United States Patent [19]

Nevins

[11] **3,741,663**

[45] **June 26, 1973**

[54] **HOLE DETECTOR (FOR MOVING WEB)**

[75] Inventor: **Michael J. Nevins,** Delton, Mich.

[73] Assignee: **Nevins Machinery Corporation,** Delton, Mich.

[22] Filed: **Mar. 27, 1972**

[21] Appl. No.: **238,291**

[52] **U.S. Cl.** ..... **356/200,** 250/219 DF

[51] **Int. Cl.** **G01n 21/16,** G01n 21/32

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

[56] **References Cited**

UNITED STATES PATENTS

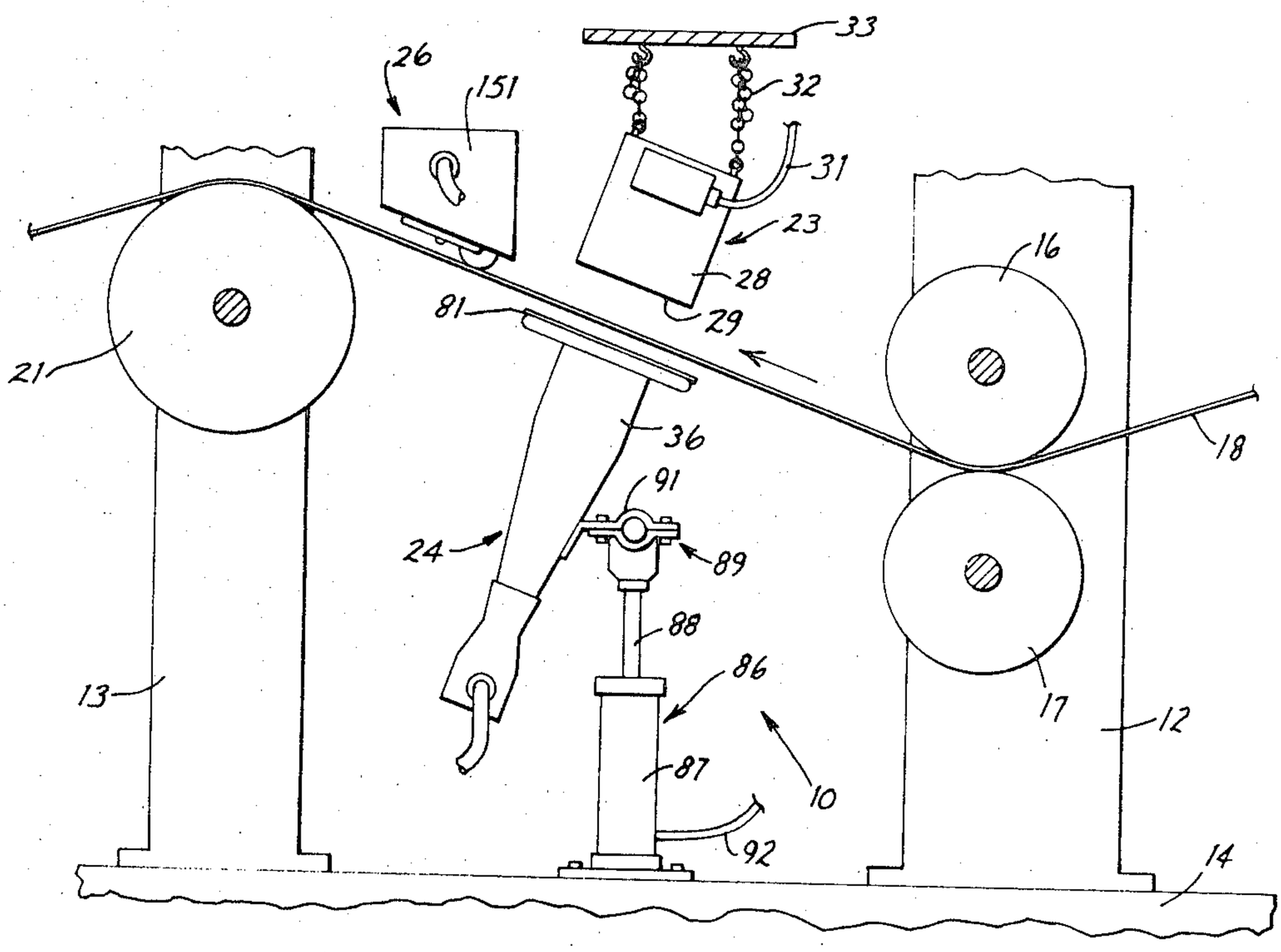
2,892,951	6/1959	Linderman	250/219 DF
2,939,016	5/1960	Cannon	250/219 DF
3,422,272	1/1969	Brosious et al.	250/219 DF

Primary Examiner—James W. Lawrence
Assistant Examiner—T. N. Grigsby
Attorney—Woodhams, Blanchard and Flynn

[57] **ABSTRACT**

A hole detector for a moving web of translucent or opaque material capable of indicating the presence of relatively small holes at high web speeds. An elongate light source and light sensing trough are spaced on opposite sides of the moving web and extend transversely across the portion of the web to be monitored. Light sensors are spaced along the bottom wall of the trough remote from the web for receiving direct light inputs through web holes passing over the open top of the trough. The light sensors are nonresponsive to spurious light inputs and each sensor responds negligibly, at most, to passage of a web hole over neighboring sensors, while permitting a space to be maintained between the web and the trough to prevent abrasion damage to the web being monitored despite normal flexing of the web. The trough depth substantially exceeds its width. The sidewalls of the trough diverge at a very shallow included angle from a bottom wall and terminate in shorter, parallel upper sidewalls. The sensors are separately compartmented within the trough, the walls of each compartment being substantially fully light absorptive. The trough has externally extending flanges at the top thereof for preventing light reflected from the undersurface of the web from reaching the sensors. The device is adapted to handle webs of decreased widths and includes devices for indicating the presence and locations of holes in the web.

13 Claims, 12 Drawing Figures



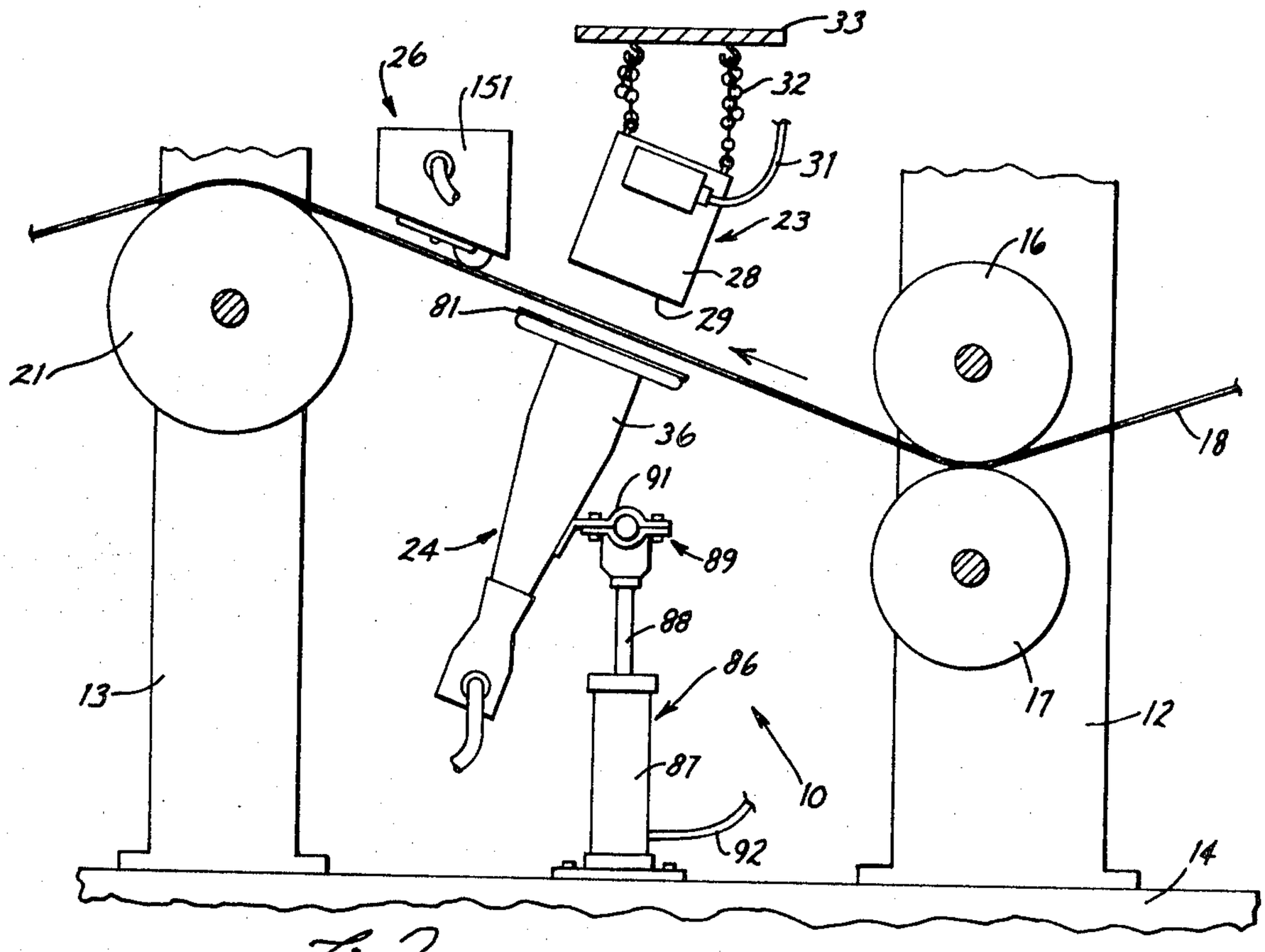

33
26
151
32
31
23
28
29
81
16
21
36
18
91
24
89
88
86
13
17
12
87
10
92
14

Fig. 2

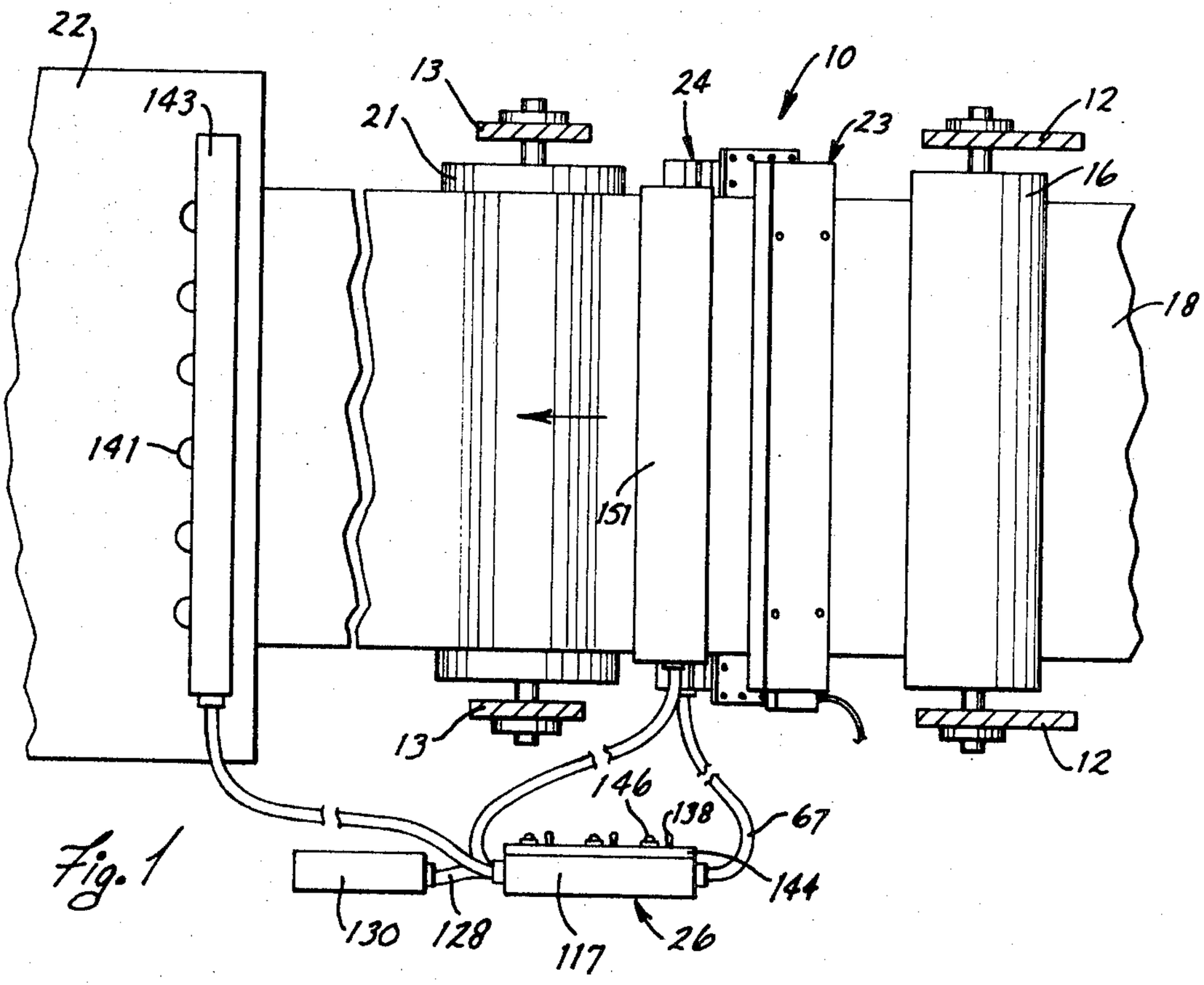

22
143
13
10
24
21
23
12
16
18
141
151
13
12
146
138
67
144
130
128
117
26

Fig. 1

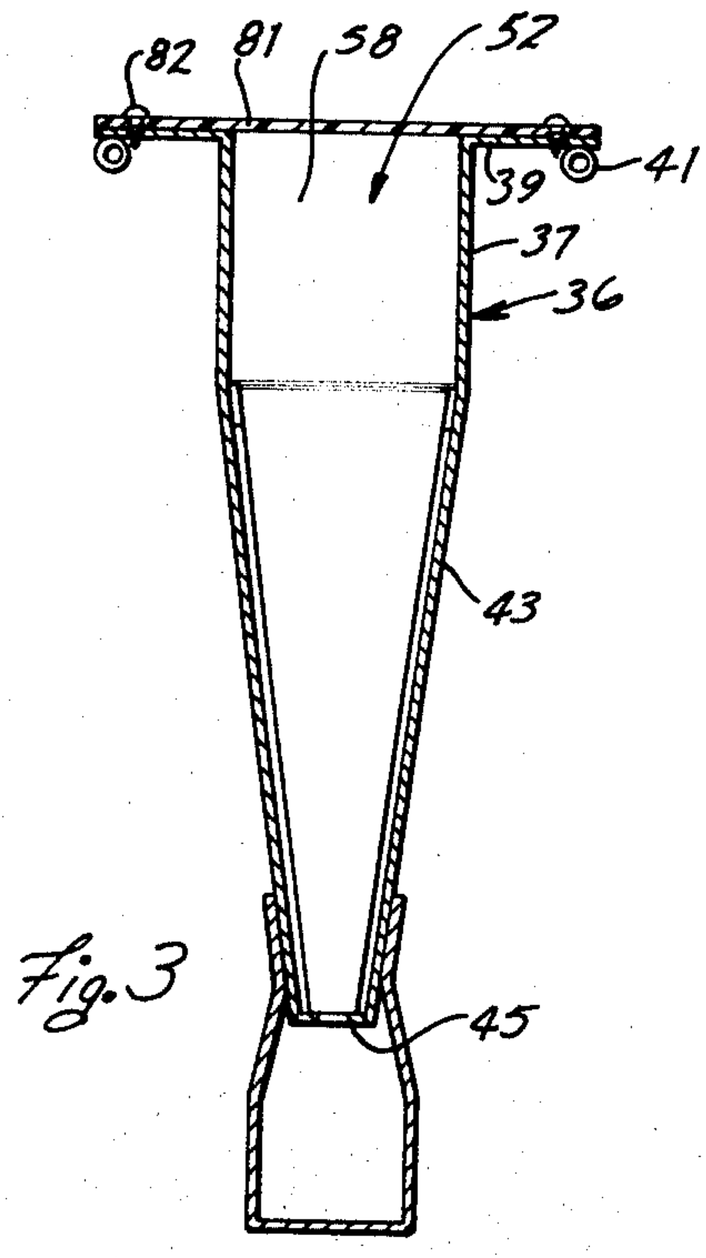


Fig. 3

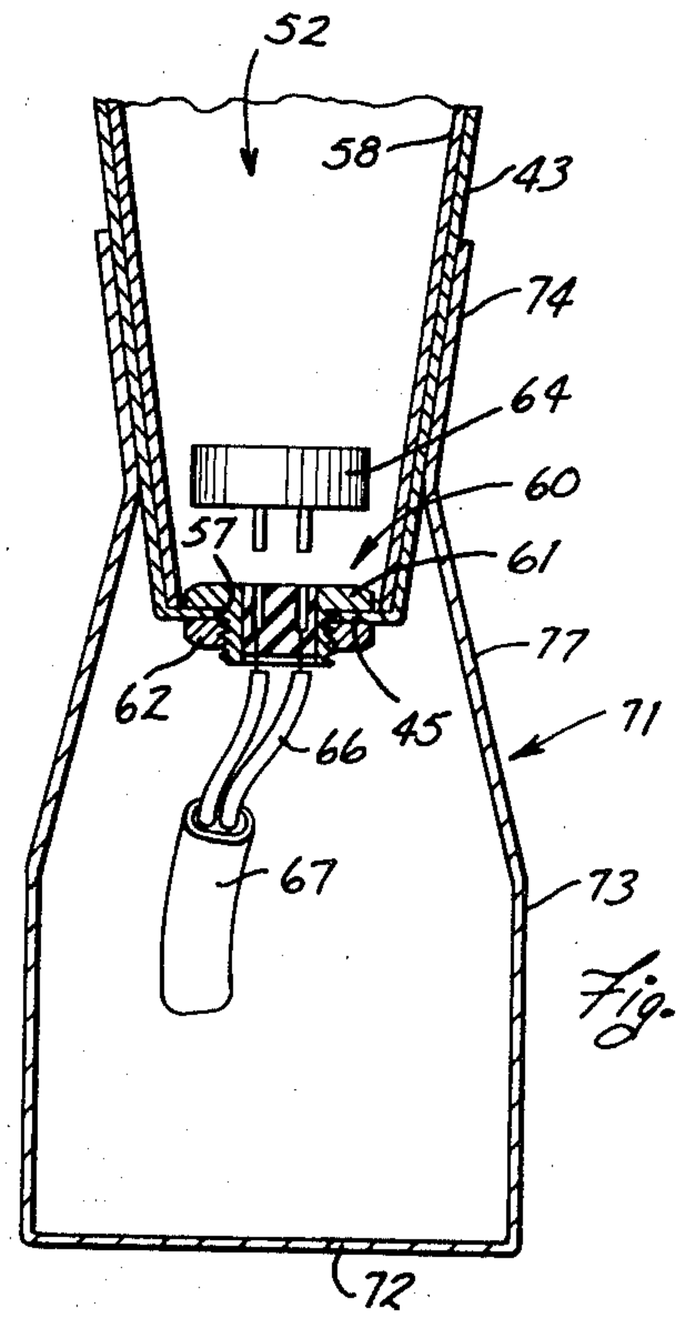


Fig. 6

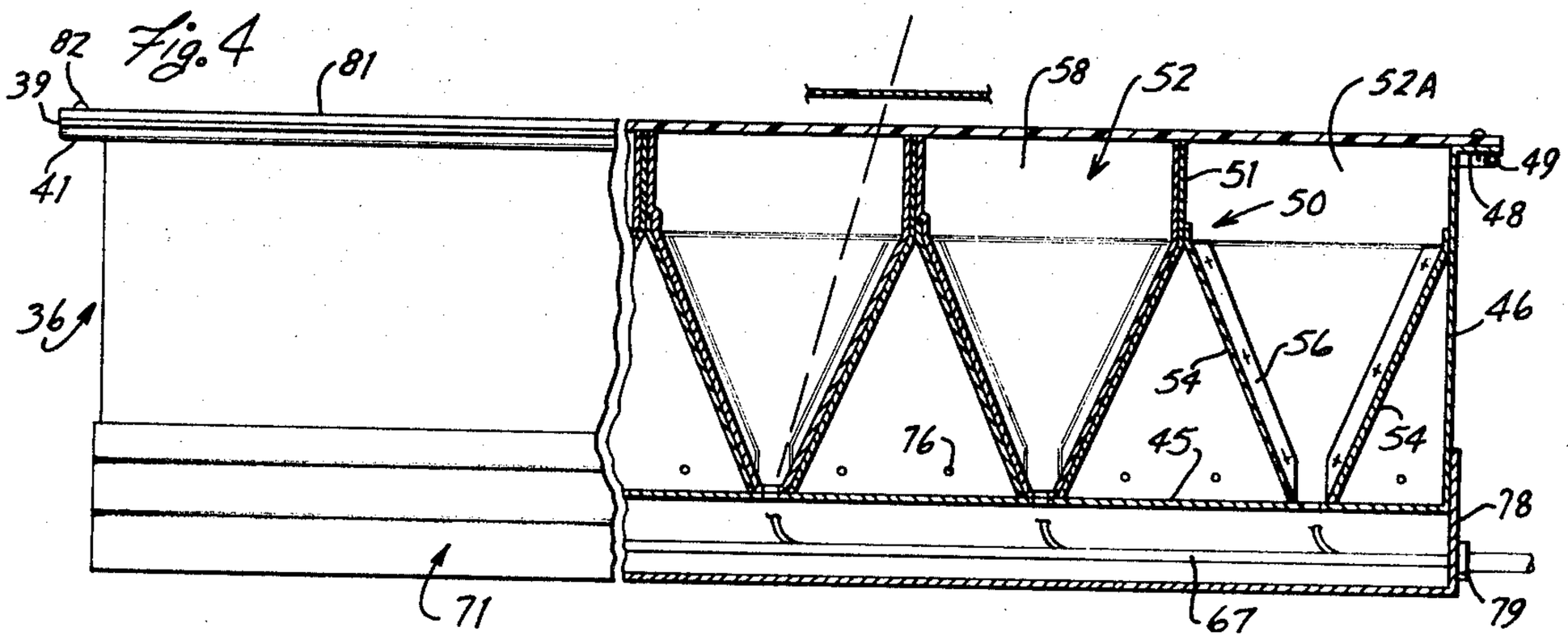


Fig. 4

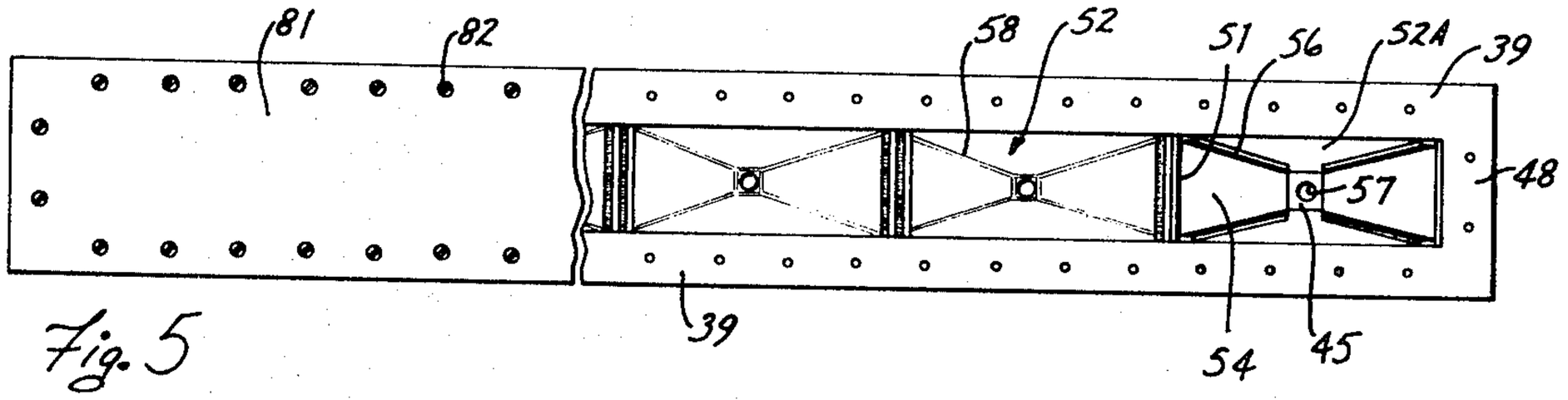


Fig. 5

Fig. 7

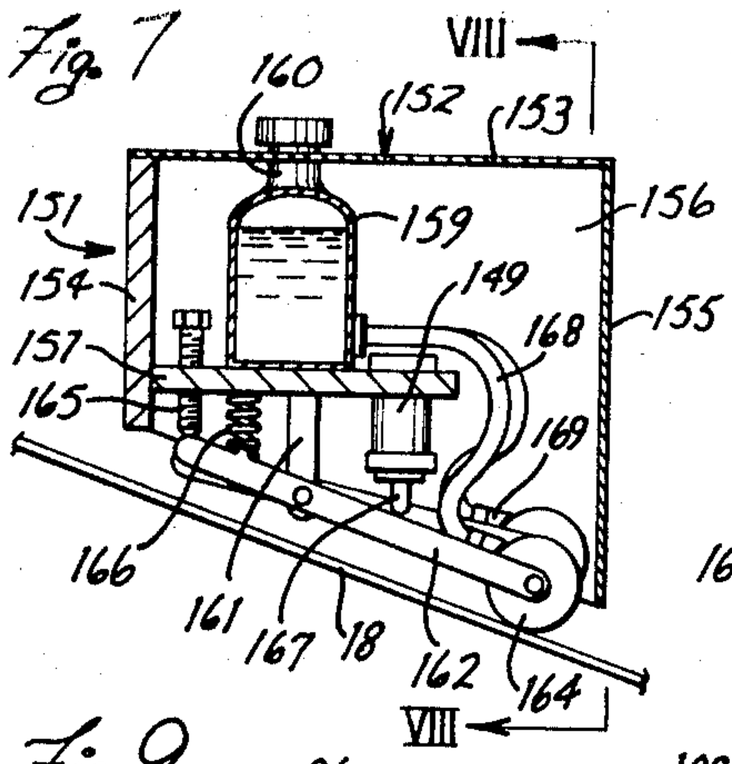


Fig. 8

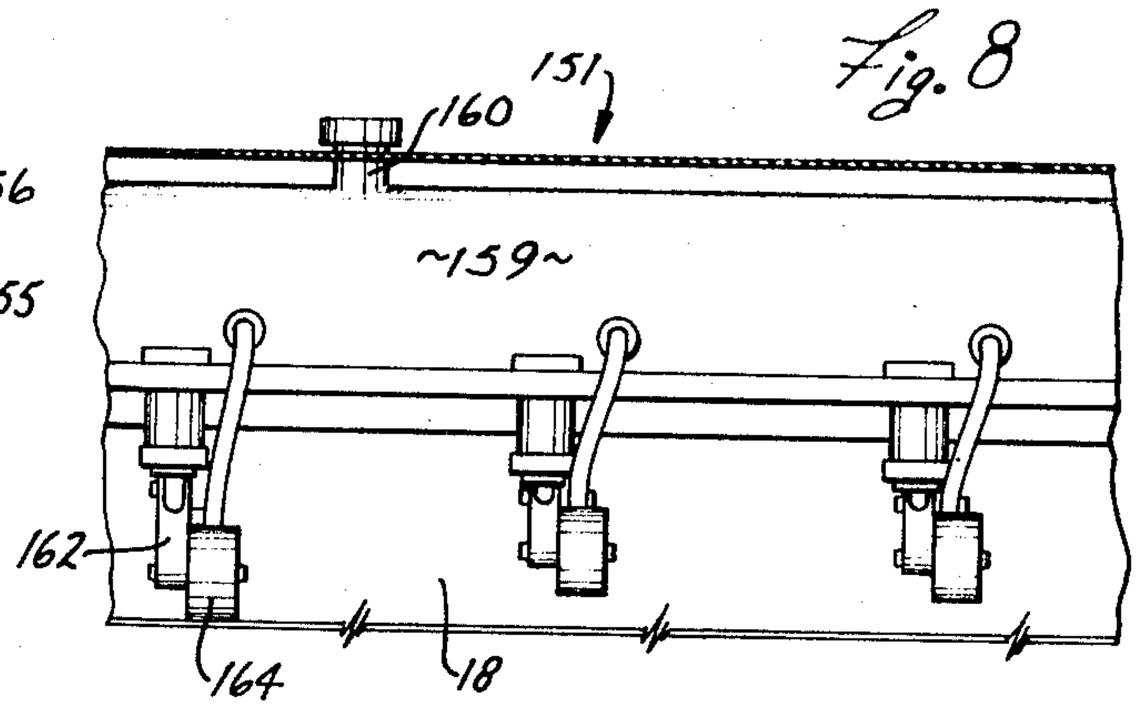


Fig. 9

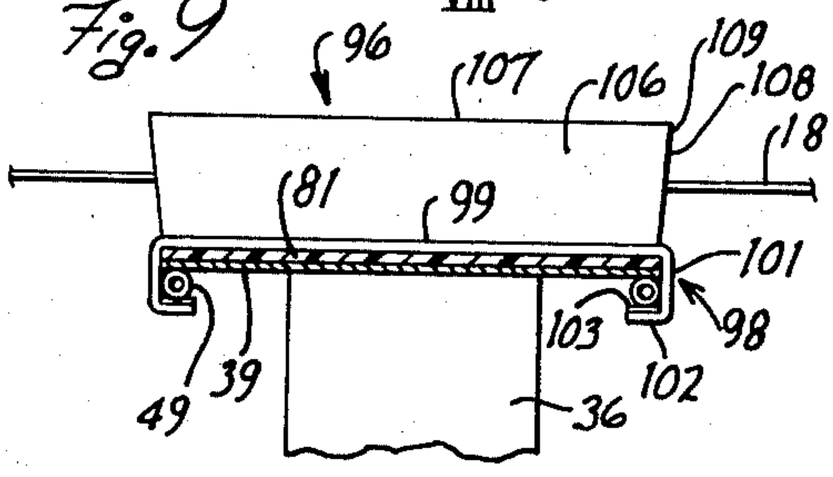
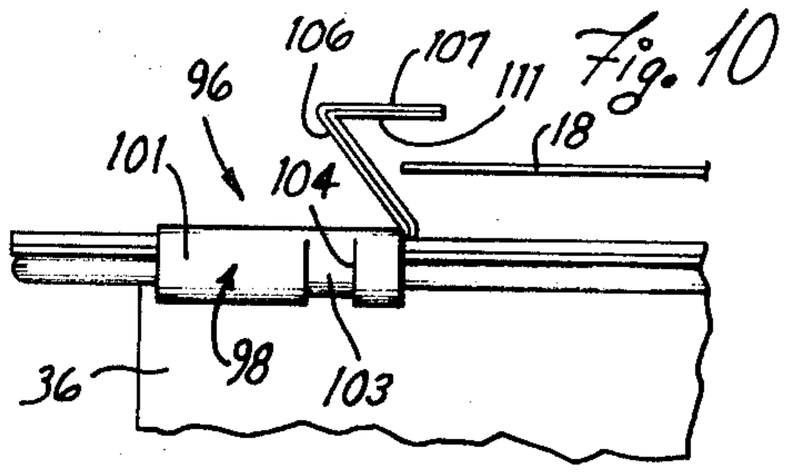


Fig. 10



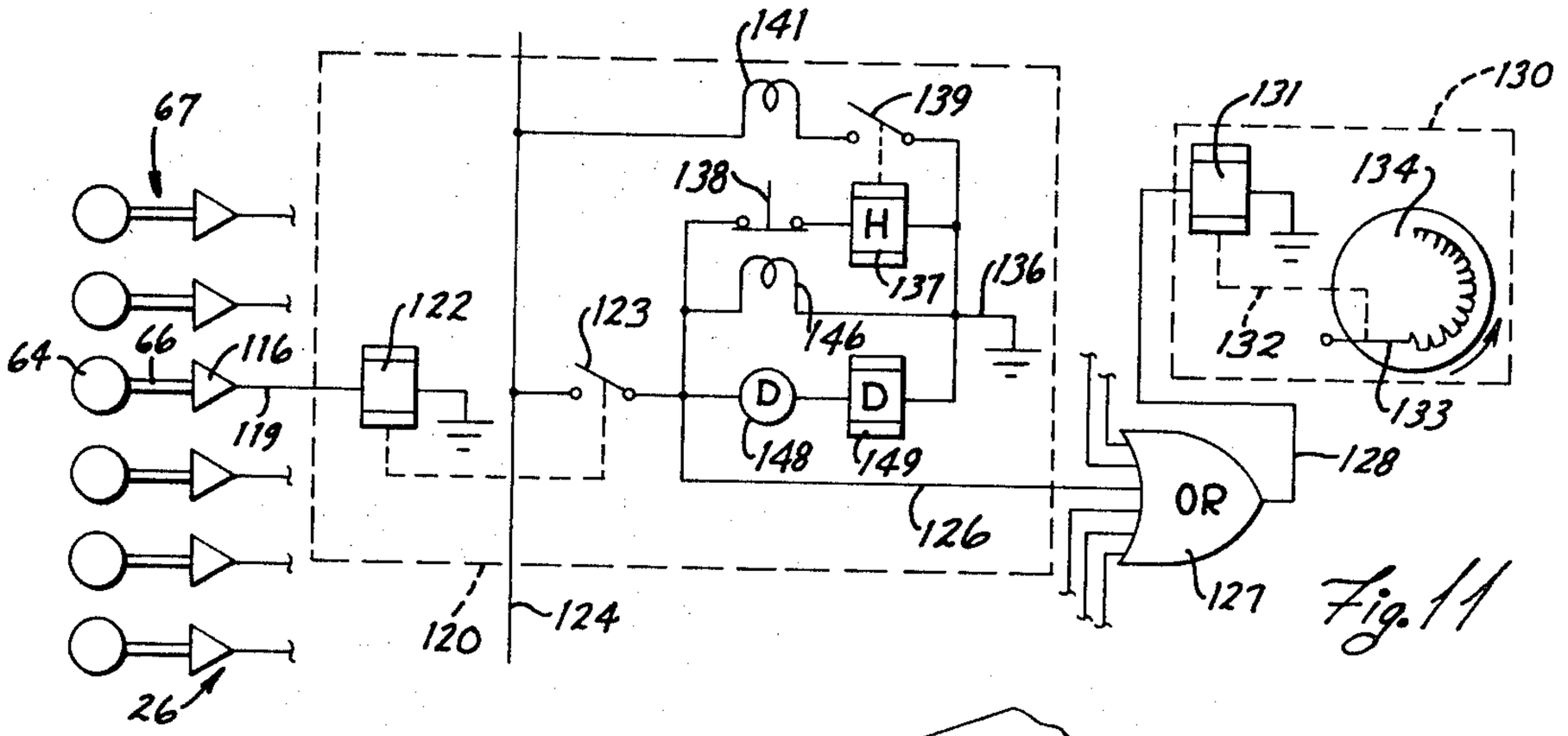


Fig. 11

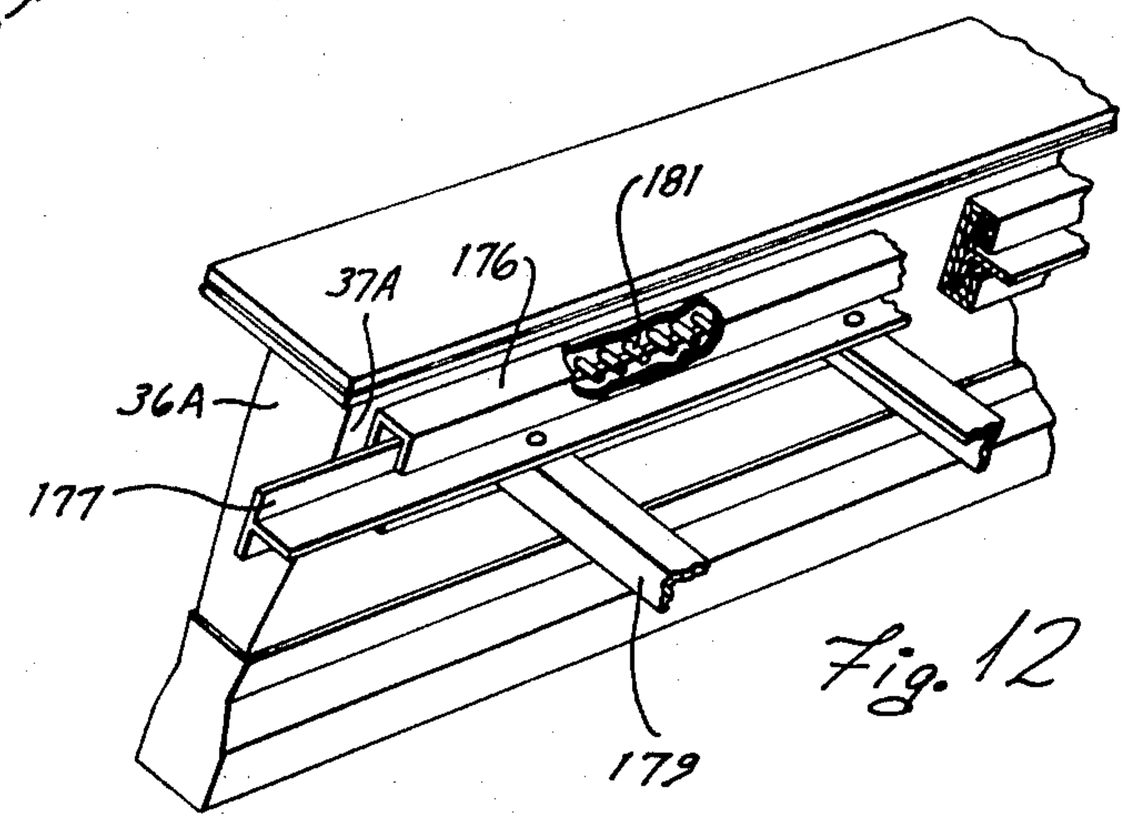


Fig. 12

HOLE DETECTOR (FOR MOVING WEB)

FIELD OF THE INVENTION

This invention relates to a hole detector for a moving web and more particularly relates to such apparatus particularly resistant to false alarms due to stray light inputs.

BACKGROUND OF THE INVENTION

The present invention was developed in connection with hole detection in webs in the paper making industry, more particularly for detecting holes in paper of various types including so-called board and particularly for use within the paper or board machine producing the web. A number of special problems arise in connection with hole detection in paper webs. Among these are the fact that such webs are normally light or white in color and have a substantial capacity for reflecting light. Further, paper particularly of thinner grades, may have a relatively high translucency, or light-transmitting capability, in unholed portions thereof. Further, paper and board machines are typically operated in areas having relating high ambient lighting to facilitate visual inspection of the paper as it moves through the paper machine and, to enable the usual manual threading of the machine and to enable machine adjustments and maintenance. Certain paper and board, e.g. coated stock, are relatively fragile or have readily marred surfaces which may be damaged by contact with foreign objects, particularly if the stock is in the form of a web moving at high speed. Surface damage may render the paper unsaleable. Although it is with these and other special problems of paper production in mind that the present invention has been developed, adaptation of the present invention to hole detection in webs of other types is contemplated.

Optical hole detectors have been known for a number of years, particularly those wherein a web to be monitored for holes is moved between a light source and a light sensor. However, many of these prior art devices are not fully satisfactory for use in hole detection in connection with paper or paper board webs, failing to satisfactorily meet problems such as those above stated. In addition, many of the prior art hole detection devices are of substantial structural complexity and have been found to be excessively costly, particularly in smaller or marginal mills wherein the purchase and installation cost may be prohibitive. As a result, many mills exist wherein hole detection is either omitted or carried out manually, by visual inspection, the latter being both unreliable and costly over a long period of time.

Accordingly, the objects of this invention include provision of:

1. A hole detector for a moving web which responds with substantial sensitivity to direct light inputs through holes in a web moving therepast but which is substantially unaffected by direct or reflected light inputs from other sources.

2. An apparatus, as aforesaid, having a low optical noise level, i.e., being capable of detecting relatively small holes in relatively rapidly moving webs.

3. An apparatus, as aforesaid, particularly adapted to detection of holes in a paper, or paper board, web moving through a paper machine during the process of manufacture of such web.

4. An apparatus, as aforesaid, which is compact and capable of being interfitted between close spaced portions of a paper machine.

5. An apparatus, as aforesaid, which may be readily adjusted in position to meet requirements of a variety of web positions and angles and/or to facilitate maintenance thereof and of the paper machine as well as threading of the ladder.

6. An apparatus, as aforesaid, capable of indicating with high reliability the part of the web in which a hole has occurred and wherein passage of a hole in the web therepast will actuate one sensor of the apparatus while having, at most, a negligible effect on others.

7. An apparatus, as aforesaid, readily adaptable to decreasing web widths without degradation of performance.

8. An apparatus, as aforesaid, capable of indicating a hole condition in any of several ways to enable paper machine operators to note and/or eliminate damaged portions of the paper web.

9. An apparatus, as aforesaid, constructable and saleable at a low cost and which is of substantial structural simplicity and capable of operation over long periods of time without degradation of operation.

Other objects and purposes of this invention will be apparent to persons acquainted with apparatus of this general type upon reading the following specification and inspecting the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partially broken fragmentary view of a paper machine with the apparatus embodying the invention installed in operating position with respect to a moving web.

FIG. 2 is a fragmentary side elevational view of the apparatus of FIG. 1.

FIG. 3 is an enlarged, central cross sectional view of the trough of FIG. 2.

FIG. 4 is a partially broken, fragmentary side elevational view, in reduced scale, of the trough of FIG. 3.

FIG. 5 is a fragmentary partially broken top view of the trough of FIG. 4.

FIG. 6 is an enlarged portion of the trough of FIG. 3 showing a light sensor in exploded relation to it.

FIG. 7 is an enlarged, central cross sectional view of a marking device shown in FIG. 2.

FIG. 8 is a fragmentary sectional view substantially as taken on the line VIII—VIII of FIG. 7.

FIG. 9 is a partially broken, fragmentary end view of the trough of FIG. 3 with an edge light shield installed thereon.

FIG. 10 is a fragmentary, side elevational view of the apparatus of FIG. 9.

FIG. 11 is a schematic diagram of a portion of the electrical circuitry associated with the apparatus of FIG. 1.

FIG. 12 is a fragmentary, partially broken pictorial view of the trough of FIG. 2 disclosing a modified mounting therefor.

SUMMARY OF THE INVENTION

The objects and purposes of the invention are met by providing a hole detector for a moving web of translucent or opaque material capable of indicating the presence of relatively small holes at high web speeds. An elongate light source and light sensing trough are spaced on opposite sides of a moving web and extend

transversely across the portion of the web to be monitored. Light sensors are spaced along the bottom wall of the trough remote from the web for receiving direct light inputs through web holes passing over the open top of the trough. The light sensors are made nonresponsive to other potential light inputs and each sensor responds negligibly, at most, to passage of a web hole over neighboring sensors while permitting a space to be maintained between the web and the trough to prevent abrasion damage to the web being monitored despite normal flexing of the web. The trough depth substantially exceeds its width. The sidewalls of the trough diverge at a very shallow included angle from the bottom wall and terminate in shorter, parallel upper sidewalls. The sensors are separately compartmented within the trough, the walls of each compartment being substantially fully light absorptive. The trough has externally extending flanges at the top thereof for preventing light reflected from the undersurface of the web from reaching the sensors. The device is adapted to handle webs of decreased widths and includes devices for indicating the presence and locations of holes in the web.

DETAILED DESCRIPTION

The apparatus **10** (FIGS. **1** and **2**) embodying the invention is shown, for purposes of illustration, installed between roll supports **12** and **13** upstanding from the floor **14**, in a conventional paper machine. The support **12** carries rolls **16** and **17** between the nip of which leftwardly passes a web **18** to be monitored for holes. The web **18** moves from the rolls **16** and **17** past the apparatus **10** and thence over a roll **21** carried by the support **13** toward the output end of the paper machine.

The apparatus **10** was developed primarily for use in hole detection in rapidly moving paper or paper board webs and will be described herein in connection with such use, though it is contemplated that at least in certain instances the apparatus **10** is readily adapted to use with other types of moving webs for hole detection. The apparatus **10** may be used at a number of locations along the length of a paper machine, particularly following the fourdrinier section. A useful and convenient location for the apparatus **10** is, however, at the output of the drier section of the paper machine and ahead of the output section **22** of the machine. The output section **22** may, for example, consist of a reeling section for producing paper rolls, a sheet cutting section for producing stacks of sheets of predetermined size, a coater, etc. and a machine operator is normally stationed thereat. The apparatus **10** may also be used at locations remote from the paper machine, for example, in a separate coating or reeling machine.

In general, the apparatus **10** embodying the invention comprises a light source **23**, a hole detector unit **24**, and an output unit **26.** The light source **23** and detector unit **24** are disposed on opposite sides of the web **18** and are aligned transversely thereof. Normally, the apparatus **10** is most conveniently installed with the light source **23** located above the web and the detector unit **24** located below the web, although the apparatus **10** will function with the units **23** and **24** in reverse location. As shown in FIG. **2**, the web **18** is sloped. The apparatus **10** is also usable with webs extending horizontally or vertically.

The light source **23** here comprises a generally rectangular housing **28** which extends transversely across the web **18**, preferably the full width thereof. The housing may be of any convenient construction, sheet metal being preferred and is preferably closed on all sides except the side **29** which faces the web and is normally spaced therefrom by a distance of several inches. The housing **28** contains a source of light (not shown) of any conventional nature, for example a spaced series of flood lamps. The light source is supplied electrical current normally from a conventional **110** volt AC source (not shown) through the cable **31.** The light source **23** may be supported above the web by any convenient means, here through adjustable length chains **32** dependent from a catwalk **33** of the paper machine. The apparatus **10** has a relatively low light input requirement. Thus, where relatively large holes, for example above an inch in diameter, are to be detected in a substantially opaque, low reflectivity web and a relatively high ambient light level is maintained in the region of the paper machine occupied by the apparatus **10,** the light source **23** may be omitted.

The hole detector unit **24** (FIGS. **2–6**) comprises an elongate trough or light sensor housing **36.** For convenience in reference, the trough **36** is described below in its upright position of FIGS. **2–5,** though in use it may be oriented as desired. The trough **36,** in length, extends the width of, and preferably beyond the edges of, the web **18** and, in depth, preferably extends perpendicularly away from the web. The top of the trough is preferably parallel to the web and close spaced therefrom, normally by a dimension in the range of one half to 2 inches, frequently about an inch. The spacing of the trough **36** from the web depends upon the normal deviation of the web from its mean path during operation of the machine, and is selected to prevent contact between the trough and web, to avoid damage to the relatively delicate surface of the web.

The width of the trough is small compared to the depth thereof as hereinafter discussed. The trough **36** is of compact cross section to enable same to fit between close spaced adjacent web carrying units of the paper machine.

The trough **36** (FIG. **3**) comprises a pair of upstanding, spaced and parallel upper sidewalls **37.** Coplanar flanges **39** extend outwardly from the upper edges of the upper sidewalls **37** and terminate at their outermost edge extremities in a roll, here provided by welding of suitable tubing **41** or the like thereto, to protect operating personnel moving therepast from injury by contact with such flanges **39.** Integrally and downwardly extending from each of the upper sidewalls **37** are lower sidewalls **43** of depth substantially exceeding that of the upper sidewalls **37.** The lower sidewalls **43** converge very gradually, here at approximately 12° included angle, to a connecting, preferably integral bottom wall **45.** The particularly favorite embodiment of the invention, the upper sidewall **37** and lower sidewalls **43** are, respectively, 4 and 8 inches in depth, the upper sidewalls are spaced at approximately 3 inches and the width of the bottom wall **45** is approximately 1 ½ inches. Thus, the trough is deep relative to its width, tapers for most of its length and is of compact cross-section compared, for example, to the normal width of paper webs, e.g. 200 inches.

Upstanding end walls **46** (FIG. **4**) close the ends of the trough. The end walls **46** have outwardly extending flanges **48** and tubing elements **49** in the manner above described with respect to the sidewalls.

A plurality of barriers **50** are evenly spaced along the length of the trough **36** and extend between, and preferably to the height of, the sidewalls. The barriers divide the trough into upwardly opening compartments **52.** Each of the barriers **50** comprises a pair of downwardly diverging, frusto-triangular lower barrier walls **54** (FIGS. **4** and **5**) which extend between the lower sidewalls **43** to the bottom wall **45** and an upstanding upper barrier wall **51** which is preferably an upward continuation of one of the sloped lower barrier walls **54.** The length of the compartments **52** is determined by the number of sensing compartments **52** desired for a given width of web and a dimension in the range of 6 to 24 inches is contemplated, the length and the particular embodiment shown being approximately 9 inches. The upper and lower barrier walls **51** and **54** are fixed within the trough by any convenient means, here by integral flanges **56** secured, for example, by screws, riveting, welding, etc., to the widewalls of the trough. Each of the compartments **52** so formed is lighttight except for the open upper end thereof and for a central sensor mounting hole **57** (FIGS. **5** and **6**) in the bottom wall **45.**

The walls of each compartment **52** are fully covered, e.g. coated or lined, with a suitable material which is highly light absorptive. For example, in the particular embodiment shown, a layer of black felt **58** is cemented to and covers the walls **37, 43, 51** and **54** within each compartment. The light absorptive lining is omitted in FIGS. **4** and **5** from the rightwardmost compartment **52A** only to illustrate more clearly the construction and interconnection of the sidewalls and barriers thereof. The compartment **52A** would in use be lined in the manner above described with respect to the remaining ones of the compartments **52** shown.

A suitable sensor mounting socket **60** (FIG. **6**) is provided in the bottom of each compartment **52** and here comprises a socket member **61** which extends downwardly through the opening **57** in the bottom wall **45** and is fixed in place by a nut **62.** The socket **60** receives a light sensor **64** with the light input surface thereof facing upwardly from the bottom of the compartment **52.** In the particular embodiment shown, the light sensor **64** is of the cadmium sulfide type, Model No. CL603 manufactured by Clairex Electronics, Inc. of New York, N.Y. and which provides a light to dark resistance ratio of 1:10,000. Electrical connection is made to the socket **60** via conductors **66** of a harness or cable **67** which extends along the length of the trough **36** below the bottom wall **45** for providing independent electrical connection to the light sensors in the compartments **52** to thereby obtain independent electrical outputs corresponding to the amount of light falling on the upper face of such sensors.

A cable housing **71** (FIGS. **4** and **6**) extends the length of the trough **36** for supporting and protecting the cable **67.** The cable housing **71** is compact and in the particular embodiment shown comprises a bottom wall **72** and upstanding sidewalls **73** which terminate in upwardly flared edge portions **74.** The edge portions overlap the lower trough sidewalls **43** and are preferably releasably secured thereto by screws **76** located between the compartments **52.** Though shown here in a relatively enlarged form having upwardly converging and intermediate wall portions **77,** it is contemplated that the cable housing **71** may be of strictly rectangular cross-section, except for the flared edge portions **74,**

and may correspond in width and height to the width of the floor **45.** The cable housing has closed end walls **78** which overlap the trough end walls **46,** one of such cable housing end walls **78** being pierced and having a fitting **79** for admitting the cable **67** therethrough.

The upper end of the trough **36,** and hence the upper ends of the compartments **52,** are closed by a transparent plate **81,** for example a sheet of rigid plastic, which extends across the tops of the upper barriers **51** and is supported upon the upper faces of the joined side and end flanges **39** and **48.** The edges of the sheet **81** are removably secured to the flanges by spaced screws **82** to seal the compartments **52** against incursions of foreign material, particularly paper dust, which might impair the sensitivity of the sensor **64** and the light absorbency of the lining **58.** The transparent plate **81** also serves to protect the interior of the trough from mechanical damage and incursions of water or other liquids (as when the apparatus **10** is used near the wet end of a paper machine or in a coating apparatus).

A support device **86** (FIG. **2**) supports the trough **36** above the floor **14,** to allow movement of the trough **36** downwardly away from the web to facilitate threading of the web **18** through the paper machine as well as to allow access to the interior of the trough **36,** for example for changing the sensors **64.** The support device **86** here comprises a plurality of fluid operated jack **87** having upstanding reciprocable piston rods **88** spaced along the length of the trough. Each rod **88** terminates in a bracket **89** including a portion **91** fixed as by welding to the adjacent lower sidewall of the trough **36.** The jacks **87** may be remotely operated through control of a fluid pressure supply (not shown) connected to a supply line **92.**

A light shield **96** (FIGS. **9** and **10**) is appliable to the trough **36** when webs of width less than the length of such trough are to be monitored for holes so as to prevent against spurious light inputs to the endmost compartments of the trough. The light shield **96** is preferably formed of sheet metal and comprises a base **98** of substantially C-shaped cross-section which is snugly slidable over and along the upper end of the trough surrounding the flanges **39** and tubes **49** and overlying the transparent plate **81.** Thus, the base **98** comprises a central platelike portion **99** which lies atop the transparent plate **81** and preferably contacts same with a nonabrasive surface (not shown) such as a felt pad. The side edges of the plate integrally connect with depending flanges **101** which in turn at their lower ends terminate in inwardly extending flange extensions **102.** An intermediate portion **103** of each interconnected flange **101** and flange extension **102** is separated from the remainder thereof by cuts **104** extending from the free edges of the respective flange extension **102,** the intermediate portions **103** being formed to more snugly grip the tubing **104** and provide resistance to unintentional sliding displacement of the shield **96** along the length of the trough and thereby hold same in place on such trough.

Angled upwardly and outwardly from the inner edge of the central portion **99** is a shield flange which terminates at its upper end in a substantially horizontally inwardly extending top shield **107** integral therewith. The side edges **108** of the shield flange **106** diverge upwardly, the corresponding side edges of the top shield preferably extending substantially in parallellism therefrom and thereby overhanging the transparent plate **81**

and flanges **39.** The light shield **96** is normally placed on the trough so that the leftward (as seen in FIG. **10**) or outward end thereof covers the outer end of the end compartment **52** located thereunder to prevent entry of light thereinto and so that the web **18** lies in the pocket **111** formed by the shield flange **106** and top shield **107** for preventing direct light inputs from above and outboard of the edge of the web **18** from entering the trough **36.** The inner faces (those defining the pocket **111**) of the shield flange **106** and top shield **107** are preferably lined or coated with a light absorbing material such as black felt to prevent reflection of light striking same into the interior of the trough.

Referring to FIGS. **1** and **11,** sensor output from the conductors **66** of cable **67** is applied to the output unit **26.** The output unit **26** includes a plurality, preferably one per sensor, of amplifiers **116** which are adjustable for gain and operated from a conventional electrical source not shown. The amplifiers are located in a housing **117.** If desired the housing **117** may be located remotely of the paper machine and hole detector unit **24.** System operations have been conducted with amplifier housing **117** located as much as **25** feet away from the detector unit **24.** Since in the particular embodiment shown the sensors **64** are photoresistive, the amplifiers **116** include means for providing operating current through the corresponding one of said photoresistors and for monitoring the resistance thereof to an output voltage which changes in relation to resistance change in the photoresistor and thereby in relation to the light input thereto. Output from each of the amplifiers **116** is applied through a line **119** (FIG. **11**) to a corresponding one of a plurality of control circuits **120,** one thereof being shown within the broken line box in FIG. **11.** The control circuits **120** are preferably identical and only one such control circuit need be shown.

The control circuit **120** includes a master relay **122** actuated by an output on line **119,** indicating detection of a hole by the corresponding sensor **64.** The minimum hole size required for actuation of the relay **122** is controlled by a conventional gain control (not shown) in the amplifier **116.** The relay **122** has a normally open contact **123** connected to an operating potential supply line **124,** connected to a suitable electrical power source (not shown).

The contact **123** when closed connects the supply line **124** to an output line **126.** One such output line **126** connects from each of the several circuits **120** to corresponding inputs of a logical OR function device **127.** When actuated, the OR gate **127** provides an output on a line **128** to a generalized, or all system, detection indication device **130.** In the preferred embodiment shown, the all system indicator **130** is a chart recorded which includes a solenoid **131** which mechanically drives, as indicated at **132,** a stylus **133** across a chart **134** to record, for example over the period of one working shift, the totality of holes detected by the apparatus embodying the invention.

Each control circuit further includes, connected in series between the relay contact **123** and the ground side **136** of the power supply (not shown) connected to the supply line **124,** a series line comprising a holding relay **137** and a normally closed lamp de-energizing switch **138.** Connected in series from the potential line **124** to the ground line **136** are a normally open contact **139** of holding relay **137** and a holding warning lamp **141.**

The lamps **141** associated with each of the sensors **64** are preferably supported by a lamp housing **143** (FIG. **1**) adjacent the paper machine output device **22** and above the particular segment of the web **18** which traverses the compartment associated with the corresponding sensor **64** for warning operating personnel located at the paper machine output device **22** that a hole has been detected in a given part of the web and will soon arrive at the output device **22.** The lamp deactuating switch **138** is preferably located on the front panel **144** of the circuit housing **117.** In such instance the housing **117** is preferably located for convenient access by the operating personnel at the output station **22.** Further holding or memory lamps (not shown), wired in parallel with each of the lamps **141** may be provided on the front panel **144** adjacent the switches **138** to assist operating personnel in deactuating the corresponding solenoid **137** after proper steps have been taken to eliminate, flag or identify the portion of the web bearing the hole.

Also connected in series between the contact **123** and ground **136** for each circuit **120** is an instantaneous lamp **146** preferably mounted on the front panel **144** of circuitry housing **117** for providing, by a brief ignition of predetermined duration, a further indication of detection of a hole in the web. Corresponding lamps (not shown) may be wired in parallel with the lamps **146** and located in the housing **143.**

The control circuit **120** further includes, connected between the relay contact **123** and ground **136,** a series circuit comprising an electrical time delay device **148** of any convenient type and a delay solenoid **149.** The delay solenoid **149** is of a conventional type which upon actuation maintains itself actuated for a short predetermined time after operating current is removed therefrom. The delay solenoid **149** is associated with a corresponding section of a multisection web marking device **151** (FIGS. **1, 2, 7** and **8**).

The web marking device **151** is located adjacent the web **18** and downstream of the detector unit **24.** In the particular embodiment shown in FIGS. **1** and **2,** the web marker **151** is located closely adjacent the detector **24** and as a result, the delay device **148** may be omitted or have a very short duration. On the other hand, it may be desired to locate the marker **151** substantially further downstream of the detector unit **24,** such as near the machine output station **22** in which case the delay device **148** may provide a substantial, and preferably adjustable, duration to correspond to the distance traveled by a hole in the web between the detector **24** and marker **151.**

The marker **151** is actuated slightly before passage of a detected hole therepast and is deactuated sometime thereafter to provide a visible marking on the moving web which extends for a distance before and after the detected hole sufficient to enable machine operating personnel to readily visually spot the hole. The onset of the mark is determined by the delay **148** and the length of the mark is determined by the on time of the delay solenoid **149** as hereinafter indicated.

The web marker **151** is fixedly supported, preferably above the web, by any convenient means not shown for example including the catwalk **33** of FIG. **2.**

The marker **151** (FIGS. **7** and **8**) comprises a generally downwardly opening housing **152** having a top wall **153,** sidewalls **154** and **155** and end walls **156.** The housing **152** preferably extends the full width of the

web **18.** The sidewalls and end walls of the housing extend downwardly to within a short distance, for example one half to two inches, from the web **18.** The housing includes a shelf **156** on which is supported an ink or dye reservoir **159** fillable through a capped neck **160** which extends upwardly through the top wall **152** of the housing. Spaced supports **161** depend from the shelf **157** to a point near the web **18** and carry at the lower ends thereof, in pivotal relation thereto, the intermediate portions of levers **162.** Each of the levers **162** carries at one end, here the upstream end thereof, a rotatable permeable roller **164.** The rollers **164** are each preferably substantially aligned longitudinally of the web with a corresponding one of the sensors **64** and are, upon clockwise pivoting as seen in FIG. **7** of the corresponding lever **162,** capable of contact with the upper surface of the web **18.** The maximum clockwise pivotal movement of each lever **162** is limited by a stop screw **165** which threads downwardly through the shelf **157.** A compression spring **166** contacts the upper face of lever **162** adjacent the leftward end thereof and bears on the underside of shelf **157** to resiliently maintain the roller **164** thereof raised out of contact with the web **18.** The delay solenoid **149,** above described with respect to FIG. **11,** fixedly depends from the shelf **157** and has a plunger **167** which is extensible upon operation of such solenoid **149** into contact with the rightward portion of the lever **162** to urge the roller **164** against the web **18.** Flexible tubes **168** connect from the reservoir **159** to wicklike tips **169** fixed to the levers **162** and bearing on the rollers **164** for applying a film of a dye or other marking fluid to such rollers. Thus, actuation of the delay solenoid **149** marks the web **18** in alignment with the actuated one of the detectors **64** and in overlapping relation with the hole causing such actuation. One such assembly of elements **161** through **169** is provided for each of the sensors **64** and in alignment therewith longitudinally of the web.

OPERATION

For convenient threading of the web **18** through the paper machine, the hole detector unit **24** is preferably moved away from the path of the web, here by lowering of jacks **86.** Similarly, the light source **23** and web marker **151** may be raised away from the path of the web. Once the web has been threaded through the machine, the hole detector unit **24,** light source **23** and marker **151** may be returned to their operative positions shown in FIG. **2.**

As the web **18** begins to run through the machine, the apparatus **10** embodying the invention may be activated. More particularly, the light source **23** and the circuitry of FIG. **11** are energized from any convenient source of electrical power (not shown). Thus, the apparatus is ready for detection of the holes in the web **18.**

The light shields **96** (FIGS. **9** and **10**) may be adjusted on the ends of the longitudinal trough flanges **39** for covering end portions of the trough interior not overlaid by the web **18,** so that the generally V-shaped pockets **111** receive therewithin, and in spaced relation to the walls **106** and **107** thereof, the adjacent edges of the web **118.**

Each shield **96** blocks ambient direct light inputs from above the plane of the web, including light inputs from zones inboard, outboard, upstream and downstream thereof, from entering the interior of the trough. Light rays sloping from above the web into the pocket **111** fail to reach the interior of the trough due to the angle of the wall **106** and the light absorbent lining of the pocket **111.** Same applies to light reflected into the pocket **111** from the top of the web **118** near the edge thereof.

Ambient light rays may enter the zone between the web **18** and the plate **81,** if suitably angled, by passing beyond the upstream and downstream ends of the light shield wall **106.** However, no significant portion of such light input reaches the sensors **64.** More particularly, the angle of incidence of such light rays striking the top of the transparent plate **81** is so shallow that much of the light is reflected upwardly therefrom. Any remaining portion which passes through the transparent plate **81** strikes the upper sidewalls **37** and one of the upper barrier walls **51** and due to its angle of incidence would have to be reflected many times by the compartment walls before reaching a sensor. However, due to the highly light absorbtive lining of these walls, negligible light is reflected therefrom.

Upwardly angled ambient light rays may be reflected from the bottom surface of the web **18** toward the top of the trough. Of these, light rays which proceed toward the web at a relatively large angle thereto (near normal thereto), are blocked by the relatively wide flanges **39** at the upper end of the trough and so do not reach the underface of the web.

The underface of the web is relatively close to the trough, as compared to the width of the flanges **39** and the depth of the trough. Also, the trough is relatively narrow. Thus, in the particular embodiment shown, upwardly directly ambient light rays reflected from the underface of the web toward the top of the trough (i.e., not blocked by the flanges **39,** lie at a relatively shallow angle, about 30° or less, to the face of the web. A portion of such light inputs will be reflected by the transparent plate **81** due to their shallow angle of incidence. The remaining portion must upon entering the trough strike the sidewalls and/or barriers thereof several times before reaching the bottom of the trough and hence, as a practical manner, are completely absorbed before reaching a sensor.

Thus, as a practical matter, any light inputs to the sensor **64** pass through the web **18.** It is believed that it is for this reason that the device embodying the invention works well not only with opaque paper webs but also with paper webs which pass some light therethrough, though less than through a hole in the web.

Noting that light transmitted to a sensor **64,** through an unholed portion of a semitranslucent web constitutes a steady background light level, and gives rise to a steady sensor background output level, use of a conventional amplifier which in effect ignores all or a portion of such background output level and amplifies exclusively or primarily the transient change in sensor output level resulting from a direct light input through a passing web hole, enhances the use of the apparatus **10** with webs of substantial translucency. Thus, the amplifier **116** may incorporate, for example, a d.c. differential amplifier circuitry with a preselected reference level input and a sensor level input, or an a.c. amplifier, the relay **122** being actuated by the amplified transient resulting from a web hole.

When the web **18** passing over the detector unit **24** includes a hole therethrough, a hole in passing over the trough provides a direct and substantially loss free path for light rays, through the web and into one of the com-

partments **52** located therebelow. Because of the upper barriers **51**, and the light absorbent lighting of the compartments **52**, little if any light from such a hole is applied to the sensors **64** of neighboring compartments. Because of the breadth of the light source above the web, a beam of light will pass therefrom through the hole in the web, the transparent plate **81** and into the corresponding compartment **52** located therebelow to strike the sensor **64** at the bottom thereof. Normally only one of the sensors will react to passage of a hole across the trough, the only exception occurring in relatively rare instances where the hole passes virtually directly above one of the upper barrier walls **51** dividing two of the compartments. The sensors **64** employed are sufficiently sensitive as to detect relatively small holes or even in high web transient rates and despite the narrowness above described of the trough, the sensors reacting virtually instantaneously, at least as compared to the transient time of the hole across the trough, to effect detection thereof. It will be noted that, as long as the hole in the web is over the open upper end of the trough, there is a direct line of sight path between such hole and a sensor.

Upon activation of one of the sensors, for example the sensor indicated at **64** in FIG. **11**, by a hole in the web so passing above the corresponding compartment of the trough, the relay **122** is actuated by the corresponding amplifier **116** to close the contact **123.** The contact **123** remains closed substantially for the time duration of hole detection by the sensor **64** and such time may be increased by using a delay drop out relay at **122.** As a result of closure of the contact **123,** a signal is applied from the potential line **124** through the OR gate **127** to the chart recorder, activating the relay **131** and causing the stylus **133** to record a mark indicating a detection on the chart **134** so as to indicate the time of occurrence of the hole for future reference. The number of holes detected in a time period may then be determined by counting the number of marks on the chart **134.**

Closure of the switch **123** also activates the corresponding lamp **146** and, through holding relay **137** and contact **139,** the corresponding memory lamp **141.** Thus, operating personnel at the output station **22** of the machine are forewarned of the occurrence of a hole in the web, and of the transverse location of the hole in the web, by reason of ignition of the corresponding lamps **141** and **146** at the output station. The operating personnel can then take appropriate measures to flag or remove the holed portion of the web. Thereafter, opening of the switch **138** by such operating personnel restores the ignited memory lamp **141** to its off state.

The aforementioned closure of the contact **123** also actuates through delay element **148,** the delay relay **149** of the marker **151.** The actuated delay relay **149** extends its plunger **167** for pivoting the corresponding marker roller **164** into contact with the web for applying to the web a readily visible dye or ink mark which sufficiently overlaps the hole longitudinally to provide a readily visible mark at the operating speed of the web.

It will be noted that if several holes occur substantially at the same time in different sectors of the web, that the lamps **146** and **141** and the marker roller **164** corresponding to each thereof will be simultaneously actuated. Simultaneous occurrence of two holes in the same sector of the web cause no problem in that the corresponding lamps **146** and **141** and marker **164** will be actuated whether one or several holes occurrs at the same time in the same segment of the web and appropriate action can be taken by operating personnel whether one or several holes have occurred. Although several holes may occur in rapid succession in the same segment of the web, whereby the memory lamp **141** may not yet be extinguished before the occurrence of the second of such closely occurring holes, the presence of such second hole will be signaled by reignition of the corresponding instantaneous lamp **146** and, given sufficient hole spacing, by a further mark by the appropriate marking roller **164.**

MODIFICATION

FIG. **12** discloses a modified mounting for the detector unit. Parts of the apparatus of FIG. **12** corresponding to similar parts of the apparatus **10** above described with respect to FIGS. **1** through **11** will carry the same reference numerals thereas with the suffix A added thereto. Thus, the trough **36A** of FIG. **12** is provided with a generally C-shaped track **176** which extends substantially the length thereof and is fixed to the upper sidewall **37A** thereof by any convenient means not shown. A preferably T-shaped guide **177** is disposed within the C-shaped track **176** and is fixedly mounted, as by attachment to fixed portions of the adjacent paper machine or the like by brackets **179.** Antifriction means, here indicated as rollers **181,** are preferably interposed between the C-shaped track **176** and T-shaped guide **177** to provide for free sliding support of the trough **36A**. The rollers **181** preferably are positively located within the upper and lower portions of the C-shaped track **176** for bearing upon the upper and lower edges of the T-shaped guide **177.** By selecting the length of the guide **177** to exceed that of the trough **36A**, the trough **36A** can be moved transversely of the web to a position partially or completely out of the path of the web to improve access for threading of the web through the paper machine or the like and/or for maintenance of the detector unit.

Although particular preferred embodiments of the invention have been disclosed in detail for illustrative purposes, it will be recognized that variations or modifications of the disclosed apparatus, including the rearrangement of parts, lie within the scope of the present invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A hole detector for a moving web having a light source on one side thereof, comprising in combination:

an elongate trough having a depth substantially exceeding its width, said trough being substantially V-shaped in cross-section and having opposed longitudinal sidewalls diverging at a narrow angle from a narrow longitudinal bottom wall and fixedly carrying a substantially transparent covering plate;

a plurality of pairs of substantially triangular barrier walls distributed along the length of the trough, the barrier walls of each said pair extending divergently from said bottom wall between and in contact with the sidewall, each of said barrier wall pair defining a separated substantially pyramidal compartment opening at its larger end toward the plate, the opposed surfaces of the wall of each of said compartment being light absorptive and nonreflecting;

a light sensor at the bottom wall of each compartment oriented for receiving direct light entering said compartment through said plate;

support means locating said trough on the opposite side of said web and with said plate in close spaced, substantially parallel relation to said web, said trough extending transversely across said web so that light transmitted through a hole in said web and through said plate will strike one of said sensors;

shielding means on said trough adjacent said plate and cooperating with said web for preventing light inputs other than through web holes from entering said trough at an angle to strike said sensors;

indicating means responsive to actuation of said sensors by light for indicating the presence of a hole in said web.

2. The device of claim **1,** in which said indicating means includes a plurality of amplifiers connected to corresponding ones of said light sensors, a control circuit connected to the output of each amplifier and a plurality of output devices associated with each said control circuit for indicating the presence of a hole in a width segment of the web corresponding to an actuated one of said sensors.

3. The device of claim **2,** including OR gate means having a plurality of inputs each connected to one of said control circuits and an output terminal, recorder means actuable by the output of said OR gate means for making a visual recording of the occurrence in time of holes in the moving web.

4. The device of claim **2,** in which said control circuit includes an instantaneous lamp, means for actuating same for substantially the duration of passage of a hole in said web across said trough, a memory lamp, means for actuating said memory lamp in response to the passage of a hole in said web across said trough and for holding said memory lamp in an on condition thereafter and manually actuatable means for de-energizing said memory lamp.

5. The device of claim **2,** in which said control circuit includes an actuator responsive to energization of a corresponding sensor and capable of remaining actuated for a preselected time duration beginning in preselected time relation with the energization of said sensor, marking means opposed to the face of the web and extending thereacross, said marking means including a plurality of marking units which correspond in alignment along the web with ones of said sensors, each marking unit being capable of applying an elongated visible mark to the web in the transverse segment of the web corresponding to a hole sensed by the corresponding sensor and extending longitudinally of the web on both sides of said hole for visually indicating the presence of a hole in the web.

6. The device according to claim **5,** in which said marking means includes a marking fluid reservoir supported in fixed relation to the trough and adjacent the web downstream of said trough, said marking units each comprising a fluid applicator pivotally mounted with respect to said reservoir and responsive to the corresponding actuator means for contacting the opposed face of the web, each said applicator being supplied marking fluid by means connected to said reservoir.

7. The device of claim **1,** in which said indicating means comprises a chart recorder arranged for recording over a period of time holes detected in the moving web, a plurality each of instantaneous warning lights, memory lights and web marking units, each of said lights and marking units being associated with at least one of said sensors, said marking devices each being located adjacent the web and in longitudinally aligned relation with and downstream of their corresponding sensor, said lights being arranged in distributed relation across the web at a station along the web spaced from said trough and downstream thereof, said lights being aligned longitudinally of the web with their corresponding sensor whereby ignition of one of said lights indicates a hole in the corresponding segment of the web located adjacent thereto, and circuitry connecting said lights and marking devices and said recorder with said sensors.

8. The device of claim **1,** in which said shielding means comprises a flange extending around the periphery of said trough and at least extending the length of the sidewalls of said trough and located in contacting and underlying supporting relation with said plate, the width of the flanges being at least half the width of the trough for preventing spurious light inputs from below the trough from extending therepast and being reflected by the web into the trough in alignment with the light sensors.

9. The device of claim **1,** in which said shielding means includes a light shield at each end of said trough slidable along the length of said trough atop said plate, each said shield having substantially C-shaped portion for securing same for sliding motion along said plate and further having a first upwardly and outwardly angled wall and a second substantially horizontal and inwardly extending wall atop said first wall, said first and second walls of said light shields defining opposed pockets for receiving the edge portions of said web, each said edge portion of said web being located in spaced relation to the adjacent first and second walls but overlapping both sidewalls so as to prevent spurious light inputs into said trough from the ends thereof by passage between said plate and said web.

10. The device of claim **9,** in which the shield means further includes substantially coplanar flanges surrounding said trough and lying at the free longitudinal edges of said sidewalls for snugly contacting said plate in underlying relation therewith, said flanges being provided with curved, thickened outer edge portions, the C-shaped portions of said light shields folding over the thickened flange outer edge portions, said C-shaped portions including spaced slots defining resilient fingers which grip said flange outer edges for preventing unintended shifting of said light shields longitudinally of said trough.

11. The device of claim **1,** in which said support means includes a base portion fixed with respect to the path of the web and a movable portion fixed to the trough for allowing shifting of said trough out of adjacency with said web to facilitate web threading and access to said sensors.

12. The device of claim **1,** in which said sidewalls of said trough comprise an angled bottom portion extending from said bottom wall and substantially parallel upper portions extending from said lower portions to adjacency with said plate, said angled lower portions being of height approximating twice that of said upper portions, said barrier walls each including substantially triangular shaped lower portions joined at the base edges thereof substantially in a plane passing through

the line of joining of the upper and lower sidewalls, said barrier walls each further including an upstanding substantially rectangular upper barrier wall portion extending integrally from the base edge of one of said triangular portions substantially to said plate, said upper barrier wall portion being equally angled with respect to both of the adjacent lower barrier wall portions. Said trough further having end walls shaped to conform to the cross-sectional configuration of said trough and having one lower barrier portion angling inboard therefrom toward said bottom wall.

13. The device of claim 1, including a plurality of conductors connected to the light sensors of each of said compartments and defining a cable extending adjacent and outside of the bottom wall of said trough and further including a hollow cable housing fixed to the sidewalls of said trough and in spaced surrounding relationship to the exterior face of the bottom wall of said trough for enclosing said cable, said cable exiting from one end of said cable enclosure.

* * * * *