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Hayward et al.

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[45] **Sept. 3, 1974**

[54] **METHOD AND APPARATUS FOR INSPECTING SEALED CONTAINERS**

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[73] Assignee: **Benthos, Inc.,** N. Falmouth, Mass.

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[52] **U.S. Cl.** **73/52**

[51] **Int. Cl.** **G01m 3/24**

[58] **Field of Search** 73/52, 67.2; 209/111.9, 209/DIG. 3

[56] **References Cited**

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2,608,089 8/1952 Raymond et al..... 73/52

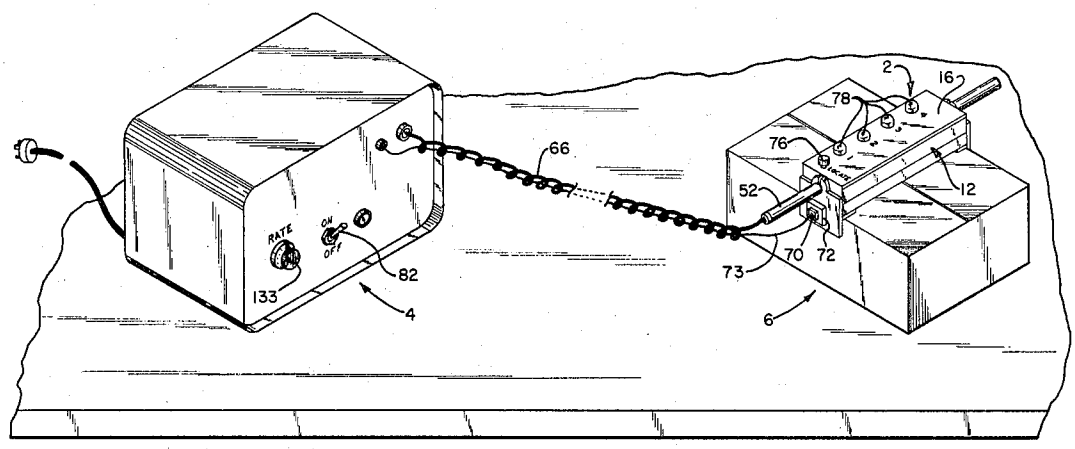
Primary Examiner—Donald O. Woodiel

Attorney, Agent, or Firm—Schiller & Pandiscio

[57] **ABSTRACT**

The invention is a method and apparatus for inspecting containers, e.g., vacuum-packed cans of food, enclosed in a shipping carton or case. It comprises providing a row of electromagnetic transducer coils, moving the row of coils relative to the carton so that the several rows of containers in the carton are successively aligned with the coils, and sequentially and repeatedly energizing the coils at a selected repetition rate while they are aligned with a row of containers so that the end closures of the containers will be caused to vibrate at a frequency which is a function of the internal pressures of the containers and so that the sounds produced by the vibrating end closures provide a tonal pattern distinctive of the presence or absence of a container with unsatisfactory internal pressure.

21 Claims, 7 Drawing Figures



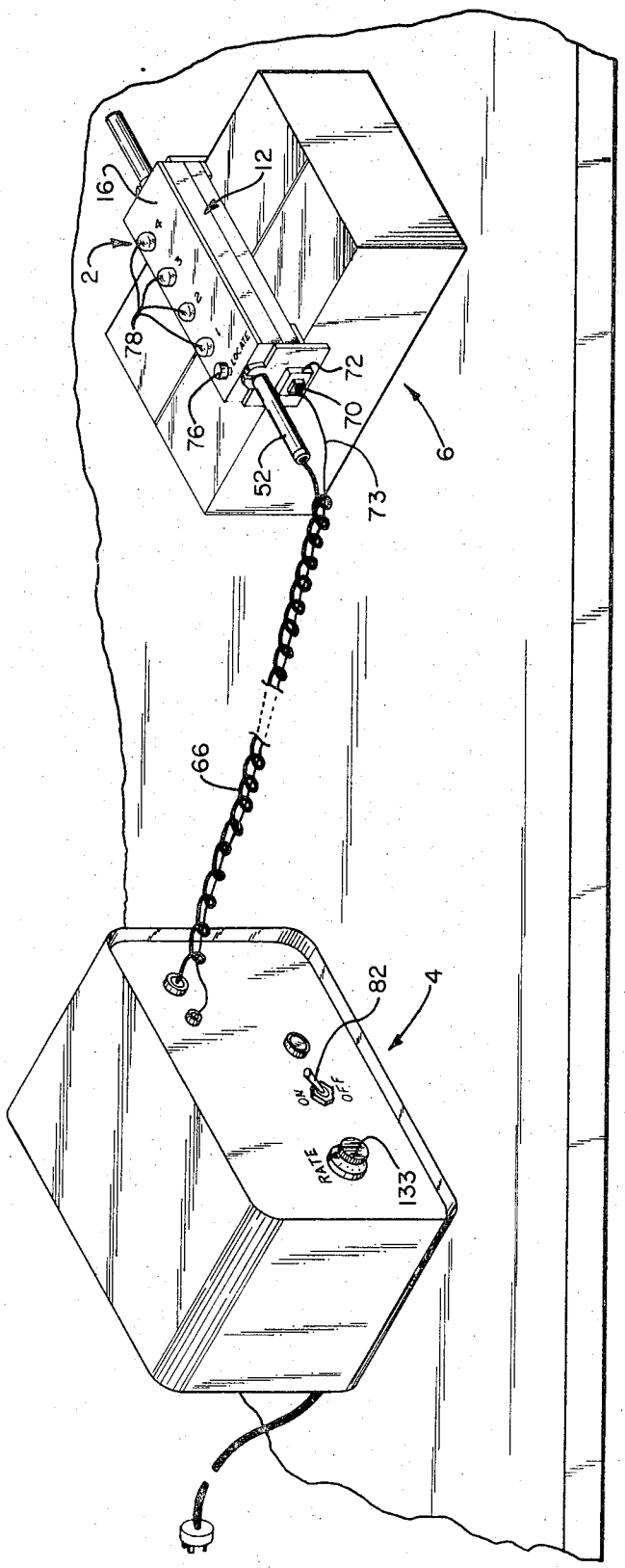


FIG. 1

FIG. 2

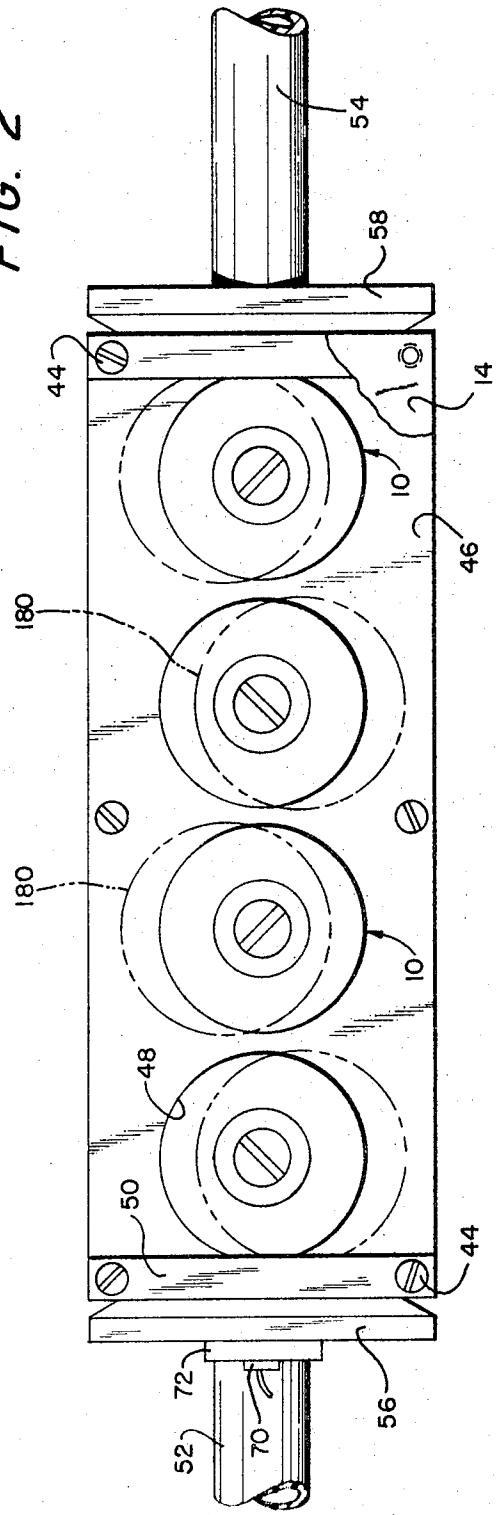
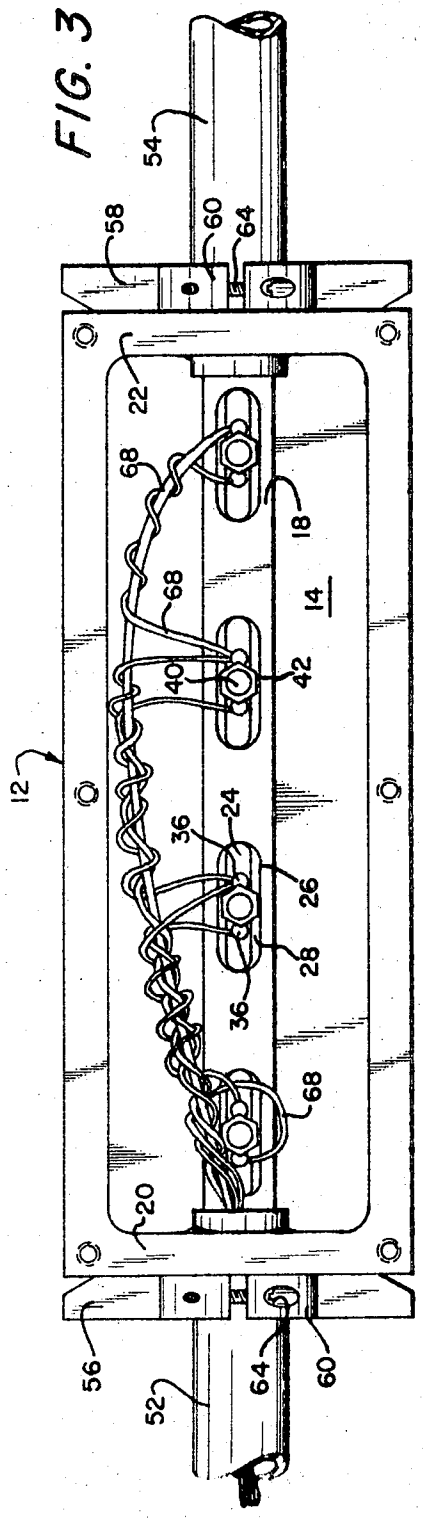

54
58
44
14
10
46
180
180
10
48
50
44
72
52
70
56

FIG. 3


54
58
60
64
22
68
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68
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12
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24
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28
36
68
20
56
52
64
60

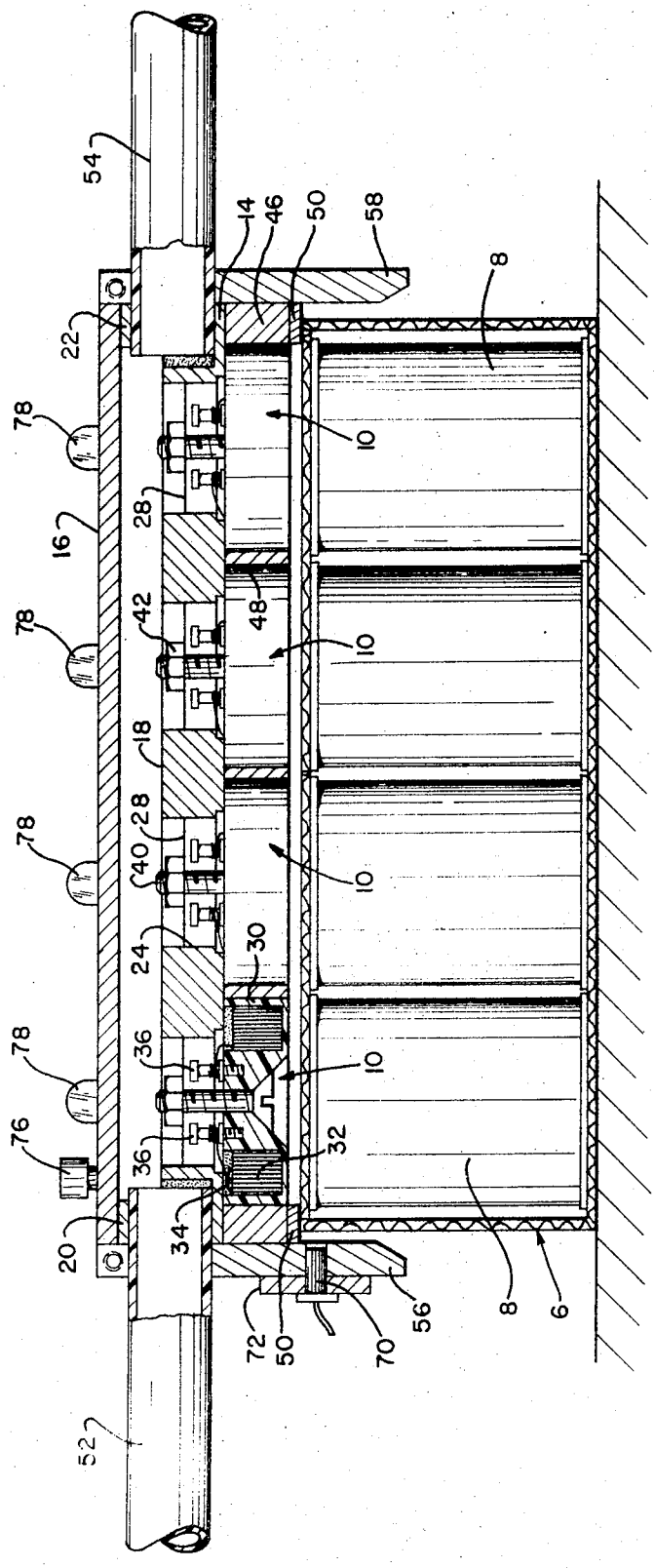

54
14
46
50
58
8
22
78
10
28
16
48
42
18
40
24
30
36
32
76
34
20
72
70
56
6
52

FIG. 4

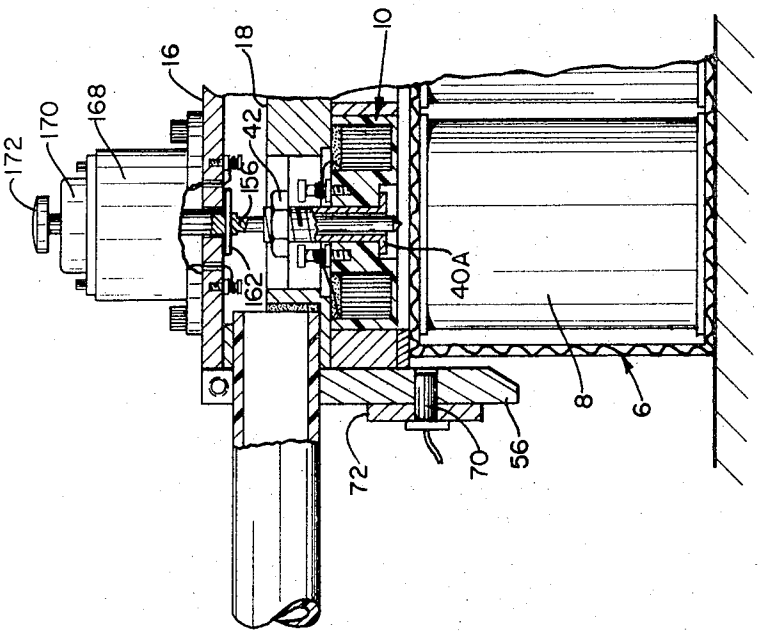

172
170
168
16
18
10
42
156
162
40A
8
6
72
70
56

FIG. 5B

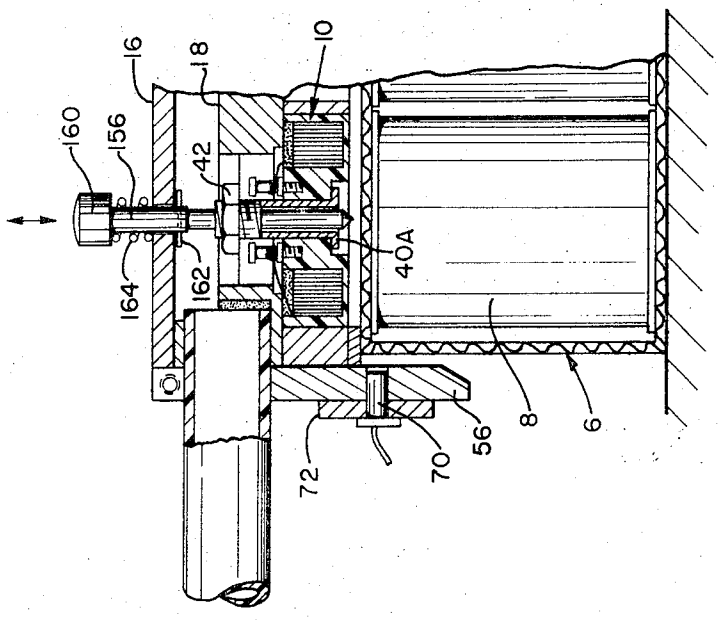

160
156
16
18
10
42
164
162
40A
8
6
72
70
56

FIG. 5A

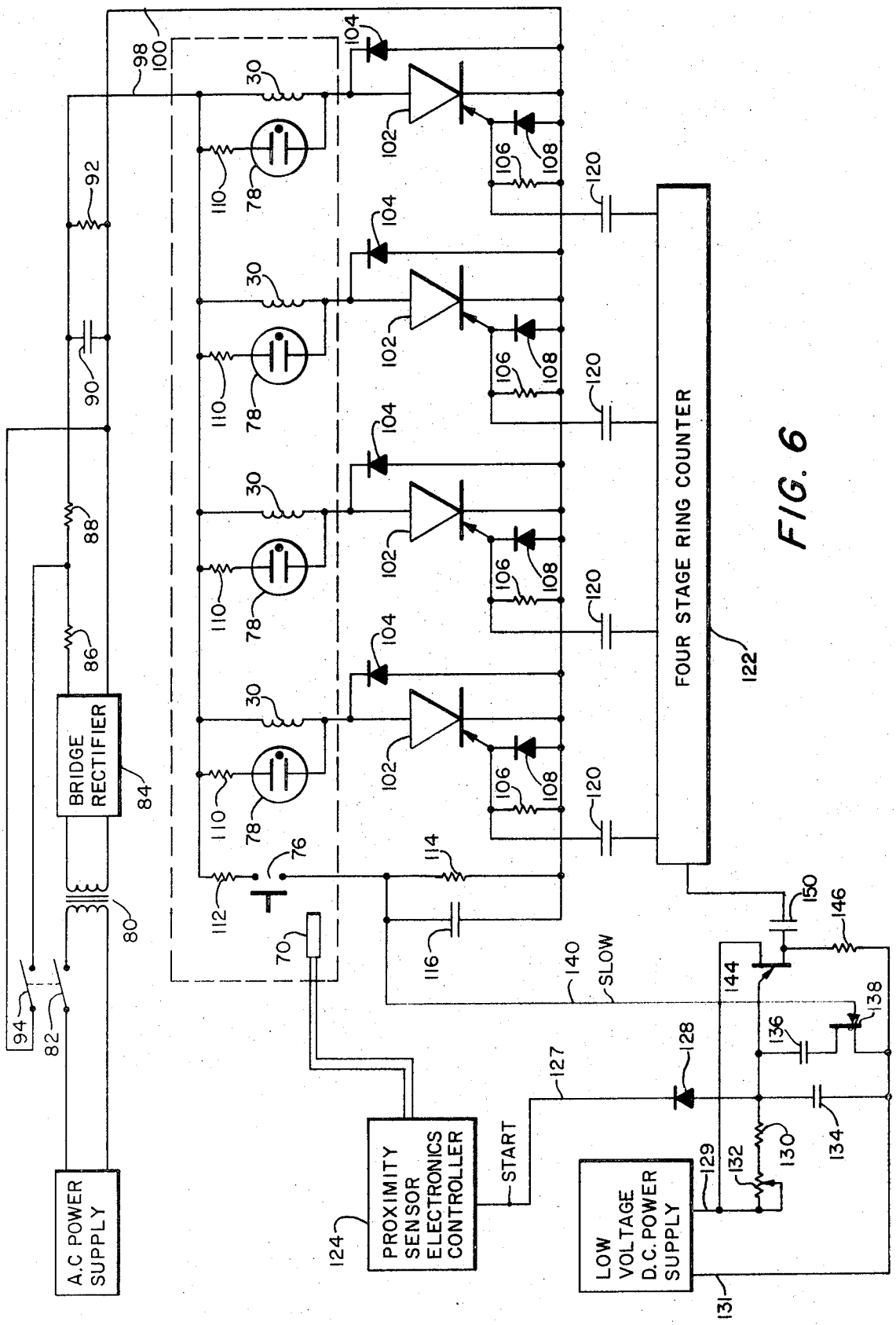

A.C POWER SUPPLY
BRIDGE RECTIFIER
FOUR STAGE RING COUNTER
PROXIMITY SENSOR ELECTRONICS CONTROLLER
LOW VOLTAGE D.C. POWER SUPPLY
START
SLOW

FIG. 6

METHOD AND APPARATUS FOR INSPECTING SEALED CONTAINERS

This invention relates to a non-descructive method and apparatus for monitoring the pressure in sealed containers disposed in sealed shipping cartons, and more particularly for inspection of (a) vacuum-packed jars or cans containing perishable foods or other materials, (b) containers of carbonated beverages, and (c) containers of other pressurized or evacuated products.

Heretofore a variety of methods and apparatus have been devised for determining the internal pressure in sealed containers having at least one flexible wall portion, e.g., metal cans and jars or bottles having metal covers or caps. Some of the prior art in this field is exemplified by U.S. Pat. Nos. 3,513,689, 3,416,360, 3,290,922, 3,137,160, 2,648,977, 2,608,089, 1,956,301, 1,869,067 and other references cited in such patents. These prior methods and equipment have not been fully satisfactory and as a result in many packing and bottling plants, inspection is performed by destructive testing methods or visually, e.g., inspecting vacuum-packed cans for bulging ends.

A particular problem exists with respect to sealed cans or jars that have previously been packed in closed cartons and placed in warehouses for storage. For obvious reasons, foods are canned as rapidly as possible after harvest and the canned food products are packed in sealed cartons and stored in warehouses from which they are later withdrawn and introduced into the channels of commerce according to demand. Since such goods may remain in storage for months, it is desireable to subject them to inspection before shipment to customers to determine whether a change in the internal pressure of the sealed cans or jars has occurred due to leakage or food spoilage or corrosion of the container.

Accordingly, the primary object of this invention is to provide an improved method and new equipment for non-destructively checking the internal pressure conditions of sealed containers that are encased within a closed shipping carton and without physically contacting the sealed containers with the inspection apparatus. The invention is useful for testing containers that have been sealed either under a partial vacuum (less than atmospheric pressure) or positive (more than atmospheric) pressure. Accordingly, unless otherwise indicated or rendered obvious by the context in which it is used, the term "pressure" is used throughout the following specification and claims to denote either positive or negative pressure within a container relative to the pressure outside of the container.

A more specific object is to improve upon the method and apparatus of the invention disclosed in U.S. Pat. No. 2,608,089. This prior invention consists of providing a plurality of electromagnetic coil transducers, one for each sealed container in a closed carton, mounting the transducers in rows and columns in an array corresponding to the disposition of the containers in the carton, positioning the carton to be inspected and the transducers so that each transducer is aligned with a container, energizing each coil so that its magnetic fields will cause the adjacent metal can end or jar lid to flex and vibrate and thereby produce an audible sound wave at a frequency that is a function of the pressure in the container, and monitoring the audible

sounds (hereinafter sometimes referred to as "pings") to determine by their tonal qualities the relative magnitude of the internal pressure in each can or jar. A judgment as to whether a can is good or bad is made according to the tonal quality of the ping. In this prior art method, means are provided for automatically energizing the coils in a predetermined sequence such that audible sounds or pings are produced starting with the cans at one end and ending with the cans at the opposite end of the carton.

This prior art technique, which has not been adopted by the canning industry, has a number of disadvantages — notably, lack of reliability of discrimination by the user, the cost of providing one transducer for each can or jar to be tested, the inability to use the same array of transducers to test different size cans or jars, the difficulty in adapting the apparatus for use with different size cartons (e.g., cartons containing 12, 24 or 36 cans or jars), and unsuitability for use with cartons on a continuously moving conveyor.

It has been determined that the foregoing disadvantages of the method and apparatus of U.S. Pat. No. 2,608,089 are due to a number of factors, notably (1) variations in the abilities of different operators to detect and evaluate the tonal qualities of the pings and thereby judge the magnitude of the pressures in the containers being tested, and (2) the matrix transducer arrangement and particularly use of a plurality of transducers equal in number to the number of containers in the carton under inspection. The significance of these factors is better understood by considering first the underlying concept of magnetically tapping a sealed container to check its internal pressure.

If a transducer coil is positioned adjacent to the end of a vacuum packed aluminum can, or the aluminum lid of a glass jar, and energized by a pulse of electrical current, a magnetic field will be generated by the coil. This field will increase and decrease as the current in the coil rises and falls. As the field increases, eddy currents are generated in the can end in one direction. As the field collapses, eddy currents are generated in the can end in the opposite direction. These eddy currents produce a force on the can end away from the coil. This driving force is of short duration and hence is appropriately described as a pulse of force. Application of this pulse of force will cause the can end to vibrate at its natural frequency. When the can end vibrates it causes pressure variations in the atmosphere and these pressure variations produce an audible acoustic pulse or ping whose frequency and hence pitch and tonal quality is related to the pressure in the can. Typically the ping decays to an inaudible intensity level in about 40 milliseconds.

The pinging phenomenon also occurs with can ends or jar lids made of steel. However, a louder ping is obtained from a can with an aluminum end or a jar with an aluminum lid since (1) aluminum has a much lower density and thus is more easily accelerated by the magnetic forces involved, (2) steel is magnetically attracted by the coil's field and this ferromagnetic atrraction force tends partially to cancel out the eddy current repulsion force and thus decreases the ping, and (3) aluminum is more electrically conductive. However, even with steel ends or lids it is possible to practice this invention.

An audible acoustic pulse also is produced when the end of a pressure packed container, e.g., a can of beer, is tapped in the manner described.

The natural frequency of a can end or metal jar lid is a function of the pressure difference across the end or lid and the density of the material of which the can end or lid is made. Additionally, the overall tonal quality, i.e., harmonics in the acoustic pulse, and the intensity of the ping are affected by the nature of the contents of the container, the shape of the container and whether or not the container is all metal or comprises some other material such as glass. In any event, for a fixed can design, the frequency of vibration of the can end can be used as a determination of the gas pressure within the can (the theoretical natural frequency of vibration of an ideal can end or jar lid is a function of the square root of the pressure difference across the can end or lid).

As a practical matter, the internal pressure of a sealed container need not meet exactly a predetermined value for it to be deemed good. In fact there are allowable pressure variations and only containers whose internal pressure exceeds specific limits need be judged as bad and unacceptable.

The technique of U.S. Pat. No. 2,608,089 requires the attendant to detect and evaluate the tonal qualities of the individual pings and to thereby judge the magnitude of the internal pressure of the containers under test. However, different persons have different hearing acuities and thus two different operators may evaluate the tonal quality of a given ping differently. Furthermore, it has been found that like cans or jars filled with the same goods and having substantially the same internal pressure will produce pings that may have the same predominant resonant frequency but with slightly different tonal qualities. The tonal qualities of the pings from like containers are further modified by differences in internal pressure even though the pressure in each container is within the allowable limit or limits. Hence it is quite difficult with the method and apparatus of U.S. Pat. No. 2,608,089 to determine accurately whether each can under inspection is good or bad. The discrimination problem also is increased by operator fatigue (with a consequent decrease in operator concentration) and background noises.

Consider now the problem of inspecting 24 sealed vacuum packed cans of food which are disposed in a case or carton in a 4 × 6 array, i.e., six rows each consisting of four cans. With the apparatus of U.S. Pat. No. 2,608,089, 24 coils have to be mounted in a corresponding 4 × 6 array and these coils are pulsed sequentially and row by row or column by colunn. The result is a series of individual pings which the operator must discriminate to determine if any of the cans are bad. It has been found that regardless of whether the sequential pulsing of the coils is performed only once or repetitively, the operator tends to evaluate each ping against a memorized standard, i.e., he compares each ping to his memory of what the ping from a good can should sound like. Because of the various factos noted above such as the operator's hearing acuity, the difference in tonal quality even between cans with acceptable internal pressures, operator fatigue, etc., it is difficult for an operator to accurately determine from an individual ping whether a can is good or bad. Nor is it possible for an operator to properly evaluate each container by comparing its ping with his recollection of the tonal quality of the ping of the preceding container since the latter ping may itself be in the marginal region.

Because of the matrix arrangement of the transducers, it is essential that they be properly aligned with the sealed containers in the case so that each coil can tap a different can and so that the operator can correlate the pings with the cans. If the cans and coils are not properly aligned, the pings will be relatively weak. Thus the matrix arrangement requires that there be no relative movement between the coils and containers while the coils are being pulsed, and this requirement renders the apparatus of U.S. Pat. No. 2,608,089 useless for testing the containers in cartons that are moving on a conveyor.

Accordingly, a further specific object of this invention is to provide a method and apparatus for nondestructively testing sealed cans or jars in closed cartons so as to produce audible sounds that can be reliably discriminated by the human ear to determine whether the internal pressure in the cans or jars is satisfactory.

A further specific object is to provide an improved method and apparatus of the character described that is suitable for inspecting the containers in closed cartons either while the latter are stationary or are being conveyed.

Briefly summarized, the invention consists of a plurality of transducer coils arranged in a single row, electrical means for producing and discharging an electrical pulse in each coil so that the coil produces a pulse of force that will deflect an adjacent end of a can (or the metal lid of a jar) to be inspected, whereby the can end will vibrate and produce an acoustical wave in the can end at a frequency that is a function of the internal pressure in the can, and means for operating said electrical means so that the coils are pulsed sequentially and repetitively at a selected repetition rate, whereby the sounds produced by the vibrating ends of good and bad containers occur as a rhythmic tonal pattern. In a preferred embodiment of the invention the apparatus includes means for marking the carton or case wherever a "bad" can or jar is found.

These and other features of the invention are described below with reference to the drawings in which:

FIG. 1 is a perspective view of a preferred form of apparatus embodying this invention and showing the transducer assembly in position over a carton containing sealed can goods;

FIG. 2 is a bottom perspective view on a larger scale of the transducer assembly;

FIG. 3 is a plan view of the transducer assembly with its cover plate removal;

FIG. 4 is a vertical sectional view of the transducer assembly and a carton of cans under test;

FIG. 5A is a fragmentary sectional view similar to FIG. 4 of a first modification of the invention;

FIG. 5B is a view like FIG. 5A of another modification of the invention; and

FIG. 6 is a schematic diagram of the electrical system of the apparatus of FIG. 1.

Other objects of the invention are disclosed in or rendered obvious by the following description of the invention.

The present invention is based on our discovery that the ability of an operator to evaluate whether the ping produced by electromagnetically tapping a can end or

jar lid is indicative of an acceptable or non-acceptable internal pressure is surprisingly increased to a marked degree by tapping a limited number of containers (a) sequentially and (b) repetitively at a selected repetition rate so as to produce a continuous series of pings at the aforesaid repetition rate. It has been found that with this mode of tapping the operator or attendant discriminates good and bad cans not by comparing each ping with a memorized standard or with the ping from the immediately preceding can, but by the occurrence of a rhythmic pattern or modulation in the sequentially occurring pings. The repetition rate is chosen so that (a) the operator can tell that a discrete ping is produced from each can, i.e., an audibly perceptive gap exists between successive pings, and (b) the occurrance of a bad can is reflected by the presence of a rhythmic pattern in the successively occurring pings. If for example, a series of "good" cans of like design, size and contents are pulsed sequentially and repetitively at a selected fixed repetition rate, the operator hears a series of pings which, even allowing for minor variations in tonal qualities that may occur between good cans, are sufficiently alike to produce an unmodulated or arhythmic tonal pattern. If now one of the good cans is replaced by a bad can and the same tapping process is repeated, the operator will hear a series of pings characterized by a distinctive rhythmic tonal pattern. The tone of the pings produced by the bad can will indeed be different than that of the pings from the good cans but the operator is not required to sense the exact tonal quality of the bad ping per se in order to evaluate it. Instead the operator discerns that a can is producing a ping which is sufficiently different from the pings of the other cans to produce a rythmic tonal pattern. In essence, the operator responds not to the quality of each ping individually but to the tonal pattern of the recurring series of pings.

Although the exact reason for this marked increase in operator discriminating ability is not known with certainty, it is believed to be related to the attendant's limited ability to retain the memory of the tonal qualities of a ping. It appears that with an appropriate repetition rate, each succeeding ping from a given can reinforces the operator's memory of the preceeding ping and this facilitates his ability to discern from the tonal pattern whether a ping indicative of a bad can is occurring. With this invention, the ping from a bad can is comparable to the repetitive occurrence of a blank space in a series of repetitive characters. Thus, the operator's ability to determine whether any of the cans under inspection are bad is less affected by background noise, changes in ping intensity from one can to another or from one case to another, and fatigue.

The same results can not be achieved where, in the manner taught by U.S. Pat. No. 2,608,089, all of the cans or jars in a single carton are tapped sequentially before each can is tapped again. In this connection it is to be noted that in order to detect bad cans by listening to the repetitive tonal pattern of pings from a series of cans, it is necessary for each can to be tapped between about two to eight times per second, preferably about four times per second. In order to achieve this latter repetition rate when pinging each can in a case of 24 cans sequentially, the coils would have to be pulsed at a frequency of four times 24 or 96 Hz or at intervals of slightly less than 11 milliseconds. However, since the average ping is audible for about 30–40 milliseconds, operating the coils at a frequency of 96 Hz would result in each ping occurring before a preceding ping has stopped. As a consequence, the operator would be unable to discriminate between pings at all. This ping overlap problem is not avoided by reducing the frequency so that each can is tapped twice each second. On the other hand, if the frequency is reduced sufficiently so that each ping decays to an inaudible level before the next can is tapped, the individual cans will not be tapped frequently enough to produce a series of pings wherein the ping of a bad can is emphasized by a distinctive tonal pattern.

Accordingly, an essential feature of this invention is to inspect the cans in a case a row at a time. Since most cans and jars are packed four across, it is quite possible to sequentially and repetitively pulse the cans in each row two to eight times per second without any of the pings overlapping each other, and at this repetition rate the tonal pattern of the recurring pings is such that the ping of a bad can stands out markedly and is easily detected by the attendant.

Turning now to FIG. **1**, a preferred embodiment of the invention comprises a transducer assembly identified generally by the numeral **2** and a console **4** which houses the electronic circuits that control energization of the transducer coils. In this embodiment of the invention, the transducer assembly is designed to be manually positioned over and moved along a carton **6** to be inspected. In this case the carton **6** is of a type in which vacuum-packed cans **8** are disposed in columns of four, e.g., 24 cans in a four columns by six columns array. Accordingly, the transducer assembly comprises four transducers **10** (FIGS. **2** and **4**) arranged in a row.

Referring now to FIGS. **1–4**, the transducer assembly comprises a hollow housing **12** having a bottom wall **14** and a removable top cover plate **16** that is secured in place by screws (not shown). As seen in FIGS. **3** and **4**, the inner face of bottom wall **14** has raised section or land or rib **18** that extends between the housing's side walls **20** and **22**. The land **18** is formed with four spaced openings or slots **24** that are elongated lengthwise of the land and which are countersunk as shown at **26** so as to form shoulders **28**. Attached to the bottom wall **14** are the four transducers **10**. Each transducer comprises a hollow plastic bobbin **30** containing an annular coil **32** formed by winding up an insulated flat strip of conductive material, e.g., a copper strip. Each coil **32** is secured in its bobbin by a suitable potting material **34** and its opposite ends are attached to two terminals **36** that are secured in the bobbin. Each bobbin has a center hole to accommodate a screw **40** whose head is recessed in a countersunk formed in the bottom side of the bobbin. The screws **40** extend up through the holes **24** and a nut **42** is mounted to each screw. The nuts **42** bear against the shoulders **28** and coact with the screws to draw the bobbins tight against the lower surface of the housing's bottom wall **14**.

Releaseably attached to the underside of bottom wall **14** by means of screws **44** is transducer alignment plate **46**. The latter is formed with four circular openings **48** that are just large enough to accommodate the four bobbins **30**. Plate **46** and bobbins **30** preferably have the same thickness so that their undersurfaces are flush with one another as shown in FIG. **4**. Two spacer plates **50** are attached to the underside of alignment plate **46** at each end thereof. These spacer plates prevent the transducers from contacting the carton to be inspected.

It is to be noted that the alignment plate **46** determines the spacing of the transducers and that another alignment plate with the same size but differently spaced transducer openings is used when cans different in size from cans **8** are to be tested (elongate openings **24** permit the transducers to be moved closer or further apart merely by loosening the nuts **42**).

Anchored in the side walls **20** and **22** of the housing **12** are two tubular members **52** and **54** that in this case function as handles. Mounted on these members are two adjustable side spacers or guide plates **56** and **58.** Preferably the inner faces of these members have bevelled side and bottom edges as shown so as to facilitate introducing between them a case to be inspected. Plates **56** and **58** are provided with split ears **60** that have an opening just large enough for them to be slipped onto the members **52** and **54.** Screws **64** mounted in and connecting the two portions of each ear are employed to draw them together so as to lock plates **56** and **58** to handles **52** and **54** respectively.

The tubular handle member **52** also serves as a feedthrough for a power cable **60** that extends from and is connected to the console **4.** Cable **60** comprises a plurality of electrically insulated conductors **68** that are connected to appropriate ones of the terminals **36.** A unique feature of the apparatus consists of twisting the conductors around one another as shown. This has the effect of cancelling out the magnetic fields of the coils. If the conductors are not twisted around one another, the magnetic field of the conductors will interact with one another and/or the magnetic fields of the coils and this interaction will cause the conductors to slap against the housing and create a background noise which makes it difficult for the operator to effectively determine whether a bad can is present.

The transducer assembly also includes a proximity sensor **70** which is mounted in a holder **72** that is secured to guide plate **56.** The sensor **70** extends into an opening in guide plate **56** and is flush with or preferably terminates short of the inner face of the guide plate so as to minimize the possibility of its being damaged during use. The sensor **70** functions as a proximity switch and may be of the well-known inductive or capacitive type which can detect the presence of a metal can or lid and is adapted to produce an output signal whenever a can or lid is sensed. The sensor is aligned with the centers of the four transducers and is sized so that it will produce a suitable output signal only when it is aligned with a metal can or lid. Hence the proximity sensor will not produce an output signal when the transducers are positioned between two rows of cans and will produce the desired signal as the transducers and a row of cans are brought into alignment with each other.

Various well-known proximity controls may be employed. A preferred form of control comprises the Model 4943 sensing head and Model 55141 electronic module produced by Electro Products Laboratories Inc. of 6125 West Howard St., Chicago, Ill. which together are capable of providing non-contact metal sensing at up to 5,000 operations per second. The Model **55141** electronic module produces an output voltage of +12 volts when a metal object is near the Model 4943 sensing head and a −0.5 volt output when no metal object is near the sensing head. Another suitable proximity control is disclosed in the book by Harry N. Norton, *Handbook of Transducers for Electronic Measuring Systems*, pp. 171–173 (see FIGS. 3–6 (*a*) and 3–6(*b*)), published by Prentice Hall (1969). Another metal detector which uses an unstable oscillator with an inductive probe is disclosed by D. D. Darling, *Simple R. F. Proximity Detectors*, Radio-Electronics, Dec., 1966, 47–48. The sensor is connected to the electronics in the console **4** by a cable **73** that conveniently extends through the coils of the power cable **66.**

Completing the transducer assembly are a "Locate Switch" **76** and four neon bulbs **78** that are mounted to cover plate **16.** Switch **76** is a push-button switch of the type that is normally open and remains closed only so long as its actuating button is depressed. Each of the bulbs **78** is connected in parallel with one of the transducer coils.

Referring now to FIG. **6,** the control system comprises a transformer **80** whose primary coil is connected via an ON-OFF switch **82** to an appropriate A.C. power source. The secondary of transformer **80** is connected in series with a rectifier **84** whose output terminals are connected in a charging circuit consisting of a charging resistor made up of two resistors **86** and **88** and a capacitor **90.** A bleeder resistor **92** is connected across capacitor **90.** A second switch **94** ganged to switch **82** is connected across resistor **88** and capacitor **90.** Switch **94** is closed when switch **82** is open and opens when switch **82** closes.

One side of capacitor **90** is connected via a line **98** to one end of each of the transducer coils **30.** The other side of capacitor **90** is connected via a line **100** to the cathodes of four SCR's **102** whose anodes are connected to the opposite ends of coils **30.** A diode **104** is connected across the anodes and cathodes of each of the four SCR's **102** as shown. The gates of each of the SCR's is connected to line **100** via a dropping resistor **106** as shown. A protective diode **108** is connected across each of the resistors **106.** The neon bulbs **78** are connected in series with dropping resistors **110** across the coils **30.** Connected across the capacitor **90** is a voltage divider network consisting of two resistors **112** and **114** and "Locate Switch" **76.** Connected across resistor **114** is a capacitor **116.**

The gates of the four SCR's are connected via coupling capacitors **120** to the four output lines of a four stage ring counter **122.** This form of counter is exemplified by Fitchen, *Electronic Integrated Circuits and Systems*, page346, Van Nostrand 1970. Clocking of the counter is accomplished in response to the output of the proximity sensor **70** which is connected to an electronic controller **124,** e.g., Electro Products Model 55141 electronic module, that produces a positive signal voltage when a can is detected by the sensor. Counter **122** is operated by a clock generator that is started by the output of controller **124** via a diode **128** that is coupled between the output line **127** of the controller and one output line **129** of a suitable low voltage d.c. power supply via a fixed resistor **130** and a variable resistor **132** that is adjusted by a knob **133** on the front panel of console **4.** The other output line **131** of the d.c. power supply is connected across resistors **130** and **132** via a capacitor **134.** A second capacitor **136** and the drain and source electrodes of an FET transistor **138** are connected across capacitor **134.** The gate electrode of transistor **138** is connected via a line **140** to the junction of resistor **114** and switch **76.** A unijunction transistor **144** has its Base **2** electrode connected to line **129** and its Base **1** electrode connected to line **131** via

a resistor 146. The latter electrode is connected via a coupling capacitor 150 to the clock input line of the ring counter. The emitter of unijunction transistor 144 is connected in series with resistors 130 and 132.

Operation of the foregoing electrical system is as follows: Assume that the transducer assembly is positioned over a carton of sealed cans so that the sensor 70 is proximate to a metal can or a jar with a metal lid and also switches 82 and 94 are closed and open respectively. Under these conditions, the sensor 70 will cause its associated electronic module 124 to produce a positive voltage signal along line 127. This signal, by back-biasing diode 128, permits capacitor 134 to charge via resistors 130 and 132 up to a level sufficient for the unijunction transistor 144 to fire. When this occurs the ring counter provides an output along one of its output lines that triggers one of the SCR's. The firing of an SCR causes the capacitor 90 to discharge through the transducer coil 30 associated with the triggered SCR. Capacitor 134 is discharged when transistor 144 fires and the latter shuts down when the capacitor has discharged to a suitable level. Assuming that the proximity sensor is still proximate to a can or a metal jar lid, the voltage on line 127 will remain high and transistor 144 will fire again as soon as capacitor 134 has recharged to a suitable voltage level. Hence counter 122 will be clocked again and will provide an output along another of its output lines so as to cause a second SCR to fire and discharge capacitor 90 through the transducer coil associated to the second SCR. This process will be repeated as long as the output line of the control module 124 remains high. Hence the transducer coils will be fired sequentially and repetitively at a repetition rate determined by the RC constant provided by resistors 130 and 132 and capacitor 134.

If now the LOCATE button switch 76 is closed and held so by the operator, the field effect transistor 138 will conduct and thereby place the capacitor 136 in parallel with capacitor 134. This has the effect of increasing the time required for capacitor 134 to charge up to the level required to fire transistor 144, with the result that so long as switch 76 is closed transistor 144 will fire at a lesser repetition rate. Hence, the counter 122 will cause the transducer coils 30 to fire at a reduced repetition rate. It is to be noted that the nature of a ring counter is such that so long as it is clocked at a set frequency, output signals will be produced on its output lines sequentially at the same frequency. In practice, the values of the resistors 130, 132 and 146 and the capacitors 134 and 136 preferably are set so that as long as switch 76 is open and a can is being sensed by the proximity sensor 70, the four stage ring counter will cause the transducer coils 30 to be energized sequentially at a frequency of about 16–20 times per second, and when switch 76 is closed, the counter 122 will cause the coils to be energized at a frequency of about four times per second. In other words, when switch 76 is open, each can will be pulsed four to five times per second and when it is closed, each can will be pulsed about one time per second. It is to be noted that adjustment of variable resistor 132 will modify the RC time constant controlling the firing of transistor 144, thereby varying the rate at which the ring counter is clocked to suit the preference of the individual operator.

One mode of using the above-described apparatus is as follows: With switch 80 closed, the operator places the transducer assembly over one end of a case of canned goods in the manner shown in FIG. 1. Assume that the case contains 24 cans arranged in six rows and four columns. The guide plates 56 and 58 are adjustably spaced so as to cause the transducer heads to be aligned with the four columns of cans in the carton. The operator then moves the transducer assembly relative to the carton or vice versa so that the transducer assembly passes along successive rows of cans. Each time the proximity sensor 70 is located adjacent to a can, the transducer coils 30 are energized sequentially so as to cause the cans to ping sequentially and repetitively. The operator listens to the sounds of the pings and as soon as he senses that a bad can is present, he can facilitate location of the bad can by closing the locate switch 76. This reduces the rate at which the transducer coils are repetitively energized so that the bad can or cans may be more easily located. The operator can then mark the location of the bad can on the case. Thereafter the transducer assembly is moved along the entire case so as to scan successive rows of cans in turn. The neon bulbs 78 light up sequentially as the coils with which they are associated are energized.

FIG. 5A shows a modification of the invention. In this case each of the screws 40 is replaced by hollow threaded studs 40A having flanged heads that bear against the underside of the bobbins 30. Nuts are screwed on the upper ends of these studs to hold the bobbins in place. Mounted within each hollow stud is a marker rod 156 having a point at its bottom end. The rod 156 extends through the cover plate 16 and is provided with an enlarged head 160. A roll pin 162 is secured in rod 156 to limit its upward movement. A compression spring 164 disposed between the head 160 and cover plate 16 keeps rod 156 in the retracted position shown in FIG. 5A. This modification of the invention facilitates marking the location of a bad can. As soon as the operator has determined the location of a bad can, he marks that location by pressing down on the rod 156 so as to cause its pointed end to form a permanent depression or small mark in the carton to signify the location of a bad can.

The modification of FIG. 5B is similar to that of FIG. 5A except that the rod 156 is the moveable armature of a solenoid 168 which is secured to the upper surface of cover plate 16. Attached to the upper end of the solenoid 168 is a push button switch 170. The latter is connected to the energizing circuit for the solenoid 168. In this case, when a bad can is located, the operator merely presses the operating button 172 of switch 170, thereby energizing the solenoid 168 so as to cause armature 156 to move downward to mark the carton. The built-in return spring of the solenoid causes the armature to be withdrawn when the solenoid is deenergized, which occurs when the button 172 of switch 170 is released.

A second mode of using the apparatus of this invention is to fix the transducer assembly to a suitable support over a conveyor so that cartons on the conveyor will move between the guide plates 56 and 58 immediately below the transducers. Because of the proximity sensor, the transducers will be energized sequentially each time a row of cans in a carton moves into alignment with the proximity sensor. In this mode of operation, the speed of the conveyor is preferably set so that the containers in each row of containers are each pulsed at least twice, but preferably three or four times.

This affords ample opportunity for the attendant to detect the presence of a bad can.

It is to be noted that the spacer plates **50** prevent the upper surfaces of the cartons being inspected from engaging the transducers (see FIG. **4**). Providing a gap, preferably in the order of 0.1 inch, between the cartons and the transducers is important since it maximizes the intensity of the pings being heard by the operator and also minimizes the possibility of damaging the transducer heads or cartons.

It is to be noted that some cartons are packed so that every other can or jar in a row is offset with respect to each adjacent can or jar, i.e., so that the row of containers is zig-zag instead of being straight. In such event, the transducers will be offset correspondingly in the manner illustrated by the circles **180** shown in phantom in FIG. **2**. Hence, as used in the following claims, the term "row" is to be considered as indicating both a straight row and a zig-zag row.

The switch **94** is for safety purposes. When the on-off switch **82** is reopened, switch **94** closes to discharge capacitor **90** and thus removes any high voltage hazard when the unit is off.

It is to be noted that if the transducer assembly is held stationary and the cartons moved beneath the transducers as described above, the proximity sensor may be replaced by a plurality of limit switches mounted next to the conveyor and arranged to be closed sequentially by the carton as each successive row of cans in the carton moves below the transducers. The closing of each such limit switch may be used to operate the clock generator. By way of example, the limit switches may be mechanical or may be of the photo-responsive type.

Still another operating mode is to disable the proximity sensor. This prevents diode **128** from conducting and, as a consequence, the clock will run continuously and the coils will sequentially tap the cans continuously. While one row of cans is approaching a central position under the transducer heads, the pings of sound from them get louder, reaching full intensity when the cans are centered under the row of transducers and fading out again as the row of cans moves past the centerline of the row of transducers. If all of the cans in the row have substantially the same internal pressure, the pings of sound heard have a steady tonal pattern although the amplitude of the sounds heard will slowly rise and fall. However, if there is a bad can in the row, the distinctive rhythmic pattern described above is heard clearly as the row of cans approaches, reaches, and then passes the row of transducers. This mode of operation also permits increased conveyor speeds while still providing sufficient pulses from a bad can to establish the distinctive rhythm.

It also is contemplated to modify the above-described apparatus by embodying a system for automatically operating appropriate ones of the marker solenoids **168** in response to pings indicative of bad containers. Such a system would comprise detector means, e.g., a microphone, for detecting the pings and producing therefrom electrical signals of corresponding frequencies, discriminator means for determining from the electrical signals whether the corresponding containers are good or bad and for producing an output signal each time a bad container is found, and means for operating appropriate ones of the marker solenoids in response to such output signals. A detector-discriminator system suitable for such a modification is disclosed in our copending U.S. Patent Application Ser. No. 261,528 filed June 9, 1972 for Pressure and Vacuum Monitoring Apparatus. Still other modifications will be obvious to persons skilled in the art from this specification.

What is claimed is:

1. A device for inspecting a plurality of sealed containers with electrically conducting end closures that are enclosed within a carton and are arranged in rows and column, said device comprising:

a plurality of electromagnetic coils arranged in a single row and equal in number to the total number of containers in a single row in said carton; and

electrical means for sequentially and repetitively energizing the coils in said plurality of coils by a sudden discharge of electrical energy therein so as to produce repetitive audible sounds from containers that are positioned adjacent to and in line with said coils, said electrical means being adapted to energize said coils so that the period between the energization of any two successively energized coils of said plurality of coils is substantially the same as the corresponding period of any other pair of successively energized coils of said plurality of coils.

2. A device according to claim **1** wherein said electrical means is adapted to energize each coil between about **2** and **8** times per second.

3. A device according to claim **1** consisting of four coils.

4. A device according to claim **1** further including control means for operating said electrical means only so long as said coils are adjacent to and aligned with containers.

5. A device according to claim **4** wherein said control means comprises means for sensing when said coils are adjacent to and aligned with a row of cans.

6. A device according to claim **1** wherein said electrical means comprises means for storing electrical energy, a plurality of switches equal in number to said coils, means connecting each of said switches in series with one of said coils and said electrical energy storage means, means normally biasing said switches to an open condition, means for sequentially and repetitively closing said switches so as to sequentially and repetitively energize said coils by the discharge of electrical energy from said electrical energy storage means, and means for replenishing the electrical energy through one of said coils.

7. A device according to claim **6** wherein said switches are solid state devices.

8. A device according to claim **7** wherein said switches are controlled rectifiers each having a gate electrode, and said means for sequentially and repetitively closing said switches comprises means for sequentially and repetitively applying electrical signals to said gate electrodes.

9. A device according to claim **8** wherein said means for sequentially and repetitively applying signals to said gate electrodes comprises a ring counter having a different output line for each controlled rectifier, means coupling said output lines to said gate electrodes, and means for incrementing said counter so that signals for firing said rectifier appear sequentially and repetitively on said output lines.

10. A device according to claim **9** wherein said means for incrementing said counter comprises means for generating a train of clock pulses at a steady fre-

quency, and means for applying said clock pulses to said counter.

11. A device according to claim **10** further including means for varying the frequency of said clock pulses.

12. A device according to claim **10** including means for preventing generation of said clock pulses until said coils are positioned adjacent to and in line with containers to be inspected.

13. A device according to claim **1** comprising:

a housing;

means mounting said coils to said housing;

guide means connected to said housing for aligning said housing with a carton to be inspected; and

switch means for controlling the operation of said electrical means.

14. Apparatus according to claim **1** including a support for said coils, means mounting said transducer coils to said support, and carton-marking means mounted to said support for marking the location of each container with unsatisfactory internal pressure.

15. The method of inspecting a closed carton of sealed containers that have electrically conductive end closures and are arranged in said carton in discrete rows, comprising providing a single row of electromagnetic coils, one coil for each container in a single one of said discrete rows, locating said row of coils and said carton adjacent one another so that said coils are aligned with the containers in one of said rows, sequentially and repetitively energizing said coils at a selected substantially constant repetition rate by discharging impulses of electrical energy therethrough so as to sequentially and repetitively produce audible sounds by deflection of the end closures of the containers in said one row, providing relative movement between said row of coils and said carton so that successive ones of said discrete rows are aligned with said row of coils, and repeating the aforesaid sequential and repetitive energizing of said coils each time said coils are aligned with others of said discrete rows of containers.

16. The method of inspecting a closed carton of sealed containers that have electrically conductive end closures and are arranged in said carton in discrete rows and columns, said method comprising locating a single row of electromagnetic coils and said carton so that said row of coils extends parallel to said discrete rows and each coil is aligned with a different one of said columns, providing relative movement between said row of coils and said carton so that successive ones of said discrete rows are successively aligned with said row of coils, and sequentially and repetitively energizing said coils at a selected substantially constant repetition rate by discharging impulses of electrical energy therethrough so as to sequentially and repetitively produce audible sounds by deflection and vibration of the end closures of the containers in each row.

17. The method of claim **16** wherein each of said coils is energized from about two to about eight times per second.

18. The method of claim **16** wherein said relative movement is produced by holding said coils stationary and moving said carton.

19. The method of claim **16** wherein said relative movement is achieved by moving said coils.

20. The method of claim **16** further including the step of discriminating the sounds produced by said containers row by row to determine the internal pressure conditions of the containers in each of said rows.

21. The method of claim **20** further including the step of reducing the frequency of energization of said coils whenever the sounds produced by the containers in any one of said rows are indicative of an unsatisfactory pressure condition in any one of the containers in said any one row.

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