. The resulting signal 195 is the rectified noise signal and thus its peak to peak amplitudes are halved. The time constant of the capacitor 163 and the resistors 186 and 187 is chosen in such a manner that it satisfies the low frequency response requirement of the amplifying system and as an example it is made three seconds. Therefore, the rectified continuous noise signal charges in three seconds the capacitor 163, thus biasing the coupling diodes 159 and 160 by a voltage level which is of the order of the rectified continuous noise amplitudes so that such noise signals are substantially eliminated at the input of the integrator as shown by signal 197. The integrator

input signal 196 does not have the said effect upon diodes 159 and 160 and therefore is not attenuated.

According to the present invention, the screen potential of the integrator 185 is so selected that its current is cut off when only a few volts are applied to the control grid of the integrator. Various sheet materials have different noise contents. Some sheet materials have a rather non-uniform noise content in which case the sensitivity of the integrator has to be reduced thus limiting the sensitivity of the system for the detection of the defects extending in the direction of travel of the sheet material. According to the present invention, the potential divider 194 is adjusted to various levels to match the noise level of the various materials. When the screen potential of the integrator is raised, the grid cut-off potential is increased. Therefore, according to my invention the "noise sensitivity control" member 194 is adjusted according to the noise characteristics of the various sheet materials.

As an example of this, when the peaks of noise signals 197 are -2 volts, the noise sensitivity control 194 is set in such a manner that the control grid cutoff potential of the integrator is say minus 5 volts, then the plate potential of the integrator will not reach the +223 volts at which level the coupling gate, diode 164, opens.

In accordance with the invention, the control grid, and hence the plate of the integrator 185 is switched to ground potential periodically by positive pulses 198 or 200 which are applied through coupling diode 192. Pulse 200 is initiated by the delayed output pulse 184.

When, for example, the conditions of integration programmed are such that defect-information contained in each one-inch length of the sheet material (having a width defined by the sections viewed by the photoelectric cells 98 and 99) is to be integrated, it is possible that a one-inch length containing defects which raise the plate potential of the integrator above the trigger level of the output pulse generator is followed by a one-inch length of the sheet which, while containing minor defects, should not be discarded as defective. The characteristics of the integrator circuit are such that such sections containing minor defects and which are not to be discarded could also be sensed as defective sections, unless the output pulse 184 or "sampling pulses" 198 return the integrator to its steady state, namely, when the potential of its plate is close to ground.

This effect is better understood by reference to FIG. 11 and by assuming in the example which follows that specific voltage levels are applied to the integrator. Let the sheet velocity be 100 inches per second with a faint defect one-inch long in the direction of the travel of the sheet material. Then let the signal v corresponding to this defect be -10 volts at the integrator input and let the control-grid cut-off potential of the integrator be -2 volts. The time constant of the integrator is so selected that when $v = -10$ volts, the integrator output reaches the positive supply potential +350 volts in 10 milliseconds;

$$\frac{350 \text{ volts}}{10^{-2} \text{ sec.}} = \frac{10 \text{ volts}}{CR}$$

Therefore, the trigger level of 250 volts is reached in 6.7 milliseconds and the resulting duration of the output pulse 184 would normally be 3.3 milliseconds while the defect passes under the aperture 7. Let the steady state bias of the control grid, due to grid current, be -1 volt; after 10 milliseconds the control grid reaches -2 volts which is the cut-off potential of the integrator. At the instant the defect passes beyond the aperture (t_1 in FIG. 11), the output potential starts to fall slowly; the voltage drop corresponds to $v = +2$ volts, because when the defect signal drops to zero the potential across resistor 186 is +2 volts while during the presence of the defect signal it was -9 volts. Thus for a period of approximately 15 milliseconds the integrator output voltage remains above the +250 volt trigger level and only

after a considerably longer time period can the initial potential (+10 volts) of the integrator plate be reached.

Conditions are made worse when during the slow recovery of the integrator plate minor defect or noise signals, say of the order of -2 volts occur, such signals should not be detected. Such signals however will retard the recovery of the integrator as seen in FIG. 11. Due to such slow recovery, the trigger generator is kept in its trigger state longer than required and as a result minor defects can cause retriggering.

The slow recovery of the integrator after the termination of a defect is a basic and essential feature of an integrator but by its very nature it is also responsible for the above described sluggishness of the trigger generator. By applying the positive pulses 198 or 200 to the control grid of the integrator such sluggishness is eliminated. In the example given the "PRF," or pulse repetition frequency, f of sampling signal 198 is 100, then each one-inch length of the sheet material is integrated. The "PRF" of the sampling pulses f is adjusted to be proportional to the sheet velocity and to be inversely proportional to the sheet lengths to be integrated; that is

$$f = \frac{W}{L}$$

where W is the sheet velocity and L is the length of the sampled sections in the direction of travel of the sheet material.

Alternatively, when defect signals raise the integrator output to the trigger level, the resulting trigger pulse is delayed and is used after conditioning in sampling pulse generator 199 as the resetting pulse at the control grid of the integrator. Such time relay ("Td" defines the width of the output pulse 184. The delay T_d is so selected that the width of the output pulse 184 is of the shortest duration compatible with the satisfactory operation of the control circuitry of the grading switch 16 shown in FIG. 6, or is compatible with other applications of the output pulse 184.

The integrator resetting pulse or pulses, according to either alternative, are produced in "sampling pulse generator" 199 which is shown in block form only in FIG. 10. This generator can, for example, be a transitron Miller pulse generator associated with a phase inverter both of which are well known in the art. Such generator also produces either the "in-time" equally spaced sampling pulses according to the first alternative or according to the second alternative is triggered by the leading edge of pulse 184, completes its Miller run-down defining delay T_d and at the end of such run-down generates the resetting pulse.

The width of the resetting pulse 200 or sampling pulses 198 can be varied by a multi-position switch in pulse generator 199 by conveniently switching a number of capacitors coupling the suppressor and screen grids of the transitron Miller pentode. The widths of the resetting or sampling pulses are defined by the velocity of the sheet material under inspection and by the charging time of capacitors 189 or 190, the said pulse width must be long enough to allow the return of the plate potential of the integrator to its initial condition close to ground level. The pulse width must also be as narrow as possible for the reason that during the resetting period (corresponding to the pulse width) the integrator is inactive. By arranging that the positive excursions of pulses 198 or 200 are large enough and by feeding such pulses from a high energy source of low output impedance, such as represented by the cathode follower 201, the control grid of integrator 185 is speedily driven well into its grid-current region, the resulting heavy plate current discharging capacitor 189 or 190 rapidly. Thus, the resetting period is only a small fraction of the sampling or integrating period.

In accordance with the present invention, the cathode

of silicon junction diode 192 is connected to the control grid of the integrator while its anode is connected to the cathode of the cathode follower 201. As previously stated, the potential of the control grid of the integrator is at approximately -1 volt. With the aid of the potential divider resistors 202 and 203, the control grid of the cathode follower 201 is biased through resistors 204 to say -20 volts, so that the cathode of unit 201 will be approximately -15 volts. Thus the coupling diode 192 is biased in such a manner that when the negative input potentials v are applied to resistor 186, diode 192 is not conducting and therefore represents a perfect gate having a resistance of 1000 megohms or more. The perfection of diode 192 in this non-conducting phase is essential for the reason that the resistance of resistor 186 is several megohms and the leakage path of the control grid must be of greater magnitude in order to not effect the integrator. By employing the silicon junction diode 192, this condition is well satisfied.

The resetting positive pulses 205 and 206 raise the control grid of unit 201 above ground level and hence also the potential of the cathode of unit 201. Thus, the resetting pulses 198 and 200 pass through the now conducting diode 192 and drive the control grid of the integrator 185 into the grid-current region quickly discharging capacitors 189 or 190. In FIG. 10, only two integrator capacitors 189 and 190 are shown. In order to cover the requirements of integration at sheet velocities of from 20 inches per second to 600 inches per second and integrating 1 to 20 inch lengths of the sheet material, a large number of integrating capacitors are served by switch member 191.

Further, according to my invention, the diode coupling network consisting of diodes 157, 158, 159, 160 and 164 represent near ideal gates for the various functions which the system has to perform. For example, in the presence of the positive output signal 170 diode 158 conducts and diode gates 157 and 160 are closed thus separating the open gate 159 from the signal source which opened diode 158. The negative pulse 169 then passes through the conducting diode 159 to the input of the integrator and the positive output signal 170 driving the output cathode follower 181 does not interact in any way whatsoever with the negative output signal 169 which is fed to the integrator. Should the negative output signal 169 raise the integrator gate above the level of the peak value of the output signal 170, the gate 164 opens and the resulting output pulse 184 is beneficially reinforced. The two channels of the amplifying system support but never interfere with each other. When the phase of the output signals is opposite to those of signals 169 and 170, gates which were open in the previous example close and those which were closed will open while the function of gate 164 remains identical.

When the output signals, due to faint defects, are below the trigger level of the output pulse generator and are detected by the integrator channel and as soon as the rising plate potential of the integrator reaches the biasing level of coupling diodes 157 and 158, the latter diode-gates close and the integrator output does not effect the signal content at the plates 152 and 153.

The outputs of both channels are fed via resistor 183 to the control grid of the cathode follower 181. The purpose of this resistor is to limit the consumption of the cathode follower 181 when the integrator output approaches the positive line potential +HT.

The use of coupling capacitor 163 is not essential. The outputs of gates 159 and 160 can be coupled direct to the integrator by a potential divider which is connected between the junction of diodes 159 and 160 and the negative line -HT. The point of such potential divider, which is at ground level, could then be connected to the junction of resistors 186 and 187. Other direct coupled arrangements are possible by modifying the circuit of the integrator shown in FIG. 10. When such

direct coupling is used, the rectified noise of the sheet material is also integrated. While this method is not as efficient as that of the A.C. coupled version of FIG. 10, good results are obtainable.

Further, according to the invention, the Schmitt trigger generator consisting of triodes 175 and 176, resistors 177, 178, 179, 207 and 209, capacitors 210 and 211, the integrator sampling and resetting generator 199, resetting pulse cathode follower 201 associated with resistors 202, 203, 204 and 212, potential divider 194 controlling the noise sensitivity of the integrator and the potential divider 180 biasing the coupling diodes 157 and 158 of channel one, represent a separate control unit common to all amplifying systems each of which is identical to that shown in FIG. 10. The outputs and inputs of the said control unit are fed to many amplifiers by terminals 213, 214, 215, 216, 217, 218 and 219. The corresponding connections of many amplifying systems can also be connected to the said terminals, and such amplifying systems do not interact with each other. With the present invention, whichever amplifier system first detects the defect, and which in turn raises the output potential of its cathode-follower 181 above the mean level of say 225 volts, will switch off all other output cathode-followers paralleled at terminal 218.

Changes may be made in the above and many apparently widely different embodiments constructed without departing from the spirit or the essential characteristics of the invention.

What I claim is:

1. In apparatus for detecting defects in moving sheet materials having substantially uniform reflection characteristics, which senses, by photoelectric means, variations in the intensity of light reflected from the surface of such a material as it passes over an inspection surface, an improved inspection head comprising an aperture plate mounted parallel to said inspection surface, and closely adjacent thereto, means defining an elongated narrow aperture in said plate extending transversely to the direction of motion of said material over said inspection surface, illumination means positioned to each side of said aperture for illuminating that section of said material passing over said surface below said aperture, the intensity of said illumination from each side of said aperture being substantially the same over said section of material, photoelectric means positioned adjacent said aperture responsive only to diffused light reflected from said section of material passing through said aperture, the dimension of said aperture in the direction of motion of the sheet material being of the same order of magnitude as the diameter of the smallest and most intense defect to be detected, and said aperture having a dimension transversely to the direction of motion of the sheet material substantially greater than the size of the average texture discontinuity of the unblemished sheet material, and of the order of magnitude of the length of the faintest and narrowest defect extending at right angles to said direction of motion which produces a variation upon the intensity of the light reflected from said surface of said material substantially equivalent to that produced by said smallest and most intense defect to be detected.

2. In apparatus for detecting defects in moving sheet materials having substantially uniform reflection characteristics, which senses, by photoelectric means, variations in the intensity of light reflected from the surface of such a material as it passes over an inspection surface, an improved inspection head comprising a light-tight housing mounted above said inspection surface and having a lower surface parallel thereto, an elongated narrow aperture in said lower surface extending transversely to the direction of motion of said material over said inspection surface, the dimension of said aperture in the direction of motion of the sheet material being of the same order of magnitude as the diameter of the smallest and most intense defect to be detected, and said aperture having a dimension trans-

versely to the direction of motion of the sheet material substantially greater than the size of the average texture discontinuity of the unblemished sheet material, and of the order of magnitude of the length of the faintest and narrowest defect extending at right angles to said direction of motion which produces a variation upon the intensity of the light reflected from said surface of said material substantially equivalent to that produced by said smallest and most intense defect to be detected, substantially identical first and second illumination means positioned respectively on each side of said aperture and equidistant therefrom throughout the length thereof, a plurality of photoelectric cells mounted in series inside said housing above said aperture and responsive only to diffused light entering said housing through said aperture, and shielding means integrated with said housing extending downwardly therefrom and terminating closely adjacent to the surface of said material passing over said inspection surface whereby to restrict illumination of said material surface passing beneath said aperture substantially to that provided by said illumination means.

3. In apparatus for detecting defects in moving sheet materials which senses, by photoelectric means, variations in the intensity of light reflected from the surface of such a material as it passes over an inspection surface, an inspection head having a lower surface positioned above said inspection surface and parallel thereto, means defining a narrow elongated aperture in said lower surface extending transversely to the direction of motion of said material over said inspection surface, illumination means for illuminating that section of said material passing over said inspection surface beneath said aperture, a plurality of photoelectric cells mounted above said aperture and responsive only to light reflected from said section of material passing through said aperture, said inspection surface having a convex curvature in the direction of motion of said material, said illumination means being positioned in or below that plane passing through said aperture parallel to the plane tangential to said curved inspection surface immediately adjacent said aperture.

4. In apparatus for detecting defects in moving sheet materials having substantially uniform reflection characteristics which senses, by photoelectric means, variations in the intensity of light reflected from the surface of such material as it passes over an inspection surface, an inspection head having a lower surface parallel and closely adjacent to said inspection surface, means defining an elongated narrow aperture in said lower surface extending transversely to the direction of motion of said material over said inspection surface, electrically energized illumination means illuminating that section of said material passing over said inspection surface beneath said aperture, photoelectric means positioned adjacent said aperture and responsive only to light from said illumination means reflected from said section of material passing through said aperture, an A.C. amplifier responsive only to input signals lying within a given frequency range and having its input connected to said photoelectric means, and a source of electrical energy for said illumination means, the frequency associated with any variation of light output from said illumination means effectively lying outside the said frequency range of said amplifier.

5. Apparatus as defined in claim 4 wherein said source of electrical energy is a regulated D.C. power supply.

6. Apparatus as defined in claim 4 wherein said illumination means comprises tubular fluorescent lamps having their longitudinal axes parallel to said inspection surface and said source of electric energy is a regulated D.C. power supply.

7. In apparatus for detecting defects in moving sheet materials having substantially uniform reflection coefficients, which senses, by photoelectric means, variations in the intensity of light reflected from the surface of such a material as it passes over an inspection surface, a plurality of inspection units extending serially across said

material passing over said inspection surface, each inspection unit comprising a lower surface parallel and closely adjacent to the surface of said material when passing over said inspection surface, means defining a narrow elongated aperture in said lower surface extending transversely to the direction of motion of said material and having a dimension in said direction of the same order of magnitude as the diameter of the smallest fully black defect to be detected, illumination means illuminating that section of material beneath said aperture, a group of photoelectric cells positioned above and adjacent to said aperture and responsive only to light from said illumination means reflected from said section of material passing through said aperture, a constant gain amplifier wherein the gain is controlled only by ratios of resistors for amplifying the electrical output from said group of photoelectric cells, said group being connected to the input of said amplifier, the length of said section viewed by said group at right angles to said direction of motion, being substantially greater than the diameter of the average texture discontinuity of said sheet material, the said sections associated with said inspection units together forming a continuous line extending across substantially the entire width of said material passing over said inspection surface, and every said constant gain amplifier being of equal gain and response.

8. In apparatus for detecting defects in moving sheet materials having substantially uniform reflection characteristics, which senses, by photoelectric means, variations in the intensity of light reflected from the surface of such a material as it passes over an inspection surface, an inspection head having a lower surface parallel and closely adjacent to the surface of said material when passing over said inspection surface, means defining a narrow elongated aperture in said lower surface extending transversely to the direction of motion of said material and having a dimension in said direction of the same order of magnitude as the diameter of the smallest fully black defect to be detected, illumination means illuminating that section of material beneath said aperture, a group of photoelectric cells positioned above and adjacent to said aperture and responsive only to light from said illumination means reflected from said section of material passing through said aperture, an amplifier for amplifying the electrical output from said group of photoelectric cells, said group being connected to the input of said amplifier, utilization means connected to the output of said amplifier and responsive only to electrical signals of greater amplitude than that of the background noise in said group, after amplification by said amplifier, and an integrator, connected between the output of said group of cells, and the input of said utilization means, having a charging time constant corresponding to the time of travel beneath said inspection head of a predetermined distance in said direction of motion, whereby a barely perceptible defect of dimension in said direction of motion equal to said distance and of dimension at right angles to said direction of motion insufficient to produce a change in the magnitude of the electrical output from said group of cells greater than the magnitude of said background noise level, produces an integrated output signal of sufficient amplitude to actuate said utilization means.

9. Apparatus according to claim 8 wherein said integrator is reactively coupled to the output of said group of cells, whereby said background noise is presented to said integrator as a signal of alternating polarity whose integrated output is low and substantially constant.

10. In apparatus for detecting defects in moving sheet materials, which senses, by photoelectric means, variations in the intensity of light reflected from the surface of such a material as it passes over an inspection surface, an improved inspection head having a first surface parallel and closely adjacent to said inspection surface, means defining a first narrow elongated aperture in said first

surface extending transversely to the direction of motion of said sheet material over said inspection surface, illumination means uniformly illuminating that section of material passing beneath said first aperture, photoelectric means positioned above said first aperture and responsive only to light from said illumination means reflected from said section passing through said first aperture, and a second surface parallel to said first surface, positioned intermediate said first surface and said photoelectric means, means defining a second narrow elongated aperture in said second surface parallel to said first aperture and of substantially identical dimensions to said first aperture, the distance between said first and second surfaces being one order of magnitude greater than the dimension of said first aperture in the direction of motion of said material over said inspection surface, and shielding means having an inner surface of low co-efficient of reflection, shielding said second aperture from substantially all light except that passing through said first aperture, whereby to render said photoelectric means responsive only to light reflected from said section of material passing through both of said apertures.

11. Apparatus according to claim 10 wherein said first and second apertures both lie in a plane perpendicular to the plane tangential to that portion of said inspection surface immediately adjacent said first aperture, and said illumination means comprises identical first and second lamp means positioned respectively on each side of said first aperture and illuminating said section of material uniformly and with an equal intensity of light from each side of said aperture.

12. In apparatus for detecting defects in moving sheet materials, which senses, by photoelectric means, variations in the intensity of light reflected from the surface of such a material when passing over an inspection surface, an inspection head having a lower surface parallel and closely adjacent to said inspection surface, means defining a narrow elongated aperture in said lower surface extending at right angles to the direction of motion of said sheet material when passing over said inspection surface, illumination means illuminating that section of said material passing beneath said aperture over an inspection surface, a group of photoelectric cells positioned above said aperture and responsive to light from said illumination means reflected from said section of material through said aperture, said group of cells being connected to a common set of terminals whereby to present across said terminals a change in electrical output proportional to both the intensity and dimension at right angles to said direction of motion of a defect passing beneath said inspection head, and an integrator connected to said common set of terminals for integrating said change in electrical output, said integrator having a time constant not less than the time of travel beneath said head of a distance in said direction of motion corresponding to the dimension in said direction of motion of the defect to be detected, said integrator giving an electrical output signal proportional to the product of the area and the intensity of a defect passing beneath said group of cells.

13. In apparatus for detecting defects in moving sheet materials of substantially uniform reflection characteristics which senses by photoelectric means variations in the intensity of light reflected from the surface of such a material when passing over an inspection surface, an inspection head having a lower surface parallel, and closely adjacent, to the surface of said material when passing over said inspection surface, a plurality of photoelectric cells positioned above said lower surface and adjacent thereto, each such cell viewing an associated section of said material surface through a slit-like aperture formed in said lower surface, said aperture extending at right angles to the direction of motion of said sheet material and having a dimension in the direction of motion of said sheet material of the same order of magnitude as the diameter of the smallest fully black

defect to be detected by said apparatus, lamps illuminating each said associated section, shielding means shielding each said photoelectric cell from substantially all except light from said lamps reflected from its associated section through said aperture, at least one balanced push-pull type amplifier having two balanceable input electrodes each connected to an equal number of photoelectric cells, and two output electrodes, and an utilization circuit connected across said output electrodes, whereby in phase and equal amplitude signals applied simultaneously to each input electrode produce no output signal across said utilization circuit.

14. Apparatus according to claim 13 which includes at least two of said amplifiers, and the photoelectric cells connected to the input electrodes of said amplifiers are so selected that no two photocells responsive to light reflected from contiguous associated sections are connected to either of the input electrodes of the same amplifier.

15. Apparatus according to claim 13 which includes means for balancing the direct current signal fed to each said input electrode by said equal numbers of photoelectric cells when a sheet of defect free material is positioned on said inspection surface beneath said inspection head.

16. Apparatus according to claim 13 wherein said amplifier includes signal inversion means for producing, from a defect signal of either positive or negative polarity, an inverted defect signal of opposite phase to said defect signal, said defect signal being amplified by one side of said push-pull amplifier and presented as a first output signal at one of said output electrodes, said inverted defect signal being equally amplified by the other side of said amplifier and presented as a second output signal of equal amplitude and opposite phase to said first output signal, and said utilization circuit comprises a pulse generator responsive only to signals of a predetermined polarity, having its input connected to both said output electrodes, whereby a defect signal of either polarity produces an output signal of said predetermined polarity at the input to said pulse generator.

17. Apparatus according to claim 16, wherein said signal inversion means comprises a cathode coupled long-tailed pair push-pull amplifying stage.

18. Apparatus according to claim 13 wherein said amplifier comprises a plurality of pairs of amplifying stages connected in push-pull, direct current coupled in series, at least one of said pairs having a direct current feedback link to another one of said pairs earlier in said series, and at least one reactive circuit element decoupling alternating current components of signals in said feedback link, whereby to render said amplifier as an alternating current amplifier having a frequency response lying between upper and lower frequency limits defined respectively by the time of travel beneath said inspection head of the shortest and longest defects in said direction of motion to be detected by said apparatus.

19. Apparatus according to claim 13 wherein said utilization circuit comprises a pulse generator responsive only to signals of predetermined polarity above a predetermined level, and voltage gate circuit elements connecting said pulse generator to said output electrodes passing only signals of said predetermined polarity above said predetermined level.

20. Apparatus according to claim 13 wherein said utilization circuit comprises a pulse generator responsive only to signals of predetermined polarity above a predetermined level, and voltage limiting circuit elements limiting amplified signals appearing at said output electrodes to a value greater than said predetermined level and less than that at which said amplifier is blocked by said amplified signal.

21. Apparatus according to claim 13 wherein said utilization circuit comprises a pulse generator responsive only to signals above a predetermined level connected

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to said output electrodes, an integrator connected between said output electrodes and said pulse generator, said integrator having a time constant corresponding to the time of travel beneath said inspection head of a faint defect of dimension at right angles to said direction of motion and intensity insufficient to produce an amplified defect signal at said output electrodes greater than said predetermined level, such a faint defect producing in said integrator an integrated output signal greater than said predetermined level.

22. Apparatus according to claim 21 which further includes a resetting pulse generator connected to said integrator whereby to periodically reset said integrator.

23. Apparatus according to claim 15 wherein said pulse generator is responsive only to signals of said predetermined polarity above a predetermined level and is connected to said output electrodes by first voltage gate circuit elements isolating said pulse generator from signals appearing at said output electrodes not of said predetermined polarity and above said predetermined level, and said utilization circuit further includes an integrator having its input connected to said output electrodes by second voltage gate circuit elements passing signals only of the opposite polarity to said predetermined polarity, and having its output connected to said pulse generator by a voltage gate circuit element passing only signals of said predetermined polarity above said predetermined level.

24. Apparatus according to claim 23 wherein said integrator is a Miller-type integrator, said opposite polarity is negative, the control electrode of said integrator being connected to said second voltage gate circuit elements via a capacitance and a high resistance in series, and to the output of a resetting pulse generator via an isolation diode, the steady state output level of said resetting pulse generator being more negative than the potential needed at said control electrode to cut off said integrator, said resetting pulse generator periodically emitting positive pulses of sufficient amplitude to pass said isolation diode and reset said integrator.

25. Apparatus according to claim 24 which further includes a source of variable positive potential connected to one electrode of said Miller-type integrator whereby to vary the said cut-off level of said integrator.

26. Apparatus according to claim 13 which includes a plurality of identical balanced push-pull amplifiers, and said utilization circuits comprises a pulse generator having its input connected to a like plurality of cathode follower stages, each cathode follower stage being connected to the output electrodes of a respective one of said plurality of amplifiers.

27. Apparatus according to claim 23, wherein said second voltage gate circuit elements are being connected through a capacitor to the input of said integrator, the input of the integrator also being connected through a resistor to a constant potential level, whereby background noise signals of alternating polarity present at said output electrodes are being halved and rectified and after a time interval, proportional to the time constant of said

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capacitor and resistor, are decreased to substantially zero level at the input of said integrator.

28. Apparatus according to claim 1 wherein said inspection surface is a dark surface having a low reflection coefficient whereby the detection of transparent inclusions in thick paper is improved.

29. Apparatus according to claim 1 wherein said inspection surface has a high coefficient of reflection whereby to minimize the signal variations produced in said photoelectric means by the lack of uniformity of texture in unblemished sheets of said materials due to varying transparency.

30. Apparatus according to claim 1 wherein a plurality of interchangeable inspection surfaces having different colours and coefficients of reflection are provided.

31. Apparatus according to claim 4 wherein said photoelectric means consists of a group of photoelectric cells, the number of cells in said group being not more than that required to maintain the amplitude of the background noise level produced in said group below the change in amplitude of the electrical output of said group when a fully black defect of the smallest size to be detected passes beneath a cell of said group.

32. Apparatus according to claim 4 wherein said photoelectric means consists of a group of photoelectric cells and said aperture is of such a length that the length of said section of material at right angles to said direction of motion is sufficient for a barely perceptible defect extending at right angles to the direction of motion a distance not less than said length of said section, to produce a change in the electrical output of said group of photoelectric cells of comparable magnitude to that produced when a fully black defect of the smallest size to be detected passes beneath a cell of said group.

33. Apparatus according to claim 4 wherein said photoelectric means consists of a group of photoelectric cells, and the length of said section viewed by said group at right angles to said direction of motion is substantially greater than the diameter of the average texture discontinuity of said sheet material.

References Cited in the file of this patent

UNITED STATES PATENTS

1,828,000	Ranger	Oct. 20, 1931
1,945,395	Cockrell	Jan. 30, 1934
2,054,320	Hanson	Sept. 15, 1936
2,078,800	Juchter	Apr. 17, 1937
2,336,376	Tandler et al.	Dec. 7, 1943
2,395,181	Hags	Feb. 19, 1946
2,433,685	Dowell	Dec. 30, 1947
2,438,588	Tolson	Mar. 30, 1948
2,458,926	Bassett	Jan. 11, 1949
2,565,727	Henderson	Aug. 28, 1951
2,617,528	Moore	Nov. 11, 1952
2,758,712	Linderman	Aug. 14, 1956
2,939,016	Cannon	May 31, 1960
2,966,264	Cox	Dec. 27, 1960