United States Patent

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[54] **WEB INSPECTION SYSTEM USING INTERLACED PHOTOCELLS**

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[21] Appl. No.: **50,499**

[52] **U.S. Cl.**.....**250/219 DF**, 250/211 R, 356/237

[51] **Int. Cl.**.....**G01h 21/32**

[58] **Field of Search**.....250/219 DF, 211, 211 J; 356/199, 200, 237, 238

[56] **References Cited**

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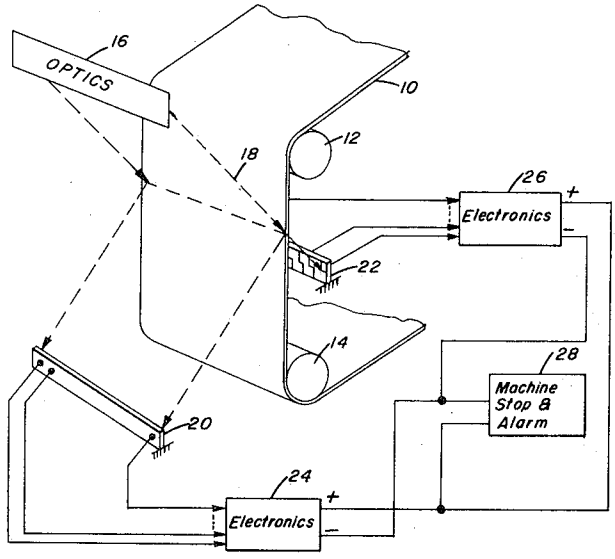
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[57] **ABSTRACT**

A movable web which is both specular an transparent is checked for defects by beaming a sheet of radiation at the web; and such radiation has an angle of incidence, with respect to the web, which is sufficient to permit some radiation to be mirrored off the web, and some to be transmitted through the web. Respective arrays of photocells cooperate with the reflected and transmitted radiation, and the photocells of such arrays, are jigsawed and interlaced together by means of photocell fingers having edges which are orthogonal to the direction of travel for the web. Pairs of photocells cooperate with respective differential devices to cancel the effect of web vibration to give false alarms; and non-adjacent photocells cooperate with the respective differential devices to prevent system blind spots.

7 Claims, 6 Drawing Figures



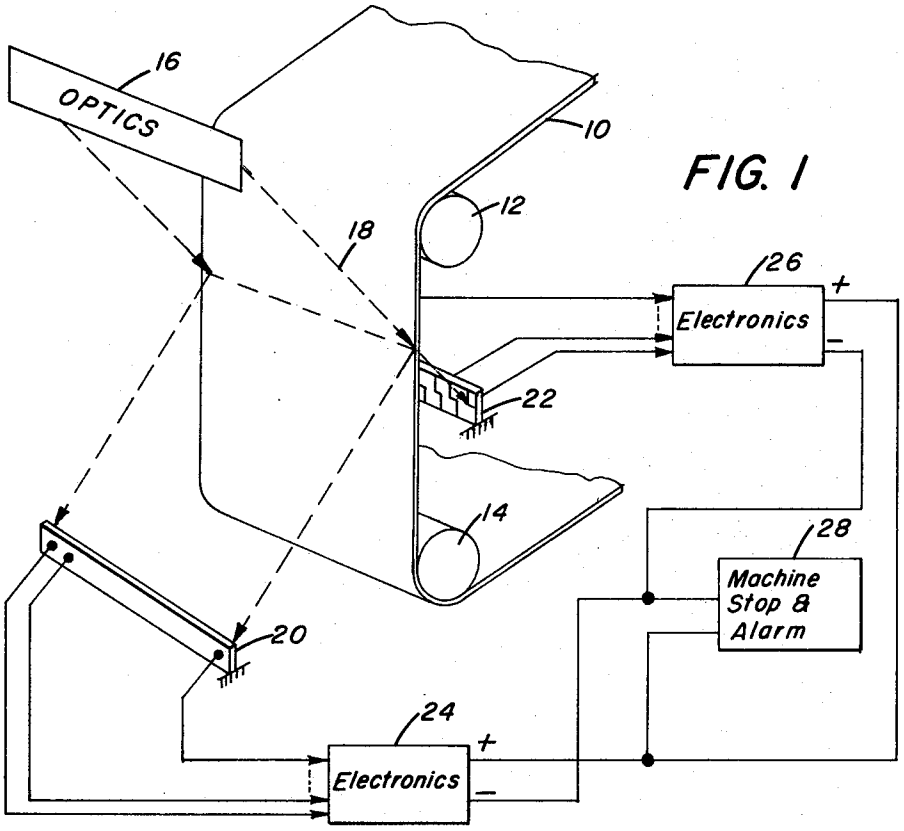


FIG. 1

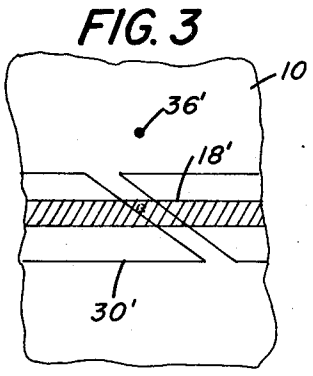


FIG. 3

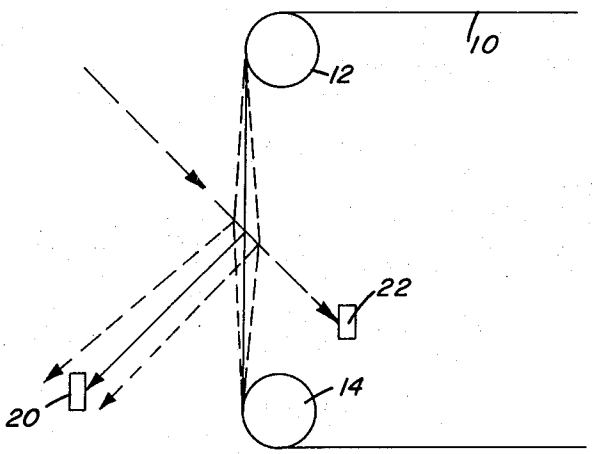


FIG. 4

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FIG. 2

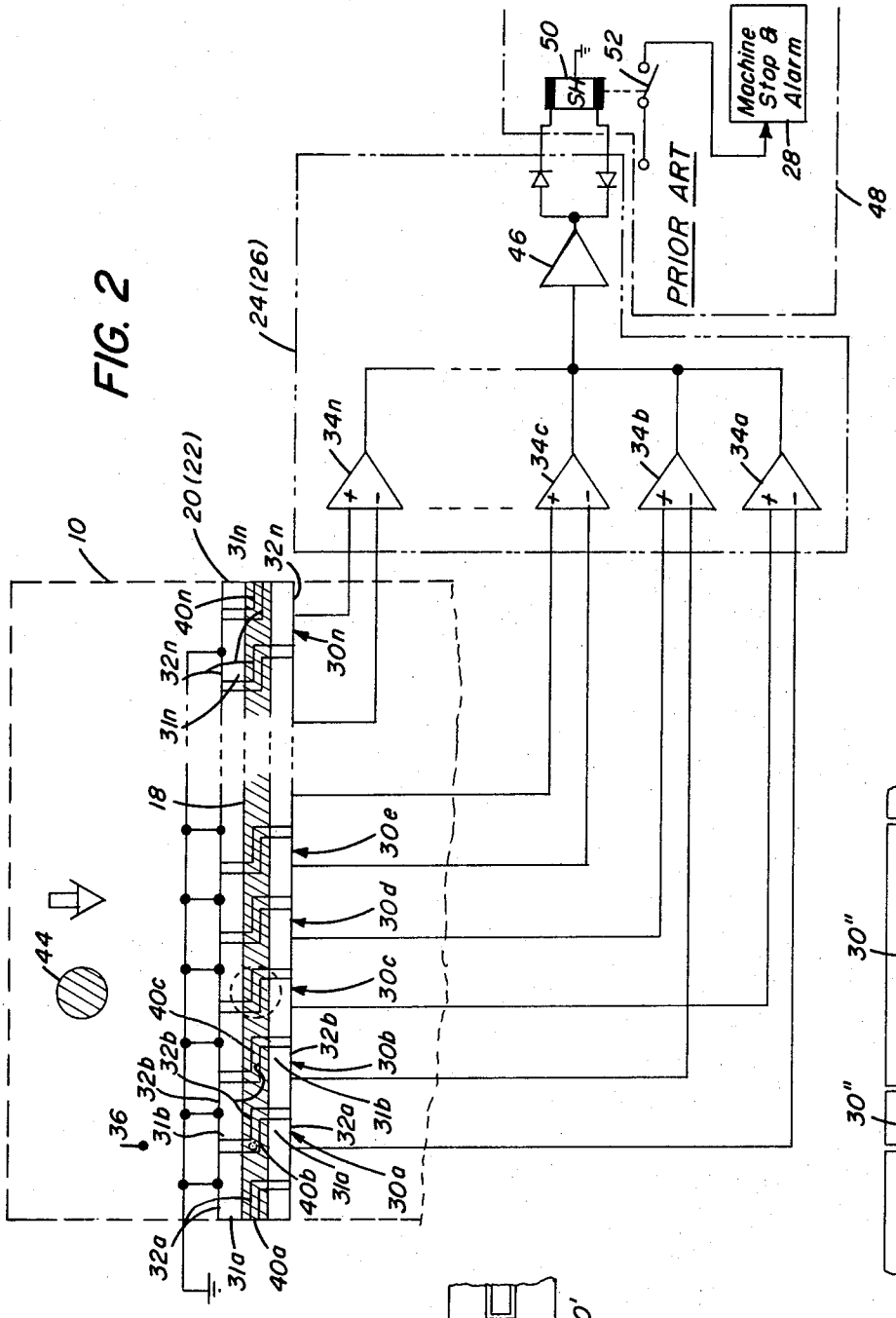


FIG. 5b

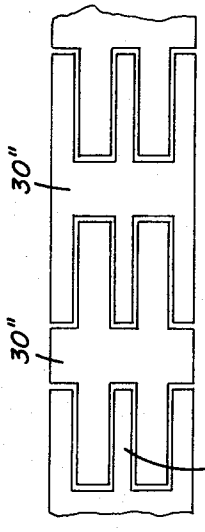
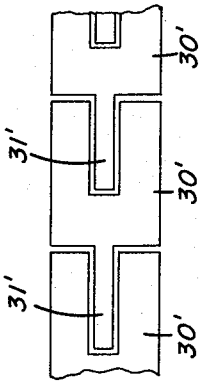


FIG. 5a



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WEB INSPECTION SYSTEM USING INTERLACED PHOTOCELLS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates in general to apparatus for detecting irregularities and defects in webs; and in particular, to apparatus for detecting irregularities and defects in webs which are both specular and transparent to incident illumination, such, for example, as photographic film.

2. Description Relative to the Prior Art

It is known that certain defects which may appear in photographic film are more easily detected by means of infrared radiation that is beamed through the film, than with infrared radiation that is mirrored off such film; whereas for other types of defects, the reverse is true. The prior art is replete with examples of web inspection by both such techniques: See for example U.S. Pat. Nos. 2,429,331; 2,272,097; and 3,206,606.

U.S. Pat. No. 3,206,606, indicated above, is most akin to the present invention: Infrared radiation is disclosed therein as being aimed, in the form of a sheet-like beam, at a travelling photographic web, and thence to an array of photocells. A defect in the web causes modulation of the radiation reaching the array of photocells; and such modulated radiation causes one (or more) of the photocells in such array to produce a signal to trigger an alarm or other using device. An array of photocells — as opposed to a single elongated barlike photocell — is disposed across the width of the web to assure not only good signal-to-noise quality, but good defect resolution as well: That is, a small web defect, while being barely able to cause the output of a large photocell to vary, would easily cause the output of a small photocell to vary appreciably.

The use of plural defect detectors creates, however, a problem which is related to the very problem which it attempts to solve, viz. it permits small defects "to ride down the channel" between pairs of adjacent photocells, and thus such defects can go undetected. Two teachings are apparent in the art to solve this problem, and these may be found in U.S. Pat. Nos. 2,272,097 and 3,206,606. U.S. Pat. No. 3,206,606 teaches that by oscillating a photocell array back and forth across the width of a web, small defects will be prevented from "riding down the channel" between pairs of adjacent photocells; and U.S. Pat. No. 2,272,097 teaches that the skewing of photocells or the like will obviate such problem: Whereas oscillating an array of photocells may be unduly complex mechanically, the skewing of photocells causes their respective frequency responses to deteriorate. This is because web defects, regardless of their respective sizes, "gradually enter and exit the fields of view" of skewed photocells.

The use of a plurality of small photocells "to look at a web" presents still another problem, if the web is to be inspected by the use of radiation that is to be both transmitted through and off the same part of a web. Such an inspection technique necessitates suspending the web, say, between a pair of rollers; and attendantly, any vibration of the web, and indeed of the whole inspection system, may cause the reflected beam to sweep back and forth across the photocell array, resulting in false alarming as to the existence of a web defect.

SUMMARY OF THE INVENTION

The invention proposes, in a web inspection system using radiation that is both transmitted through and mirrored from a web, banks of small photocells arranged in rows across the direction of web travel, such banks being hereinafter sometimes referred to as a linear array. The photocells of each such bank are jigsawed into an interlacing pattern of photocells; and attendantly, any defect which may occur in the web under inspection will be seen by at least one of a pair of photocells. Preferably, such interlacing is by means of photocell fingers which have edges that are orthogonal to the direction of web travel, whereby web defects will cause sharply defined — and easily detected — signals as such defects enter and exit the fields of view of the photocells.

To nullify the effect of web vibratory motion, and the like, as a source of alarm signaling, the invention proposes the grouping of photocells into pairs thereof; with each photocell pair being cooperative with a respective differential device, e.g., a differential amplifier, that algebraically subtracts its two input signals. Thus, when the sheet of radiation, mirrored to the linear array of photocells which is adapted to receive such radiation, varies in intensity because of web vibration, etc., the output of each differential amplifier remains unchanged. Signal differencing to cancel the effects of web vibration can, however, create still another problem if the paired signals are produced by adjacent photocells: That is, a large defect which projects onto both of a pair of photocells could go undetected if both such photocells produce substantially identical signals. To avoid such a possibility, the invention proposes that pairs of non-adjacent photocells in the detecting array cooperate with the respective differential devices. Thus, for example, the first and third photocells in the array will cooperate with one differential device; the second and fourth photocells, with another differential device; etc.

OBJECTS OF THE INVENTION

1. To maximize the detectability of web defects by the use of both reflected and transmitted radiation in cooperation with arrays of small photocells, problems inherent in such usage being obviated by a signal bucking technique that pits the outputs of pairs of non-adjacent photocells against each other.

2. To provide better signal definition and defect detectability, by the special interlacing of photocells into an array thereof.

The invention will be described with reference to the figures, wherein:

FIG. 1 is a schematic diagram, partially in perspective, illustrating apparatus according to the invention,

FIG. 2 is a schematic diagram illustrating details of the invention,

FIG. 3 is a diagram useful in describing a feature of the invention,

FIG. 4 is a view which is useful in illustrating the source of a problem solved by means of the invention, and

FIGS. 5*a* and 5*b* illustrate photocell variations according to the invention.

Referring now to FIG. 1, a photographic film web **10** which is to be checked for defects is adapted to pass over a pair of spaced apart rollers **12,14**. A source of infrared radiation (not shown) cooperates with optics **16**; and such optics define and beam a sheet of radiation **18** at the web **10**. The angle of incidence of such radiation is sufficient to allow a part of the incident radiation to be transmitted through the film web **10**, and the remainder of such radiation to be reflected off the surface of the web. A first array **20** of photocells is located to receive the reflected radiation; and a second array **22** of photocell detectors is located to receive the radiation which is transmitted through the web **10**. The specific nature of the photocells will be discussed later.

A pair of electronic circuits **24,26** cooperate, respectively, with the photocell arrays **20,22** so that, when any one of the photocells in either of the arrays produces an output signal, the circuits **24,26** cooperate to trigger the operation of an alarm and machine stop device **28**, thereby to indicate the assurance of a web defect. To be noted is that the outputs of the circuits **24,26** can be either positive or negative, indicating that some defects cause positive-going photocell signals, whereas other defects cause negative-going photocell signals.

Reference should now be had to FIG. **2** which shows a presently preferred design for photocell arrays according to the invention; and a presently preferred way to effect cooperation of the photocell arrays **20,22** with their respective electronic circuits **24,26**: The photocell array **20** (**22**) comprises a number of jigsawed photocells **30***a* through **30***n* which are effectively interlaced together; and such interlacing is by means of fingers **31***a* through **31***n* having edges **32***a* through **32***n* which are orthogonal to the direction (arrow) of travel of the web **10**. The array **20** (**22**) of photocells is so positioned that the sheet-like infrared beam **18** illuminates the "orthogonal" spacings **40***a* through **40***n* between adjacent photocells; and each photocell **30** is adapted to provide one of two input signals to differential amplifiers **34***a* through **34***n*. As shown, the output signals from adjacent photocells **30** are "not" applied to the same differential amplifier **34**; and it is this combination of jigsawed photocells, differential devices, and the select cooperation of photocells and differential devices to which the invention is largely directed:

A defect **36** in the web **10** being inspected, though sufficiently small, as indicated in phantom, "to ride within the insulation channel between the photocells **30***a* and **30***b*" must — because the photocells are interlaced together — ultimately modulate the light falling upon the photocell **30***a*. And since the edges **32***a* of the leg **31***a* are not skewed with respect to the travel of the web **10**, and its defect **36**, the photocell **30***a* does not produce a relatively hard-to-detect, gradually changing signal for application to the differential amplifier **34***a*; and instead the photocell **30***a* produces a sharply defined, easy-to-detect signal as the defect **36** abruptly enters the illuminated area of the photocell **30***a*. FIG. **3**, which may be likened to the teaching of U.S. Pat. No. 2,272,097, is presented to show how a defect **36'** gradually enters (in phantom) the illuminated area **18'** of a "skewed" photocell **30'**.

As best illustrated in FIG. **4**, vibration of the web **10** being inspected, as can relatively easily occur because of the suspension of the web between the rollers **12,14**, can cause the beam to sweep back and forth across the array **20** of photocells (and to a lesser extent with respect to the array **22** of photocells). Attendantly, though no defect may appear in the web **10**, such sweeping of the beam causes all of the photocells in the array **20** to produce respective output signals. However, since the photocell signals are paired, and pitted against each other in the differential amplifiers **34***a* through **34***n*, none of such amplifiers produces an output signal; which means, as will be appreciated below, that false alarming and machine stopping will not result from vibration of the film **10** being inspected.

The select cooperation between differential amplifiers, i.e., the matter of non-adjacency, referenced above, is for the purpose of preventing the practice of pairing signals in a differential device from creating a new source of problem for the web inspection system. FIG. **2** indicates a large defect **44** in the film web **10**: Were the adjacent photocells **30***c* and **30***d* to be cooperative with the same differential amplifier **34**, such amplifier would be substantially ineffective to produce an output signal in response to the defect **44**, because such defect (in phantom) would substantially influence the photocells **30***c* and **30***d* to the same extent. The invention teaches that such problem can be obviated by having non-adjacent photocells **30** cooperate with the respective differential amplifiers **34**; and thus, with the hookup indicated in FIG. **2**, not one, but two, differential amplifiers (**34***a*,**34***b*) are productive of output signals in response to the large defect **44** — and such a technique has the added benefit of providing system gain that varies directly with the size of the defect that is being detected.

A signal output from any of the differential amplifiers **34**, evidencing the occurrence of a defect somewhere across the width of the web **10**, is amplified (**46**) and applied to trigger the operation of a using circuit **48**. The circuit **48** forms no part of the invention and may take any of a variety of forms. For example, the defect signal may be applied to a self-holding relay **50** which is adapted to operate a switch **52** so that a machine stop and alarm signal may be applied to the circuit element **28**.

The invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention. For example, it would be within the purview of the invention to employ respective signal amplifiers for receiving the output signals of the differential amplifiers; and to employ respective filter circuits for distinguishing and weighting the effects of small and large defects on the alarming and machine stopping operations. Also, as indicated in FIGS. **5***a* and **5***b*, the jigsawing of the photocells may take a variety of other forms.

What is claimed is:

1. Apparatus for use in detecting defects in a web which is either, or both, specular or light transmissive which is adapted to be supported between spaced apart points, and over which points, said web is adapted to move, comprising:

a. means for beaming a sheet of radiation so that said radiation falls substantially widthwise across said web,

b. a plurality of photocells, arranged substantially in-pairs, positioned to receive said radiation which is transmitted from said web,

c. a plurality of differential devices, each of which is in circuit with a respective pair of photocells to receive signals from said photocells, and to produce therefrom a signal proportional to the algebraic difference between its two applied signals,

d. actuable means responsive to the output signals from any of said plurality of differential devices,

e. said photocells being arranged in an array thereof which is positioned widthwise with respect to said web, and wherein adjacent ones of said photocells in said array are electrically insulated from each other and in circuit with different ones of said differential devices.

2. The apparatus of claim 1 wherein at least some of the photocells in said array are interlaced together by means of photocell fingers having edges which are disposed substantially orthogonally to the direction of travel of the web, said array being positioned so that radiation reaching said array illuminates the said edges of said photocell fingers.

3. The apparatus of claim 1,

a. wherein said web is a photographic film product,

b. wherein said radiation is beamed at said web at an angle with respect thereto which is such that said radiation may be both transmitted through and reflected from said web,

c. wherein the said plurality of photocells receive the said reflected radiation, and

d. wherein said apparatus further includes means for detecting modulation of the radiation which is transmitted through said web.

4. The apparatus of claim 3 wherein at least some of the photocells in said array are interlaced together by means of photocell fingers having edges which are disposed substantially orthogonally to the direction of travel of the web, said array being positioned so that radiation reaching said array illuminates the said edges of said photocell fingers.

5. Apparatus for use in detecting defects in a web which is movable past an inspection location comprising:

a. an array of photocells disposed across the width of said web at the said inspection location, said photocells being electrically insulated from each other, and being provided with respective fingers for interlacing said photocells into a linear array thereof, said fingers having at least one edge thereof which runs substantially orthogonally with respect to the direction of web motion,

b. means for so beaming a sheet of radiation at said web that said radiation falls widthwise across said web and thence gets transmitted to said photocell array to illuminate the said orthogonal edges of the said photocell fingers, and

c. means for receiving signals from said photocells for indicating the occurrence of web defects.

6. The apparatus of claim 5 including a plurality of differential devices, each of which is adapted to be in circuit with, and receive signals from, a respective pair of photocells.

7. The apparatus of claim 6 wherein adjacent photocells are adapted to be in circuit with different ones of said differential devices.

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