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(54) Abstract Title
Methods for detecting surfaces in vending machines

(57) A method for detecting the presence and location of a surface in a coin validator includes the step of detecting the time taken for an acoustic pulse to reach a receiver 10, wherein the acoustic pulse is produced by an electrical discharge. A method of detecting the configuration of a coin passage by timing an acoustic pulse is also disclosed, as is a similar method for detecting the quantity of a vendible product in a vending machine. A vending machine which uses such a method may include means for transmitting an indication of the detected quantity to a remote location. The acoustic pulse may have a duration of less than 100 microseconds. The above methods can be used to evaluate the number of coins in a coin stack 4, and to detect coin jams.
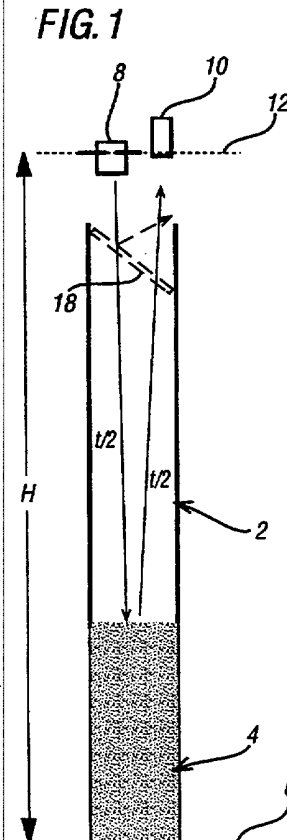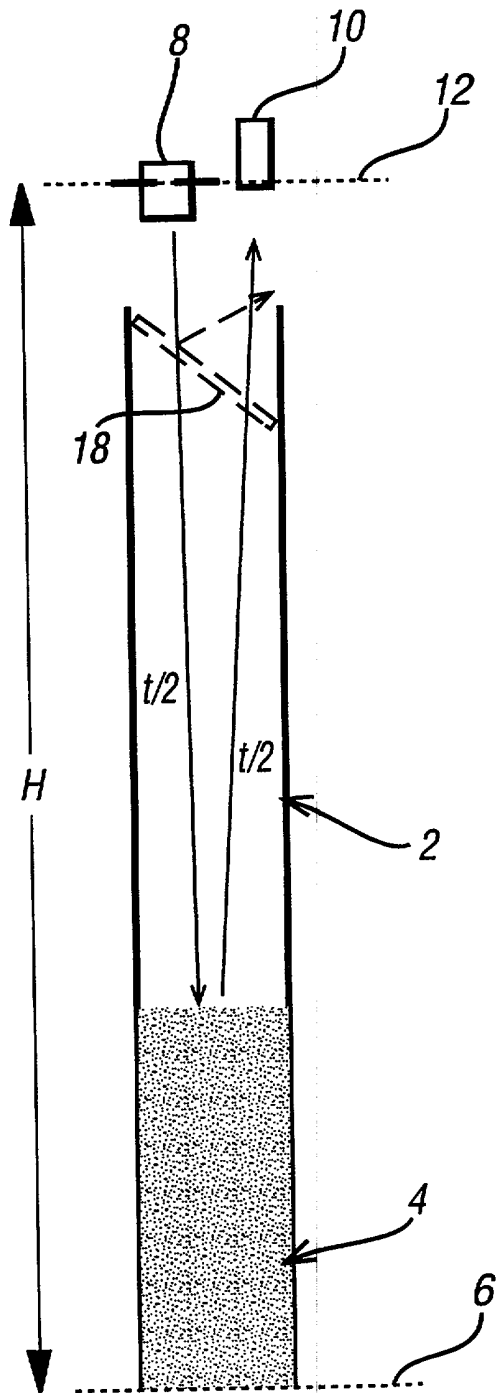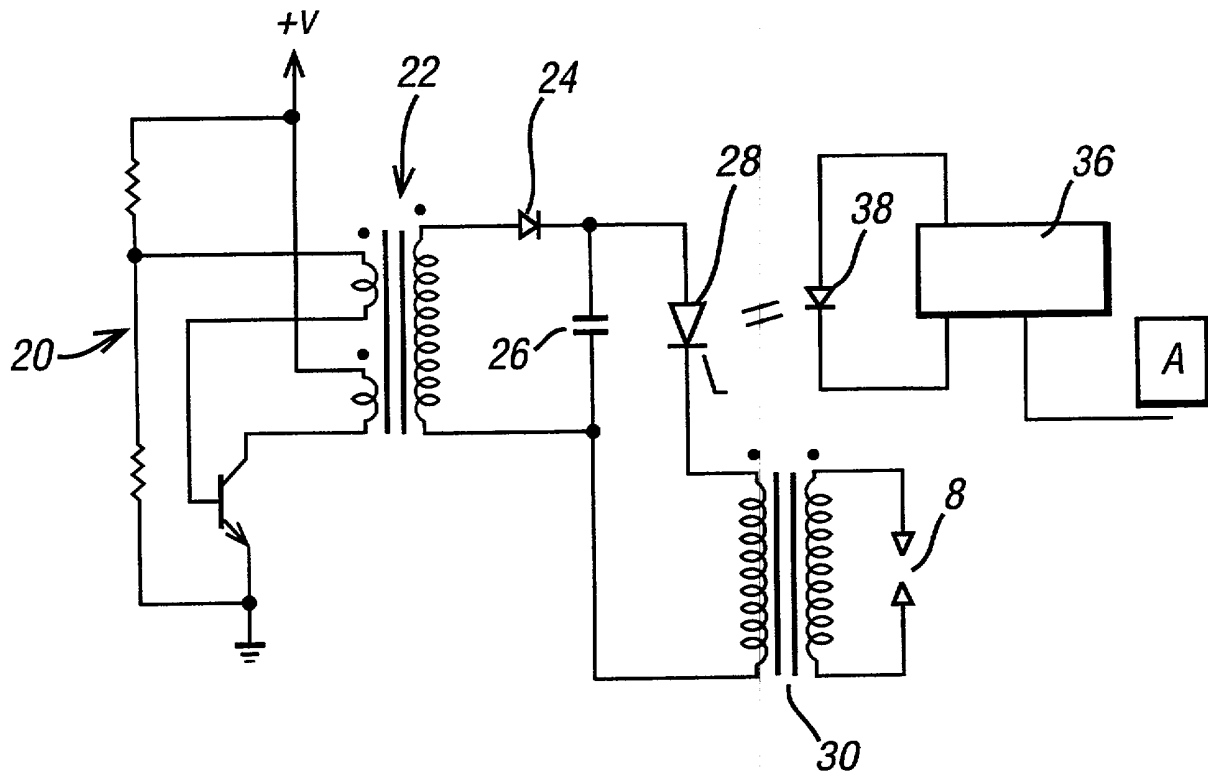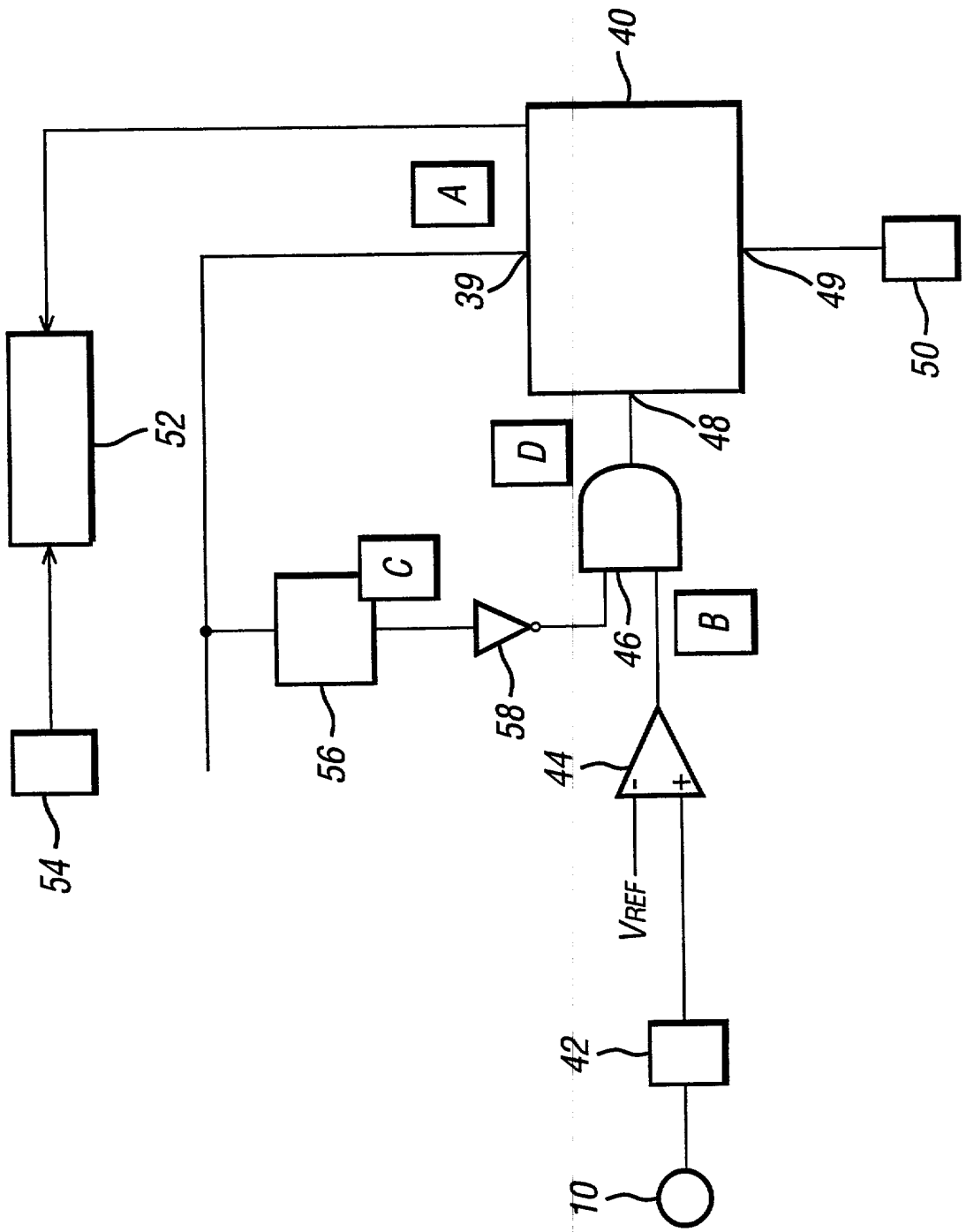
FIG. 1

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FIG. 1

FIG.2a

FIG. 2b

A

39

40

49

50

48

D

52

C

56

58

B

46

44

−

+

V_{REF}

42

54

10

FIG.3

FIG. 4a

10

84

8

82

80

FIG. 4b

10

90

8

2
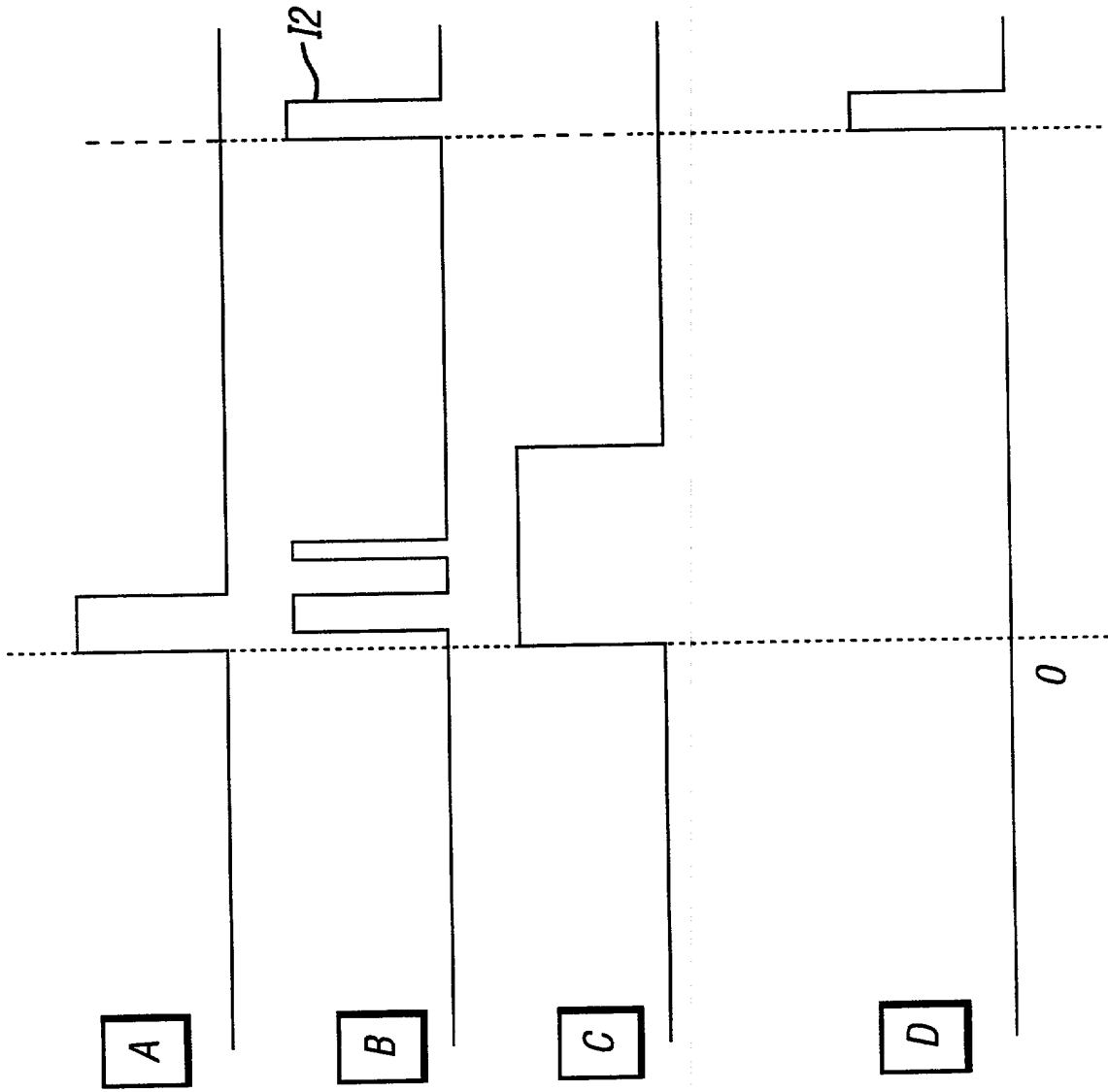
FIG. 5

FIG. 6

VENDING MACHINES AND COIN VALIDATORS

This invention relates to vending machines and coin validators.

Certain aspects of the invention are of particular relevance to vending

5   machines.

Vending machines typically have to been visited frequently by a

routeperson to check that none of the stock items has run out. The visits need

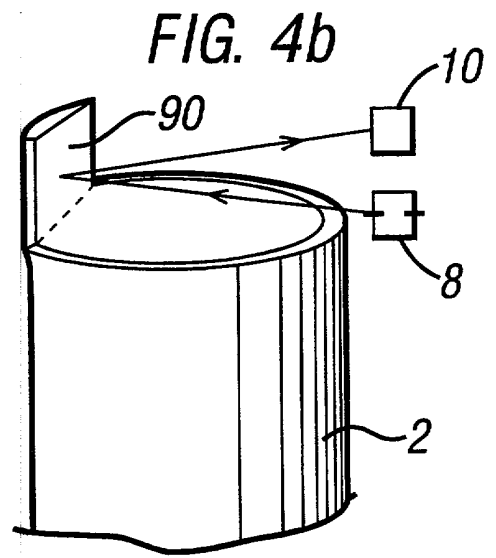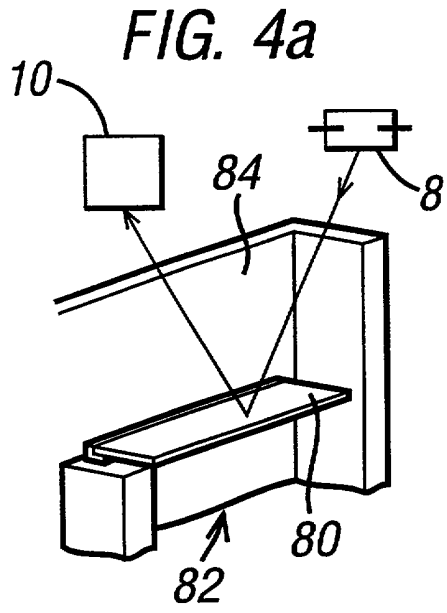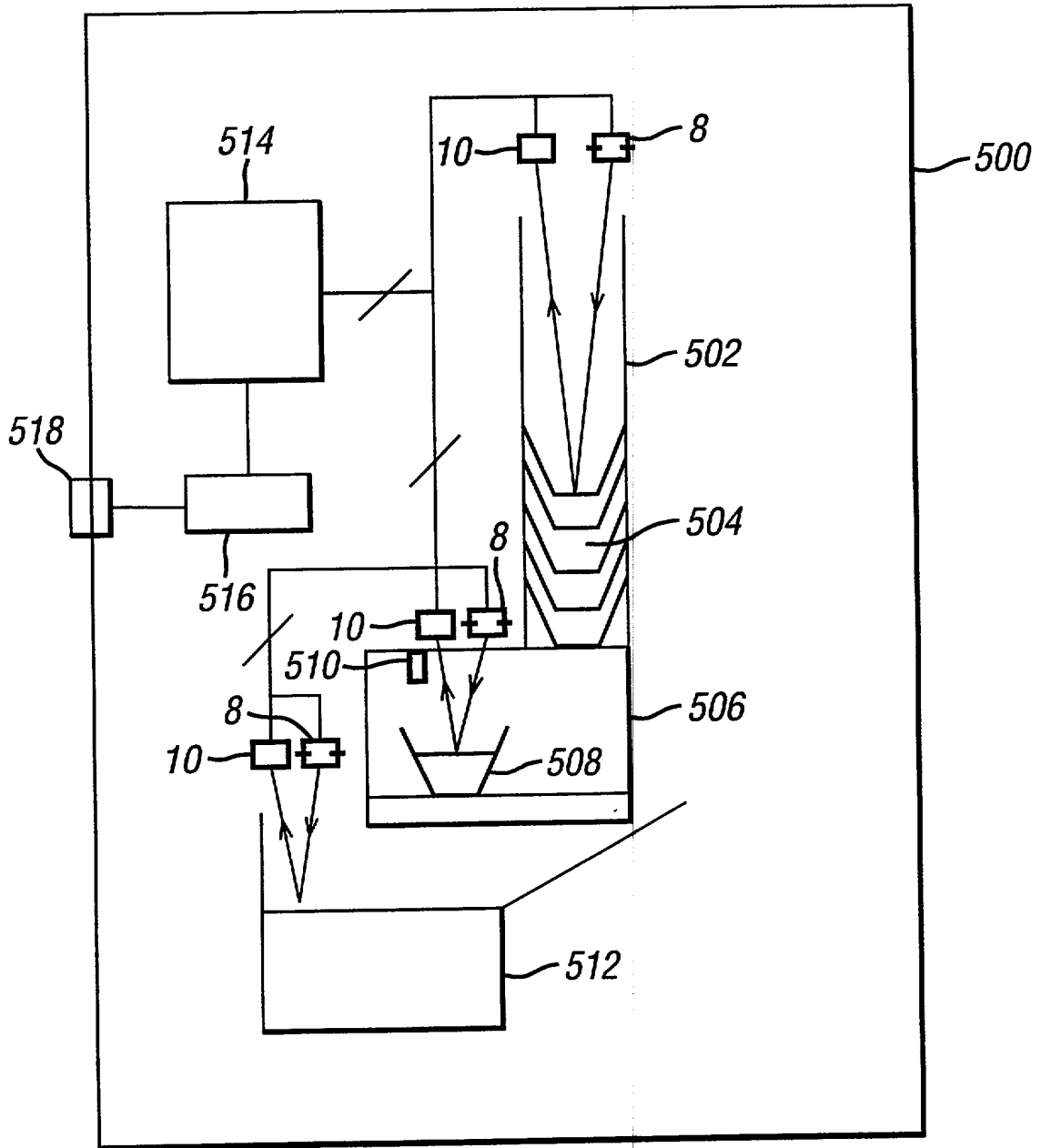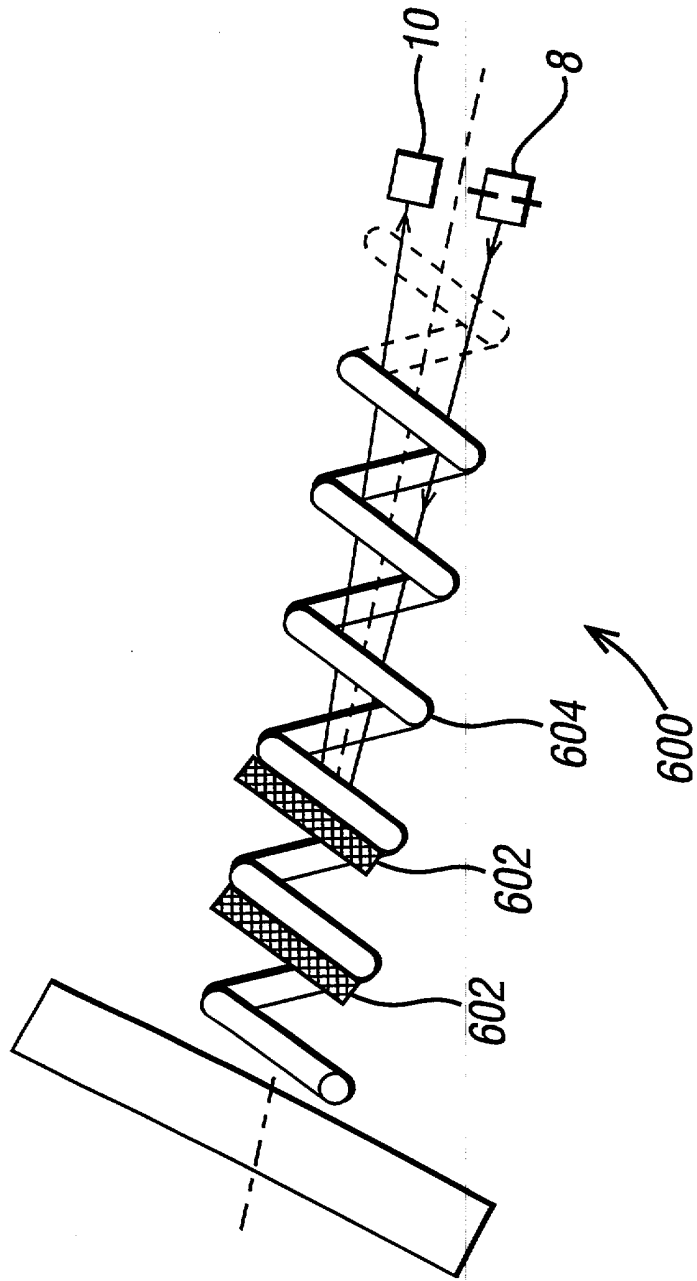to be frequent enough to prevent stock items from running out, resulting in

lost sales, but not so frequent as to result in unnecessary effort. This can be

10   difficult to plan, especially as the rate at which items are sold can vary.

Vending machines can develop faults whereby a product which is

intended to be vended becomes jammed, and therefore a customer who has

paid for an item may find that he does not receive that item. To avoid this

consequent loss, it is known to provide vending machines with sensors which

15   determine whether a product has been vended as intended. It is also known to

provide a sensor which detects when a product has run out, and in response

thereto inhibiting further vends.

According to an aspect of the present invention, there is provided a

vending machine which has means for measuring a quantity of a vendible

20   product stored therein. Such an arrangement can be used for multiple

purposes. It is possible to determine whether the quantity of the vendible

product changes following an intended vend, thereby to confirm that the vend

has taken place. If the sensed quantity does not change appropriately, the machine can be caused to attempt again to vend the product, in the hope of clearing a fault or jam. It is further possible to ensure that vends are inhibited if the level is determined to be zero. In a preferred aspect of the invention,

5 however, a signal representing the sensed quantity is transmitted to a remote location, so that it is possible to determine, before a product has run out, that replenishment will soon be required, and a visit from a routeperson can than be arranged.

Although this aspect has been described in the context of measuring

10 the quantity of products available for vending (and these products could be of any type, such as packages, cups, cans, or bulk items of liquid or granular solid), similar advantages can apply to use of the technique for measuring waste products, such as liquid overspill in a waste container, as the techniques will provide advance warning of when a routeperson is required. Another

15 alternative is to measure the quantity of an item being vended (such as liquid in a cup), so as to obtain a more accurate vend than is achieved simply by, e.g. a timing operation.

Various techniques can be used to determine the quantity of a vendible product. However, there is one particularly preferred technique, which is

20 relatively cheap to implement and which is suited for use with many different physical configurations. Consequently, according to a preferred embodiment of the invention, the quantity of a vendible product is determined by

generating an acoustic impulse and determining the time taken for a reflection of the impulse from a surface to reach a receiver. As described below, a technique like this has previously been described (in GB-A-2190749) for measuring the quantity of coins in a storage tube. There is further explained

5   below a particularly advantageous improvement which has been applied to the technique, and which is of benefit when used in a vending machine according to the present aspect of the invention.

Other aspects of the invention are of particular relevance to coin validators.

10   Coin validators commonly include many sensors, for example for detecting the properties of inserted coins, detecting the presence of coins at various locations within the coin path, detecting the level of coins within coin stores, etc. Many attempts have been made to produce sensors which are more effective, more compact and/or less expensive.

15   One example is shown in GB-A-2190749. The disclosed arrangement monitors the level of coins within a coin tube by directing a train of ultrasonic pulses towards the top of the stack and measuring the time between the emitted and reflected pulses. Such an arrangement has the advantage of providing an indication of the absolute level of coins, rather than merely an

20   indication of whether or not the level has exceeded a certain threshold, as is the case with many common level sensors. However, the described arrangement suffers from a number of disadvantages. It is difficult to

construct, because the ultrasonic transducer is a resonant structure and therefore produces ringing. Any damping used to reduce this ringing will also reduce the power output, leading to potential noise problems. Furthermore, if a substantial proportion of the transducer output is coupled into the

5   surrounding structure, this can result in saturation of the receiving microphone. The transducer has to be spaced by a large distance from the stack of coins, because otherwise the microprocessor will detect the reflected pulse before it has ceased detecting the emitted pulse, so that the overall structure is large, in addition to being difficult to assemble.

10   It would be desirable to mitigate at least some of these problems.

It would be desirable in addition to provide simple and cost-effective techniques for detecting various aspects of the configuration of a coin validator, so that faults and jams can be sensed or avoided.

According to a further aspect of the invention, a coin validator is

15   provided with an electrical spark generator. In order to detect the location or presence of a surface, the spark generator is actuated to produce a pressure wave. This is reflected from the surface (assuming the latter is present) to a microphone. The sensing of the reflection by the microphone provides an indication of the presence of the surface and the transit time provides an

20   indication of the location of the surface. The spark generates a powerful pressure wave with a very steep rise-time and a very brief duration. The steep rise time provides a very accurate result as compared with, for example, the

arrangement of GB-A-2190749, in which the relatively shallow rise time means that the calculation of the surface location from the sensing of the reflected pulse will be amplitude dependent and therefore inaccurate. The short duration of the pulse allows the spark generator to be located close to the

5   surface being detected without running the risk of the emitted pressure wave being detected contemporaneously with the reflected wave.

Other aspects of the invention are directed to the idea of using acoustic impulses for detecting the configuration of a coin validator; thus, for example, an acoustic impulse can be used to detect whether or not a coin store is present

10   or whether or not a coin routing gate is in a predetermined position, by determining whether the reflected acoustic impulse is received within a particular time period. An acoustic impulse could also be used for detecting a dimension of a coin store (for example the width of a coin tube) by sensing how long it takes for the impulse to reach the receiver after having been

15   reflected off a wall of the store. The presence of a jammed coin in a particular orientation will also be detected as a result of interference with the acoustic impulse. All these possibilities are made more practicable by the use of particularly short impulses, preferably less than 100 microsecond and more preferably less than 25 microseconds, such as may be generated by an electric

20   spark.

Various embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:

Fig. 1 is a schematic view of a coin tube of a coin validator, which has associated therewith a level sensor operating in accordance with a method of the present invention;

Figs. 2a and 2b are diagrams of a circuit for operating the level sensor;

5   Fig. 3 is a diagram of waveforms appearing in the circuit of Figs. 2a and 2b;

Figs. 4a and 4b are schematic diagrams showing various configurations of a coin validator that could be detected using the techniques of the present invention;

10   Fig. 5 is a schematic view of a vending machine according to the invention; and

Fig. 6 is a plan view of a product dispenser in another vending machine according to the invention.

Referring to Fig. 1, a coin tube 2 has stored therein coins 4 in a face-

15   to-face vertical stack, resting on a base the level of which is indicated by datum line 6. An acoustic impulse generator, in the form of a spark gap 8, and a microphone 10, are located above the coin tube 2. In this embodiment, both the spark gap 8 and the microphone 10 are located on a sensor datum 12 located at a height H above the base 6 of the coin stack (although it would be

20   possible for them to be mounted at different heights).

In order to detect the level of coins in the tube 2, a control circuit causes the triggering of a spark, and the time taken for the resulting acoustic

impulse to be reflected off the uppermost coin in the stack 4 and travel to the microphone 10 is measured. Assuming that the time taken is t, and the speed of sound is V, then the stack height is given by $S = H - Vt/2$.

$V = 331.29 \times \sqrt{(T/273)}$ m/s, where T is the absolute temperature.

5   Accurate results can be obtained by assuming an average temperature; however, in the preferred embodiment, a temperature sensor is used to provide even greater accuracy. This assumes that the height H is known to sufficient accuracy, which can be achieved either by control of manufacturing tolerances, or by an initial calibration operation in which the reflection time t

10   is measured with the coin tube empty and then H is calculated to be equal to Vt/2.

Referring to Figure 2a, an oscillator 20 is coupled to an inverter transformer 22. The output of this is rectified by a diode 24 and the DC output stored on a capacitor 26, providing approximately 250 volts DC. This

15   voltage is coupled, via a thyristor 28, across a step up transformer 30. Upon triggering of the thyristor 28, a voltage of approximately 9kV is generated at the output of step up transformer 30, which is connected across the spark gap 8. This produces a powerful spark having a rise time of less than 20 microseconds. The power of the spark is coupled directly to the air, rather

20   than to the surrounding structure, thus resulting in a very efficient and brief acoustic impulse.

The thyristor is triggered at regular intervals, e.g. 50 Hz, by a spark rate generator 36, which is coupled to the thyristor by an optical interface including an LED 38.

The spark rate generator 36 also has an output A which is delivered to the detection circuit shown in Figure 2b. This output A carries a single pulse each time a spark is generated. This pulse is applied to a start input 39 to start a counter 40.

The output of the microphone 10 is delivered through an amplifier 42 to a comparator 44. The comparator output rises whenever the microphone detects a sufficiently loud signal, such that the amplifier output exceeds a threshold V_{REF}. The rising comparator output is applied, via an AND gate 46 to a stop input 48 of the counter 40. The clock input 49 of the counter 40 is coupled to a 10 MHz clock 50. Accordingly, the counter counts for the time between the spark being generated and the reflected impulse being received by the microphone 10. A processor 52 takes the output of the counter 40, and the output of a temperature sensor 54, in order to calculate the stack height S. The temperature sensor 54 could be a discrete sensor, e.g. a thermistor, or could be an output derived from a sensor used for other purposes, e.g. an electromagnetic sensor used to measure coin properties, in which case the sensor output when no coin is present could be used to indicate temperature.

Referring additionally to Figure 3, the waveform A represents the pulse sent to the counter 40 by the spark rate generator 36. Waveform B

shows the output of the comparator 42. It will be noted that the microphone detects pulses at around the time the spark is generated. The microphone will directly detect the acoustic impulse from the spark gap. Also, because the spark is so powerful, it will create a degree of ringing in the associated structure, even though a very small proportion of the power is coupled to the structure. This may create one or more additional vibrations which are picked up by the microphone 10.

In order to stop these initial pulses from interfering with the operation of the counter 40, a delay circuit 56 is provided to generate a blanking pulse shown at C in Figure 3. This lasts for approximately 150 microseconds from the beginning of the spark trigger pulse shown at A in Figure 3, and is sufficiently long to encompass any of the initial pulses sensed by the microphone. The pulse C is applied by an inverter 58 to another input of the AND gate 46, so that no output from the comparator 44 is transferred to the stop input of the counter while the blanking pulse C exists.

In the preferred embodiment, the spark generator is continuously activated at a desired rate. In order to improve resolution, the processor 52 may take a plurality of measurements from the counter 40 and average them.

In another embodiment, the spark rate generator 36 is replaced by a generator responsive to a signal from a validation circuit (not shown) which indicates that a coin is being routed to the coin store 2. In response to this, a first spark is generated in order to measure the level of coins in the tube and,

at a predetermined delay period later, a second spark is generated to take a further measurement. These measurements are compared, and if the difference does not represent an additional thickness corresponding to a single coin, an error signal is generated. In this embodiment, the measurements are

5   event-driven.

In a preferred version of the event-driven embodiment, the spark rate generator 36 is retained, and enabled for a predetermined period each time a measurement is made. This enables a plurality of readings to be taken and averaged to form each measurement.

10   Experiments suggest that, assuming a coin set wherein the thinnest coin has a thickness of 1.75 mm, assuming no temperature compensation is used and there is a possible 10°C variation in temperature, it is possible to obtain an accuracy which corresponds to half the thickness of a coin (with a level of 29 coins). However, the error is effectively eliminated by temperature

15   compensation. In a practical arrangement, it is possible, without undue effort, to confine variations due to mechanical tolerances to 25% of the thickness of the thinnest coin. It is also found that because of the fast rise time of the acoustic impulse, it is possible to measure a reflection time to 0.1 microseconds resolution. By averaging 10 readings, it is found that a

20   resolution equating to approximately 0.18 mm is obtained.

Accordingly, using the teachings of the invention, a measurement resolution which is better than the thickness of a single coin is readily

achievable. This compares with the arrangement in GB-A-2190749, in which experiments suggest that the rise time of the acoustic impulse is likely to be of the order of 250 microseconds, and the overall time of the impulse possibly in the order of 1.5 milliseconds. Furthermore, if the transducer is damped to

5 reduce the pulse width sufficiently, the power of the impulse is so low that noise problems present themselves. Accordingly, for practical purposes the resolution of a single coin would be very difficult, if not impossible, to achieve.

As explained further below, it is possible to apply the techniques of

10 the invention for detecting parameters other than the level of coins in a coin tube. It has been determined that similar techniques can be used to advantage for other purposes, and that this is made particularly practicable if it is possible to produce acoustic impulses which have a very fast rise time and short duration, because this enables the fitting of the detector into a compact

15 coin validator. Accordingly, an electrical arc discharge arrangement such as that mentioned above is particularly desirable. However, it may be possible to use other arrangements, for example, a damped piezoelectric transducer which is energised by a brief, high voltage, although it is envisaged that this would be significantly more difficult to achieve.

20 Separate acoustic impulse generators may be provided for different purposes in the coin validator. However, in a particularly preferred embodiment of the invention, generated acoustic impulses are used for

multiple purposes. This could be achieved by having several different microphones at predetermined positions so as to detect respective reflections from respective surfaces. Alternatively, as in the arrangement described in the following paragraph, the same generator and microphone can be used for

5   more than one purpose, given a suitable arrangement for analysing the output of the detecting circuitry.

Referring again to Figure 1, the invention could be used for detecting a coin jam. For example, if a coin is jammed in the position shown in phantom at 18, the reflected impulse from the spark gap may be directed away from the

10   microphone, possibly into the side wall of the coin tube. Alternatively, the reflection may have reached the microphone during the blanking period shown at C in Figure 3. Therefore, in the preferred embodiment, in order to detect such a jam, the processor 52 is arranged to determine when the count reached by the counter 40 exceeds a particular threshold, which indicates that

15   no appropriate reflection has been received by the microphone. In response thereto, the processor generates an error signal.

A similar effect is produced also if the coin tube 2 is not present. Accordingly, even if there is no possibility of a jam in the coin tube, the processor may be arranged to generate an error signal if no reflected impulse

20   is sensed by the microphone within a predetermined interval following the generation of the spark.

Referring to Figure 4a, an acoustic signal may also be used to determine whether a gate 80 is in a first position, in which it projects into a channel 82 forming a coin path, or whether the gate has been withdrawn behind the rear wall 84 of the path.

Referring to Figure 4b, an acoustic impulse may also be used to determine the width of a coin tube 2, possibly by reflecting the acoustic impulse off an upwardly projecting extension 90 of the tube. This procedure could be used for automatically configuring the coin validator so that coins of the correct size are directed to that coin tube. In these circumstances the same sensor may be used to detect the presence of the coin tube, or of a cassette containing this and other coin tubes.

The techniques of the invention could also be used for determining the level of coins in a cashbox, even when these are disposed in a disordered manner. In these circumstances, it may be desirable to use two or more level sensors, and/or the arrangement may be such that the sensor is intended to indicate only when the level exceeds the predetermined threshold.

It should be noted that the techniques of the invention could be used exclusively for purposes other than coin level sensing.

Referring to Fig. 5, this shows schematically a vending machine 500 in accordance with the invention. The vending machine 500 is a hot drinks dispenser. A cup store 502 stores cups in a stack 504, from which the botommost cup can be delivered to a filling compartment 506, as indicated at

508. Hot water is then fed to the cup 508 via a spout 510. Any spilled liquid drains into an overspill container 512.

The machine has three pairs of acoustic impulse transmitter/receivers 8, 10 forming respective level sensors, all coupled to a central controller 514.

5 Each is structured like the level sensor of Fig. 1. The controller 514 includes a control circuit like that of Figs. 2a and 2b, and is arranged to couple the control circuit to each level sensor in turn.

The level sensors are arranged to measure (a) the number of cups in the cup store 502, (b) the level of liquid dispensed into a cup 508 and (c) the

10 level of liquid in the overspill container 512. The controller is coupled to a modem 516, which is itself connected to a socket 518 for receiving a standard telephone cable. The arrangement is such that whenever the measured level of the cups in the sore 502 falls below a predetermined level, and whenever the level in the overspill container 512 exceeds a predetermined level, the

15 controller 514 uses the modem 516 to communicate with a remote location to advise that servicing will soon be required. As an alternative, the remote location can be arranged to poll the vending machine regularly, to determine the levels in the cup store 502 and the overspill container 512.

The controller 514 is arranged to terminate the dispensing of liquid to

20 the cup 508 if the level of the liquid therein exceeds a predetermined value.

The cups may be pre-filled with appropriate ingredients. Alternatively, there may be a separate store for the ingredients, in which case a further level sensor may be provided for this store.

It is not necessary for all these sensors to be provided. If more than one sensor is provided, it may be possible for them to use a common acoustic pulse generator 8. Although it is desirable for the sensors to use electric arc discharges to produce the acoustic impulse, this is not essential, especially if more room is available and/or less accuracy is required.

Fig. 6 shows a product dispenser 600 of a further vending machine according to the invention. This is of generally known form, wherein individual products 602 are disposed in respective turns of a helical structure 604. By rotating the helical structure 604 once about its axis, all products are moved towards an aperture 606, and the endmost product falls out of the structure into the aperture.

A level sensor incorporating an electric arc discharge device 8 and a receiver 10 are provided. The acoustic impulse from the arc travels along the axis of the helical structure 604, and is reflected to the receiver 10 by the last product held in the structure, so the time of receipt of the reflected impulse represents the number of products stored in the helix. This arrangement can be controlled and used as the arrangements described above.

In the arrangements of Figs. 5 and 6, if it is detected that the level of cups or products has decreased to zero, further vending is inhibited, and if it is

detected that the level has not decreased appropriately after a vend has been

instructed, a further attempt at a vend is made.

CLAIMS:

1.   A method for detecting the presence and/or location of a surface in a coin validator by detecting the time taken for an acoustic pulse to reach a receiver, characterised in that the acoustic pulse is produced by an electrical discharge.

2.   A method as claimed in claim 1, including the step of generating a signal having a value representative of the location of the surface.

3.   A method as claimed in claim 2, wherein the value is representative of the number of coins in a coin store.

4.   A method as claimed in claim 3, wherein the coin store is a tube in which the coins are stored face-to-face in a stack.

5.   A method as claimed in claim 3, wherein the store is a cashbox.

6.   A method as claimed in any preceding claim, including providing a signal indicating whether or not the surface has been detected.

7. A method of detecting the configuration of a coin passage in a coin validator, the method comprising generating an acoustic impulse and determining the configuration from the time taken for a reflection of the impulse from a surface of the passage to reach a receiver.

5

8. A method as claimed in claim 7, wherein the acoustic impulse has a duration of less than 100 microseconds.

9. A method as claimed in claim 7 or claim 8, wherein the acoustic

10 impulse is produced by an electrical discharge.

10. A method as claimed in any preceding claim, comprising the step of producing a signal indicating a coin jam in dependence upon the output of the receiver.

15

11. A method as claimed in claim 10, wherein the signal representing the coin jam is produced if the receiver does not produce an output which exceeds a predetermined threshold within a predetermined period.

20 12. A method as claimed in any preceding claim, including the step of providing a signal indicative of the presence of a coin store in dependence on the output of the receiver.

13.   A method as claimed in any preceding claim, including the step of producing an output representing the position of a coin routing gate in dependence on the output of the receiver.

5

14.   A method as claimed in any preceding claim, including producing a signal representing the size of a coin store in dependence on the output of the receiver.

10   15.   A method as claimed in any preceding claim, including the step of detecting the ambient temperature and determining the location of a surface reflecting the acoustic impulse taking into account the time taken for the reflection to reach the receiver and the temperature.

15   16.   A method as claimed in any preceding claim, including the step of repeatedly generating acoustic impulses for the purpose of continuous monitoring.

17.   A method as claimed in any one of claims 1 to 15, including

20   generating the acoustic impulse in response to a control signal representative of a detected event.

18. A method as claimed in claim 17, including the step of generating first and second acoustic impulses in response to a signal representing that a coin has been routed to a coin store, and determining whether the response of the receiver to the acoustic impulses differs in a way which indicates that the coin has been received in the coin store.

19. A coin validator having means for performing a method as claimed in any preceding claim.

20. A method for detecting the quantity of a vendible product in a vending machine, the method comprising detecting the time taken for an acoustic pulse to reach a receiver.

21. A method as claimed in claim 20, wherein the acoustic pulse has a duration of less than 100 microseconds.

22. A method as claimed in claim 20 or claim 21, wherein the acoustic pulse is produced by an electrical discharge.

23. A method as claimed in any one of claims 20 to 22, including the step of detecting the ambient temperature and determining the location of a surface

reflecting the acoustic impulse taking into account the time taken for the reflection to reach the receiver and the temperature.

24. A vending machine having means for performing a method as claimed in any one of claims 20 to 23.

25. A vending machine having means for detecting the quantity of a vendible product stored therein.

26. A vending machine as claimed in claim 25, wherein the detecting means is operable to determine the quantity by measuring the amount of time taken for an acoustic impulse reflected from a surface to be detected.

27. A vending machine as claimed in claim 26, wherein the detecting means comprises means for producing an electric arc discharge for generating the acoustic impulse.

28. A vending machine as claimed in any one of claims 25 to 27, including means for transmitting an indication of said detected quantity to a remote location.

29.   A vending machine substantially as herein described with reference to Fig. 5 or Fig. 6 of the accompanying drawings.

30.   A coin validator substantially as herein described with reference to any of Figs. 1 to 4 of the accompanying drawings.

31.   A method of detecting the presence and/or location of a surface, substantially as herein described with reference to any of the accompanying drawings.

The
**Patent
Office**

23

Application No: GB 9930522.9	**Examiner:** Michael Logan
Claims searched: 1-6	**Date of search:** 22 June 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): G1G (GRE); G4V (VAG)

Int Cl (Ed.7): G01F 23/296; G01S 15/08; G01V 1/157; G06M 9/00; G07D; G07F;
G10K 15/06

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
Y	GB 2190749 A (BELL-FRUIT) discloses coin stack measurement using ultrasonic pulses	1-6
Y	GB 2139352 A (CEGB) discloses measurement of acoustic pulses produced by electrical discharges	1-6
Y	WO 97/35279 A1 (CASINO SOFTWARE) discloses token stack measurement using ultrasonic pulses	1-6

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		

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