COIN IDENTIFICATION APPARATUS UTILIZING RADIATION BOMBARDMENT

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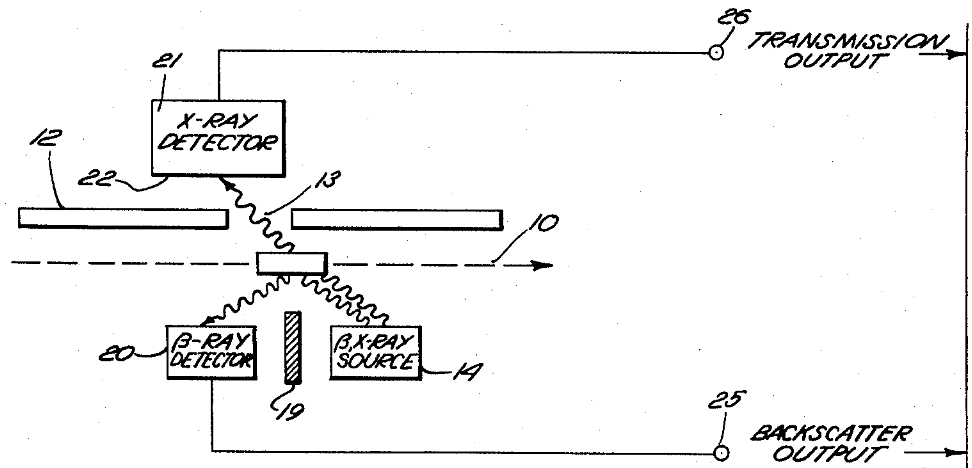

FIG. 1

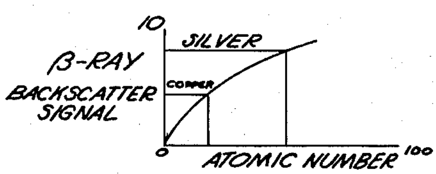

FIG. 2

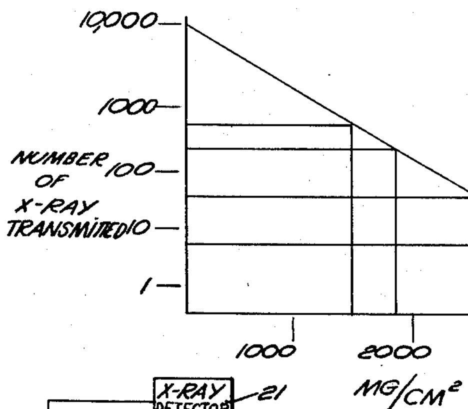

FIG. 3

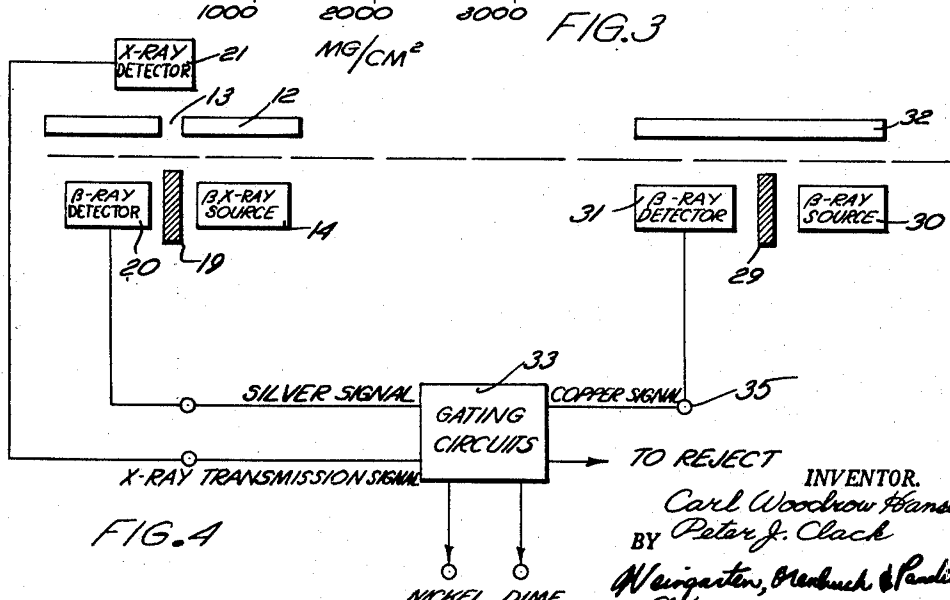

FIG. 4

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COIN IDENTIFICATION APPARATUS UTILIZING RADIATION BOMBARDMENT

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This invention relates in general to a coin identification system and, more particularly, to an apparatus for identifying coins by a determination of their atomic number and their weight per unit area.

The widespread use of coin operated vending machines and unattended coin pass meters emphasizes the necessity of having accurate and reliable coin identification apparatus. Coin identification, in the sense used here, consists of negative identification in that all coins, with the exception of a preselected choice, are rejected by the system. Thus, if a pass meter is intended to be operated by a dime, the coin identification system of the pass meter must be capable of rejecting all other coins except dimes and also rejecting slugs intended to represent dimes. While a dime-operated pass meter is a typical example, the same requirement of rejection applies to pass meters and vending machines which may operate on other types of coins or combinations of coins or specially prepared tokens. The problem, of course, becomes more complex when it involves a multi coin machine, such as a 15 cent pass meter or the like.

In the past a variety of sensor elements had been used to reject "false" coins in the above type of machines. Each of these sensor elements has been directed to particular characteristics of the coins to be accepted or to particular characteristics such as magnetic permeability of likely slug material. Thus, pass meters have usually employed feeler elements to produce an accepting output signal when the coin is of the appropriate diameter and to reject all coins of greater or lesser diameters. Generally a weight indication would be employed in combination with the diameter sensor and this weight indicator would provide an accept signal only when the weight was within preset limits. The thickness of the coin, also, is a characteristic which can readily be determined by mechanical or electromechanical means. Systems of coin identification and rejection based on these characteristics of physical dimension and total weight become complex, in terms of likely slug substitutes, and are further complicated by variations in these dimensions due to normal wear on coins. But, perhaps the chief problem with existing coin identification systems lies in the fact that these determinations of the physical dimensions depend upon mechanical contact devices. Consequently heavily used machines tend to become unreliable and require frequent and costly maintenance. The lack of reliability frequently takes the form of the machine rejecting legitimate coins or jamming and when the machine is controlling the gate of an unattended toll highway or a relatively remote street railway station, the resultant inoperability of the gate causes major inconvenience.

It is, therefore, a primary object of the present invention to provide an economic, reliable coin identification system utilizing electromagnetic radiation absorption and reflection characteristics to identify coins.

It is another object of the present invention to provide an efficient, economic, non-contacting coin identification system utilizing radioactive sources and detectors as the sensor elements.

It is still another object of the present invention to provide a reliable, economic coin or token identification

system wherein the coin identification is based upon the atomic number and weight per unit area characteristics of the coins.

Broadly speaking, the apparatus of the present invention identifies coins by determining the atomic number and weight per unit area of each coin entered into the machine. The measurement of these quantities is accomplished by means of measuring both the transmission and reflection of nuclear radiation by the coin. The back-scattering coefficient of beta radiation from a material is directly dependent upon the atomic number of that material, and hence the amount of beta radiation scattered back to a beta detector in a fixed geometrical arrangement provides a clear indication of the atomic number of the backscattering material. In addition, X-rays and gamma rays are transmitted through materials with the percent absorption of these rays depending upon the weight per unit area of the material. Hence, by interposing the coin to be identified between a source of X-rays or gamma rays and a detector, the weight per unit area can be determined by measurement of the amount of such radiation transmitted.

The table below lists the United States Currency Coins together with their metallic composition, atomic number, specific gravity, thickness and weight per unit area.

Coin	Metal	At. Number	S.G.	Thickness	Wt./unit area (mg./cm.^{2})
Penny	Copper	29	8.89	.055	1,240
Nickel	{90% copper {10% nickel	29 28	8.85	.065	1,465
Dime	98% silver	47	10.5	.045	1,200
Quarter	do	47	10.5	.060	1,590
Half dollar	do	47	10.5	.702	1,910
Dollar	do	47	10.5	.088	2,340

From the above table it can be seen in every case of coins having the same atomic number the difference in weight per unit area exceeds 10%. Even with the normal wear of coins, this difference in weight is a sufficient basis of distinction for coins of the same atomic number, and all others may be distinguished on the basis of atomic number. Hence, these two characteristics are sufficient to identify each coin as to the type and to reject the usual slug material, such as steel, lead, plastics and the like. It should be noted that in coin identification of this type there is no mechanical contact between the sensors and the coin, hence wear is greatly reduced.

Other objects and advantages will become apparent from the following detailed description when taken in conjunction with accompanying drawing in which:

FIG. 1 is an illustration in block diagrammatic form of a one embodiment of a coin identification apparatus in accordance with the principles for this invention;

FIG. 2 is a graphical illustration of the dependence of beta backscatter signal on atomic number of materials;

FIG. 3 is a graphical illustration of the dependence of transmitted radiation on the weight per unit area of the absorber; and

FIG. 4 is an illustration in block diagrammatic form of a coin identification apparatus employing multiple sensor elements.

With reference now specifically to FIG. 1, a radioactive source 14 is located to one side of the path of travel 10 of a coin 11. A radioactivity detector 20 is located on the same side of the path of travel 10 as the source 14 and is shielded from the source by a shielding member 19. A backscatter plate 12 is disposed on the opposite side of the path of travel 10 from the source 14 and has an opening 13 in it allowing radiation from the source 14 which passes through the coin 11 to pass through the opening and strike the sensitive surface 22 of a second radiation detector 21. The output of detector 20 is provided to terminal 25 labeled backscatter output, while the output of detector 21 is provided to terminal 26 labeled transmission output. This configuration of elements provides on the output 25 of detector 20 signals resulting from radiation backscattered from either a coin 11 or the backscatter plate 12. On the output terminal 26 of detector 21 the signals represent the radiation transmitted through the opening 13 in plate 12 and when a coin 11 intercepts this radiation beam, the signals represent the radiation transmitted through the coin and through the opening.

The radioactive source 14 would typically consist of a beta emitting radioisotope admixed with a high Z material so that the source would emit both the beta radiation and bremsstrahlung radiation. The portion of beta radiation backscattered from a coin travelling along path 10 is a function of the atomic number of the elements within the coin, whereas the amount of bremsstrahlung radiation transmitted through the coin is a function of the weight per unit area of the coin. Backscatter detector 20 is a beta sensitive detector, typically a geiger mueller tube or a cadmium sulphide crystal, whereas X-ray detector 21 is a detector relatively insensitive to beta radiation and typically would be a scintillation crystal and photomultiplier combination. As previously indicated, the backscatter output signal is related to the atomic number of the coin from which the beta radiation is scattered, while the transmission output is related to the weight per unit area. The device may be operated as a "no-go" instrument in which a signal should appear on terminal 25 only when the coin 11 is characterized by an atomic number different from that of the material in the "acceptable" coin. For example, if the machine is set to accept dimes, which are 98% silver having an atom number 47, then no signal should appear on backcatter output 25 when a dime is present, while signals should appear as a "no-go" signal when any other material is traversing the coin path 10. The function of the backscatter plate 12 is to provide a standardizing bias signal equivalent to the signal developed by the "acceptable" coin so that the test of acceptability becomes one relative to the signal derived from the backscatter plate when no coin is present. Since the backscatter signal depends upon both atomic number and spacing and since the backscatter plate 12 is spaced further from the source than the path of the coin 10, then the backscatter plate must be made of higher atomic number material than the acceptable coin material. Both lead plate and tungsten alloy have been found to be acceptable materials with convenient spacings.

The backscatter plate 12 may be eliminated and a second radioactive source employed to create the bias signal. This second source is arranged such that the presence of the coin absorbs the radiation from it, hence the signal from the beta detector in this case also represents only the radiation from source 14 scattered from the coin.

With reference now to FIG. 2, the dependence of the beta ray backscatter signal from a krypton 85 beta ray source on the atomic number of the backscattering material is illustrated. From this figure it can be seen that there is a significant difference between the backscatter signal from silver having an atomic number of 47 and copper having an atomic number of 29. As indicated in Table I, all U.S. coins are substantially either silver or copper. Accordingly if the device of FIG. 1 were arranged such that a silver coin only was acceptable, then other materials would provide a "no-go" signal on terminal 25. Hence, the presence or absence of a signal on terminal 25 would indicate whether the coin lay within or without the group consisting of a dime, quarter, half-dollar and dollar. With reference now to FIG. 3, the dependence on weight per unit area of X-ray transmission is shown. As indicated therein, there is a substantial difference in signal between any coins within the same atomic number group. For example, the penny and nickel, of which both are mostly copper (atomic number 29), exhibit a substantial difference in transmitted X-ray signals. The silver group, consisting of the dime, quarter, half-dollar and dollar, exhibit even more substantial differences in transmitted X-ray signals. Hence referring again to the apparatus of FIG. 1, the output terminal 25 signal distinguishes between the copper and silver group, whereas the signal on terminal 26 provides a clear indication of which coin within either group it is. In regard to "slugs," which are not coins at all, it would probably be possible to make slugs giving readings comparable to any one of the regular coins by coating relatively inexpensive material with thin coatings of lead or other heavy metal. However, the cost of these fabricated slugs would probably be equal to or greater than the value of the coin and hence a coin pass meter or the like need not be capable of distinguishing them. The device illustrated in FIG. 1 employed a backscatter plate 12 in order to provide a standardizing signal and to eliminate problems of drift and the like in the detector and circuitry. It should be clear, however, that the backscatter plate standardization is not essential to the coin detection, inasmuch as a circuit can be employed at the output of terminal 25 to distinguish between several positive signals of different magnitude.

With reference now to FIG. 4 a coin identification apparatus, capable of accepting two different preselected types of coins while rejecting all others, is shown. In this illustration like numbers refer to like parts of FIG. 1. In this embodiment the coin again travels along a path as indicated by the dotted line 10 between a backscatter plate 12 and source and detector combination 14 and 20. However, the coin travels along an extension of this path beside a second backscatter plate 32. This second backscatter plate 32 is formed of a similar material to backscatter plate 12, however, it has no opening through it. On the other side of the coin path from the backscatter plate 32 are placed a beta ray source 30 and beta ray detector 31 separated by a shielding element 29. The output of the beta detector 31 is provided to a terminal 35. In this embodiment the backscatter plate 12 is spaced appropriately from the source 14 and detector 20 combination, so that in the absence of a coin, a signal is presented on terminal 25 equivalent to the signal which would be received from a silver coin. Hence any change of signal in terminal 25 represents a "non-silver" coin passing along path 10. The output terminal 25 is connected to a gating circuit 33, as is output terminal 26 from detector 21. Similarly, the output terminal 35 of beta detector 31 is also coupled to gating circuit 33. The radioactive source 30 associated with detector 31 is a pure beta ray source, since there is no opening through plate 32 and no transmission detector associated with these components. The backscatter plate 32 may be formed conveniently of the same material as backscatter plate 12, however its spacing from the path of coin travel 10 is arranged such that the output signal from detector 31 when there is no coin between the plate 32 and source 30 is equivalent to that received when a coin formed of copper is within this area. Hence the output on terminal 35 will remain the same except when there is a non-copper coin travelling between the source 30 and plate 32. Three types of information, then, are provided to gating circuit 33, namely a signal from terminal 25 indicating a non-silver coin, a signal from terminal 35 indicating a non-copper coin, and a signal from terminal 26 indicative of the weight per unit area the coin travelling along path 10. To accept either a nickel or a dime and provide an output indicating whether a coin is a nickel, a dime or neither can then be accomplished by normal coincidence gating techniques. For example, a coincidence between a signal from terminal 25 and terminal 35 would indicate a coin which is neither silver nor copper and hence automatically would provide a reject output.

An absence of a "no-silver" signal from terminal 25, coupled with a signal from terminal 26 indicating a weight per unit area of approximately 1200 mm./cm.^{2}, would be indicative of a dime hence provide a positive signal on a dime output. On the other hand, an absence of a "no-silver" signal from terminal 25, coupled with any other weight per unit area, would again provide a reject output. Similarly, absence of a "no-copper" signal from terminal 35 coupled with a weight per unit area indication from terminal 26 of 1465 mg./cm.^{2} would provide a positive nickel output, whereas an absence of a "no-copper" signal coupled with any other weight would again provide a reject output. By an extension of these gating circuit principles, it is apparent that the device may be made to provide a positive output indication of any type of coin.

While the devices has been described above in terms of United States coins, the invention is not so limited. It is apparent that the same principles and apparatus may be applied to the identification of special tokens and the like, as well as suitable types of non U.S. coins. Having descibed the invention herein, it is apparent that many modifications and improvements may now be made by those skilled in the art, and it is intended that the invention disclosed herein should be limited only by the spirit and scope of the appended claims.

What is claimed is:

1. Apparatus for identifying coins comprising, means defining a path of travel for said coins; a radioactive source disposed in fixed relationship to said path, said radioactive source being adapted to emit a beam of beta rays and X-rays impinging upon said coin within said path; a beta ray detector disposed in a manner to receive beta rays backscattered from said coin; a shielding element adapted to shield said detector from non-scattered beta rays from said source; an X-ray detector disposed to receive X-rays from said source transmitted through said coins, means responsive to the outputs of said beta ray and said X-ray detectors providing an output indicative of the type of said coin.

2. Apparatus providing an output signal indicative of the presence of a preselected type of coin comprising, means defining a path of travel for said coins; a radioactive source emitting a beam of beta rays and X-rays, said source being disposed on one side of said path in such a manner that said X-rays and said beta rays impinge upon said coin within said path; an X-ray detector disposed on the opposite side of said path from said source; a beta ray detector disposed on the same side of said path as said source; a scattering plate interposed between said coin path and said X-ray detector, said plate having an opening therethrough allowing X-rays transmitted from said source through said coin within said path to reach said X-ray detector; said plate being formed in such a manner as to scatter the same amount of beta rays from said source into said beta ray detector when no coin is present as is scattered from said preselected type of coin; shielding means disposed between said source and said beta detector to shield said beta detector from direct beta radiation from said source.

3. Apparatus in accordance with claim 1 wherein said radioactive source comprises krypton 85 mixed with a high Z material.

4. Apparatus providing output signals indicative of the presence of preselected types of coins comprising, means defining a path of travel for said coins; a first radioactive source emitting a beam of beta rays and X-rays, said beam being incident upon said coins in said path; a first X-ray detector disposed on the opposite side of said path from said first radioactive source; a first backscatter plate interposed between said coin path and said X-ray detector, said first backscatter plate having an opening therethrough for passing X-rays transmitted through said coin to said X-ray detector; a first beta ray detector disposed on the same side of said coin path as said beta ray first radioactive source, said first backscatter plate being adapted to scatter the same amount of beta rays from said first radioactive source into said beta ray detector when no coin is travelling along said path as is scattered from a first preselected one of said coin types travelling along said path; a second radioactive source emitting a beam of beta radiation, said second radioactive source being spaced apart from said first radioactive source and disposed in a manner such that said beta ray beam impinges upon coins travelling along said path; a second backscatter plate disposed on the opposite side of said path from said second radioactive source, said second backscatter plate being adapted to scatter the same amount of beta rays from said second source to said second beta ray detector when no coin is travelling along said path between said second source and said second plate as is scattered from a second preselected one of said coin types when passing along said path, the signals from said X-ray detector, said first beta detector and said second beta detector being provided as independent outputs indicative of the types of coins passing along said path.

5. Apparatus in accordance with claim 4 wherein said first and said second backscatter plates are both formed of tungsten alloy.

6. Apparatus in accordance with claim 2 in which said beta detector is a cadmium sufide crystal and said X-ray detector is a scintillation crystal operating in conjunction with a photomultiplier tube.

7. Apparatus providing an output signal indicative of the presence of a preselected type of coin comprising, means defining a path of travel for said coins; a first radioactive source emitting a beam of beta rays and X-rays, said source being disposed on one side of said path in such a manner that said X-rays and said beta rays impinge upon said coin within said path; an X-ray detector disposed on the opposite side of said path from said first radioactive source; a beta ray detector disposed on the same side of said path as said first source; a shielding member disposed in a manner to shield said beta detector from direct rays from said source; a second radioactive source disposed on the opposite side of said path from said beta detector; said second radioactive source being adapted to provide, with no coin present, an amount of radiation to said beta detector equivalent to the amount scattered to said beta detector from said first source by said preselected type of coin; said second source being disposed such that said preselected type of coin within said path prevents beta rays from said second source from reaching said detector.

8. Apparatus for identifying coins comprised of radioactive source emitting a beam of beta rays and X-rays, said beam being impingent upon said coins; first detector means providing an output signal indicating the quantity of beta rays backscattered from each of said coins; second detector means providing independent output signals indicating the quantity of X-rays transmitted through each of said coins; and means responsive to said output signal from said first detector and said output signal from said second detector for providing an output indication of the type of coin.

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