United States Patent

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[54] **METAL OBJECT SEPARATION SYSTEM**
4 Claims, 4 Drawing Figs.

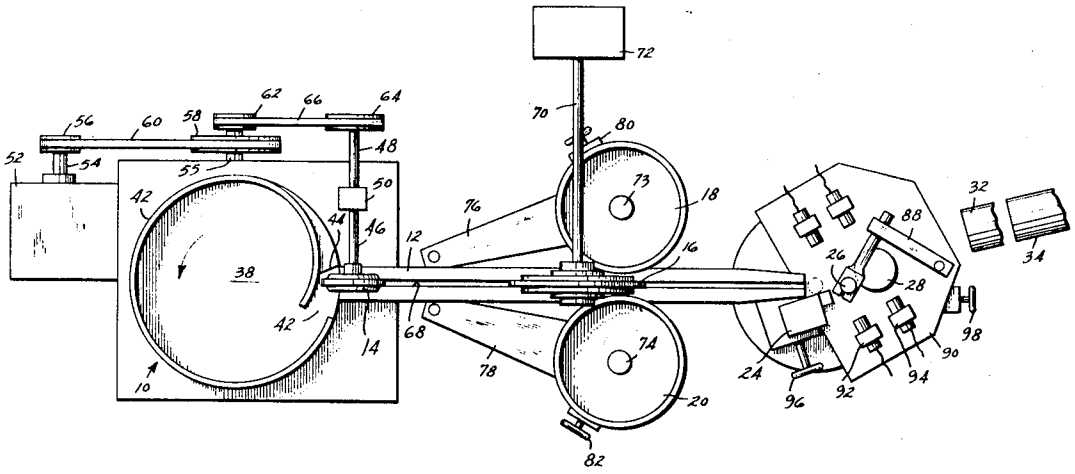
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[51] **Int. Cl.** **B07c 5/34**
[50] **Field of Search** ..... 133/3; 194/100, 100.5, 101; 209/111.9, (Inquired)

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ABSTRACT: The invention comprises means for projecting a metal object against an anvil, means for detecting the dominant frequency of vibration caused thereby, an electromagnetic coil, and means for activating the electromagnetic coil in response to the detection of a predetermined frequency.



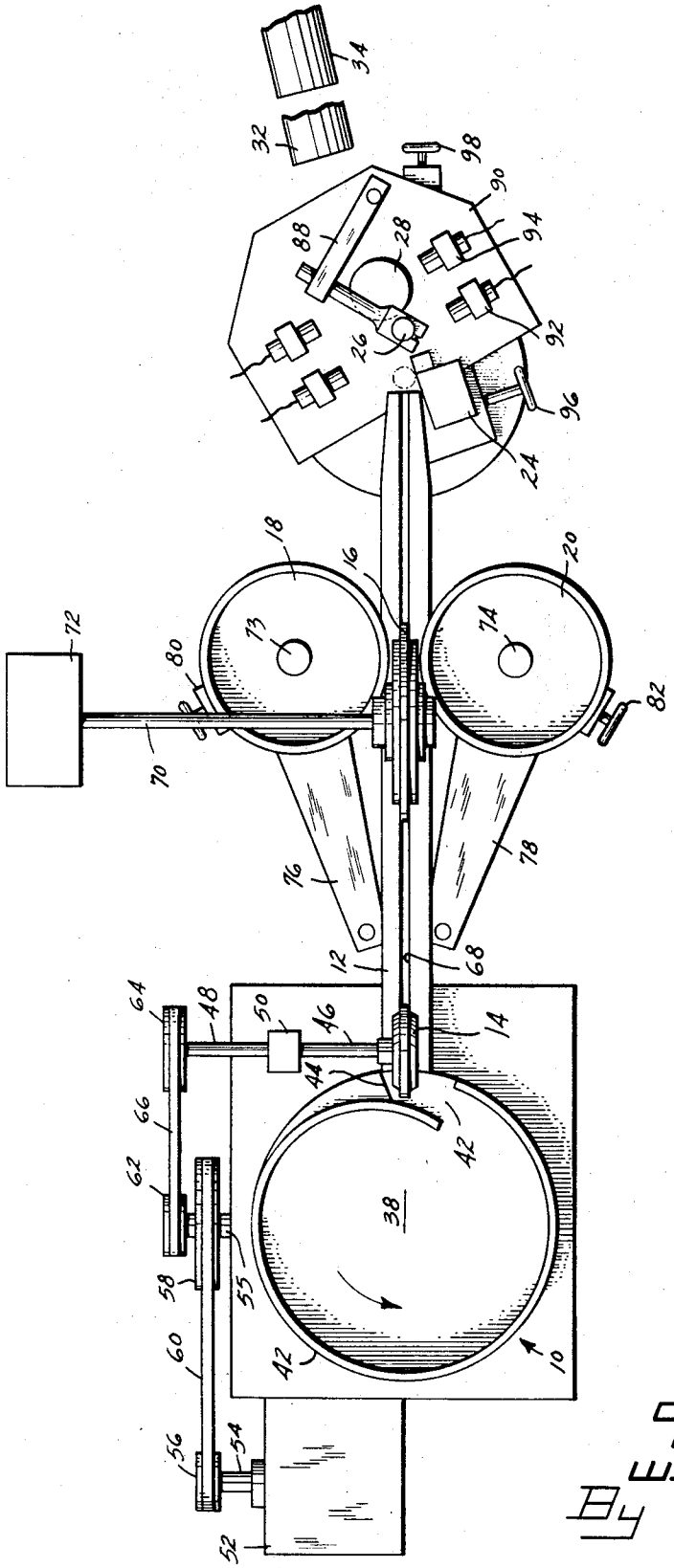


FIG. 1

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FIG. 2

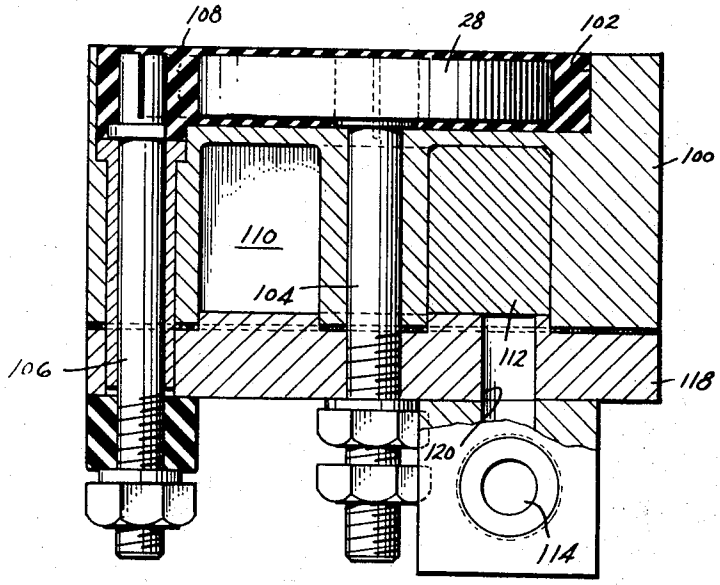
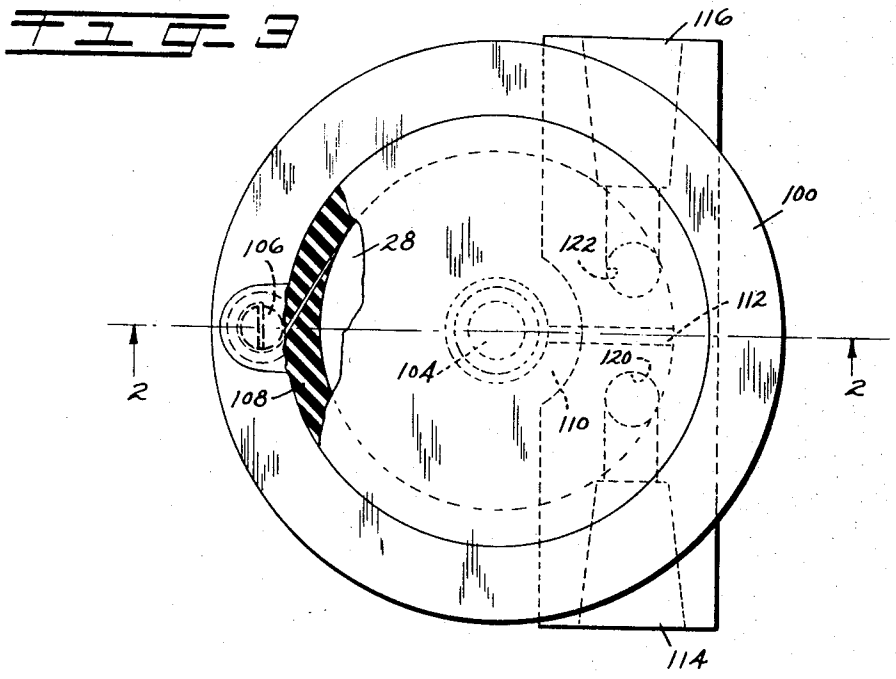

108
28
102
100
110
104
106
112
118
120
114

FIG. 3


116
100
106
28
122
112
2
104
120
2
108
110
114

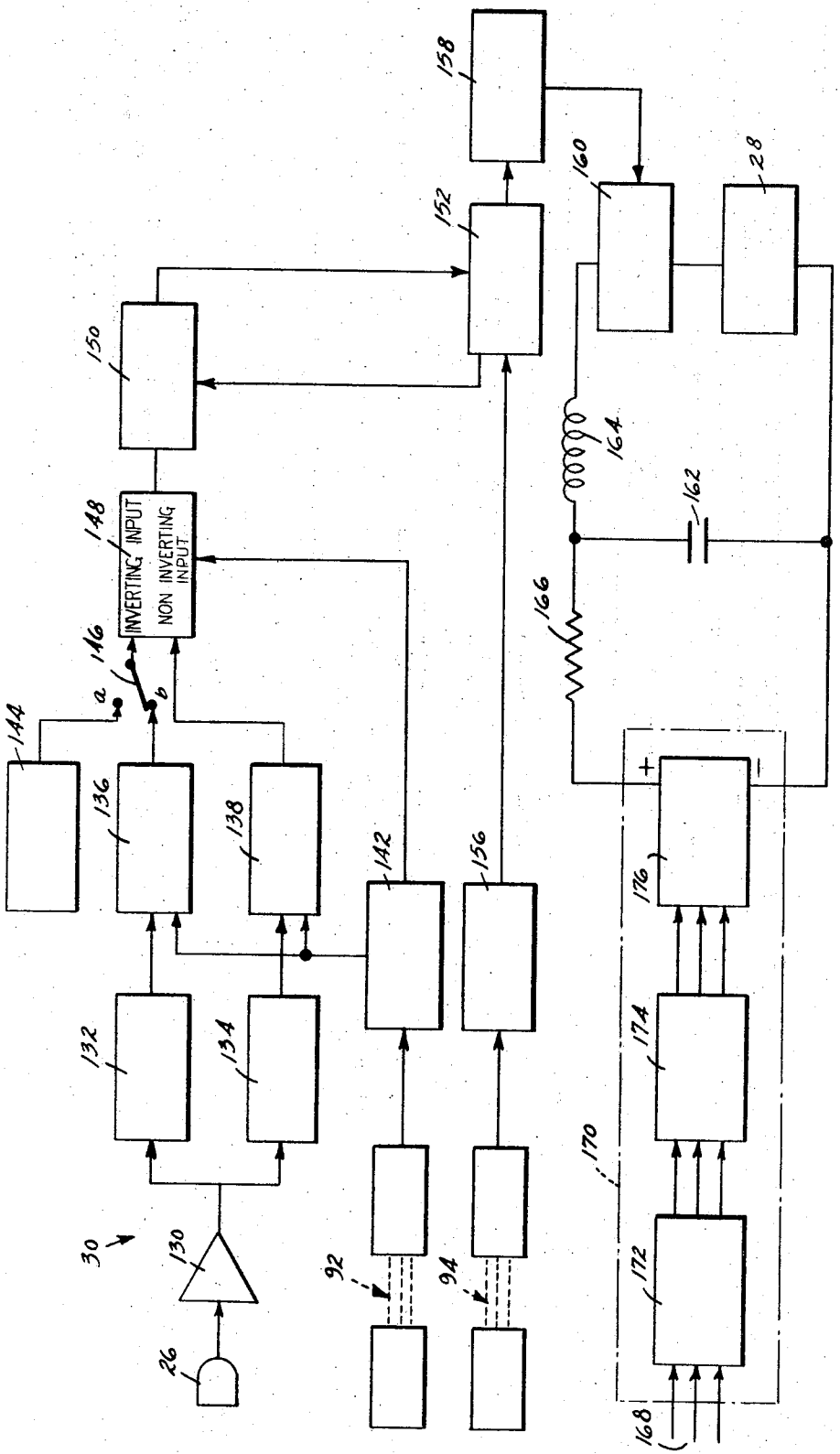

158
160
28
152
150
164
162
148
INVERTING INPUT
NON INVERTING INPUT
166
146
a
b
144
136
138
142
156
176
132
134
174
170
30
130
92
94
172
26
168

FIG. 4

METAL OBJECT SEPARATION SYSTEM

BACKGROUND

This invention relates to the separation of metallic objects having like exterior characteristics but different metallic makeup, and more particularly to the separation of silver coins from the new clad coins of the same denomination.

It is known in the art to separate like metal objects according to their metallic makeup by detecting differences in their dominant frequencies of vibration when they are projected against an anvil. However, high-speed separation has heretofore been precluded since the actual physical separation, after detection, has been accomplished by low-speed electron-mechanical units, such as solenoid operated gates.

SUMMARY

It is, therefore, an object of this invention to provide a high-speed metal object separation system.

It is a further object to provide a metallic object separation system including an electronic separating means.

It is a more particular object of this invention to provide an electromagnetic separating device operable to separate metallic objects without physically engaging them.

It is a still more particular object of this invention to provide a high-speed system for separating coins by projecting them over an electronically controlled electromagnetic coil, wherein coins of one characteristic are propelled into a different trajectory than those of other characteristics.

In accordance with these and other objects, the invention comprises means for projecting a metal object against an anvil, means for detecting the dominant frequency of vibration caused thereby, an electromagnetic coil, and means for activating the electromagnetic coil in response to the detection of a predetermined frequency.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of a preferred embodiment of the invention.

FIG. 2 is a sectional elevation view of an electromagnetic coil according to the invention taken along line 2–2 of FIG. 3.

FIG. 3 is a plan view with portions broken away of the electromechanical coil of FIG. 2.

FIG. 4 is a schematic block diagram of a preferred circuit for the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to the drawings, a preferred embodiment of the invention is hereinafter described as a separator for coins of like denomination but different metallic makeup, but it is to be understood that the invention is not limited to the separation of coins and can be utilized to separate any metal objects, such as planchets, blanks, etc.

Referring now to FIG. 1, apparatus according to the invention may comprise an Abbott coin feeder 10 for feeding coins one at the time to the entrance end of a track 12. A feed wheel 14 is mounted above the leading end of track 12 such that the periphery thereof engages coins in the track and advances them therealong to a rate wheel 16. The rate wheel is also mounted above the track and extends therein to engage coins in the track to advance them further therealong. The rate wheel controls the rate with which coins are inspected and separated. Coins fed along the tracks from rate wheel 16 are engaged by impeller wheels 18 and 20 which hurl the coins down the remaining portion of the track and out the exit end thereof at a speed of upwards of 250 inches per second.

An anvil 24 is mounted adjacent the trailing end of the track in a position such that coins hurled from the track by the impeller wheels strike the anvil, are deflected to a new path and are caused to vibrate. A transducer 26 is mounted adjacent to anvil 24 and just above the path of coins deflected by the anvil. The transducer is operable to convert the vibrations of the coins into an electric signal of the same frequency.

An electromagnetic coil 28 is mounted just under the deflected path of the coins beyond transducer 26, and upon the activation thereof is operable to form a high intensity magnetic field which functions to induce current in the coin which creates a magnetic field surrounding the coin passing thereover that is counter to the one emanating from the coil, thus propelling the coin upwardly out of its normal path. A circuit 30 (FIG. 4) is provided between transducer 26 and coil 28 to activate the coil only upon the detection by the transducer of a predetermined frequency. A pair of collection chutes 32 and 34 are mounted in alinement with anvil 24. The collection chutes are positioned such coins that do not vibrate at the predetermined frequency and thus do not have their trajectory changed by coil 28 fall into chute 32 while coins that have been acted upon by the coil will fall into chute 34.

More specifically, the Abbott coin feeder 10 includes a rotatable (counterclockwise as seen in FIG. 1) base plate 38 and a substantially circular sidewall 40. An aperture 42 is provided in the sidewall 38 adjacent the leading end of track 12. A plate 44 is mounted past the aperture to direct coins into the track.

Feed wheel 14 is mounted on a shaft 46. A drive shaft 48 is provided in axial alinement with shaft 46 and the latter is driven by the former through a clutch 50.

Both the Abbott coin feeder and drive shaft 48 are driven by a motor 52. The motor includes an output shaft 54 which is parallel spaced relationship with drive shaft 48 and a drive shaft 55 for the Abbott coin feeder. Spaced drive belt mounts 56 and 58 are mounted on output shaft 54 and drive shaft 55, respectively, and a drive belt 60 transmits the rotary motion of the former to the latter. A second drive belt mount 62 is mounted on shaft 55 in spaced relationship with a drive belt mount 64 on drive shaft 48. A drive belt 66 transmits the rotary motion of the shaft 55 to drive shaft 48. Of course, the drive belt mounts and drive belts just described could just as well within the scope of the invention be sprockets and chains or any other means for transmitting power to shafts 55 and 48.

Upon activation of motor 52, the Abbott coin feeder feeds a succession of coins to track 12 whereat feed wheel 14, which extends into the track from the top thereof through an aperture 68, advances the coins in a row to rate wheel 16. Since the feed wheel rotates faster than the rate wheel, the coins will backup behind the rate wheel. In this situation, clutch 50 will prevent jam-ups in the apparatus by halting the rotation of shaft 46 until a coin has been advanced past the rate wheel, whereupon the row of coins will be advanced.

The rate wheel controls, by the angular velocity of its rotation, the rate at which coins are inspected and separated by circuit 30 and electromagnetic coil 28 respectively. The rate wheel, which also extends through aperture 68 to engage the coins in the track, is mounted on shaft 70 which is the output shaft of a controllable variable speed device 72.

Impeller wheels 18 and 20 extend into the track from the sides thereof and engage coins fed past the rate wheel to hurl them down the track at high speeds. The high-angular velocity of the impeller wheels are imparted thereto by shafts 73 and 74 respectively, each connected to a high-speed electric motor (not shown). Each impeller wheel is mounted on a pivotal mounting member, 76 and 78 respectively, the angular attitude of which is controllable by adjusting handles 80 and 82, respectively. Thus, the position of the impeller wheels with respect to the track may be adjusted for engaging coins of different sizes.

The anvil 24 is mounted adjacent the exit end of track 12. The operative face 86 of anvil 24 is vertically disposed at an acute angle to the path of coins leaving the track. Thus, the edges of coins projected down the track by the impeller wheels strike the anvil. This changes their path in the horizontal plane and causes the coins to vibrate, or "ring."

Transducer 26, which is preferably, but not limited to, a microphone, is mounted above the deflected path of the coins by a stand 88. Stand 88 is mounted on a base 90 which also supports the anvil 24. The electromagnetic coil 28 is mounted in base 90, with its upper surface being flush therewith.

An adjustment means **96** is connected to anvil **24** to vary the position thereof with respect to the track to compensate for different coin sizes. An adjustment means **98** is connected to base **90** to change the position of the photoelectric means and the electromagnetic coil with respect to the track and the anvil for the same purpose.

Referring now to FIGS. **2** and **3**, electromagnetic coil **28** is mounted in a housing **100**, which in turn is mounted in base **90**. Housing **100** includes a recess **102** in the upper surface thereof to receive the coil. The coil itself comprises alternate windings of strips of copper and Kapton, the latter being a dielectric manufactured by the DuPont Company. The coil is mounted in recess **102** such that the inner end thereof is connected to a centrally located terminal **104**. The peripheral end of the coil is extended out near the periphery of the housing and connected to a terminal **106**.

The coil is imbedded in an epoxy bed **108** to aid in dissipating heat. Cooling is provided by passing water through an annular chamber **110** in the housing. A separating wall **112** is mounted in the annular chamber to define a path for the water coolant. The water is injected into chamber **110** through a feed line **114** and exits through a conduit **116**. A cap **118** is provided for the housing and forms one end of the chamber **110**. Cap **118** includes ports **120** and **122** to transmit water to and from the chamber from the infeed and exit lines **114** and **116** respectively. FIG. **4** shows a schematic block diagram of circuit **30**. The circuit operates to activate electromagnetic coil **28** in response to the detection of a predetermined frequency of vibration adjacent anvil **24** by transducer **26**. The circuit **30** described immediately hereinbelow is operative to separate two types of coins that therefore will oscillate at two different dominant or resonant frequencies.

The output signal of transducer **26**, which is a microphone, is sent to a buffer amplifier **130** which has an output which serves as the input for two band pass filters, **132** and **134**. The center frequencies of the band pass filters depends upon the objects being separated, but the Q of the two filters should be such that there is at least 50 db. separation at the center frequency. The output signals of the filters are each fed to separate amplifier/integrator circuits, **136** and **138** respectively.

Each amplifier/integrator circuit consists of a variable gain amplifier section, a demodulator section and an integrator section. The integrator section requires an external gating pulse to integrate. During that pulse, a relay contact is opened (which normally shuts the capacitive feed back element of an operational amplifier) to produce a signal proportional to the integral of the input signal to that section.

The external gating pulse is supplied to the integrator sections of the amplifier/integrators **136** and **138** when the leading edge of the coin interrupts the light beam on photocell **92** and activates the photo diode thereof. The pulse is sustained by a gate interval timer **142** for a period of approximately 3½ milliseconds During this time each amplifier/integrator output is integrating the electrical signal which is proportional to the mechanical energy at the frequency consistent with the center frequencies of the band pass filters in the coin passed through the respective band pass filters. The output of the two amplifier/integrators **136** and **138** serves as the input to a comparator **148**, with amplifier/integrator **136** being connected thereto through contact **146*b*** of a switch **146**.

The comparator is the element that determines whether coil **28** will be actuated. The center frequencies of the two band pass filters are selected such that one will pass the signal generated by coins having a desired metallic makeup and the other will pass the signal generated by coins of an undesired metallic makeup. The respective amplifier/integrator integrate these respective signals.

The output of the comparator is clamped to a negative level until a strobe signal is received from the gate interval timer **142**. This strobe signal occurs at the end of the gating pulse. The output polarity of the comparator after the strobe signal is received is a function of relative levels of the integrator outputs at that time. This output polarity determines whether or not the coil will be activated. For explanation purposes, assume amplifier/integrator **136** is connected to the inverting input and amplifier/integrator **138** is connected to the noninverting input. Then, if the signal level of amplifier/integrator **138** is greater than amplifier/integrator **136** the comparator output at the strobe time goes to a positive level for the duration of the strobe pulse. If the converse is true, i.e., the signal level of amplifier/integrator **136** is greater than that of amplifier/integrator **138**, the comparator output remains negative when the strobe is received. Thus the comparator output is a bilevel function of the integrator outputs and thus the sr strength of the coin vibrations at the two band pass filter center frequencies.

Therefore, where selecting band pass filters, the center frequency of the band pass filter connected to the amplifier/integrator connected to the noninverting input of the comparator is such to coincide with the dominant or resonant frequency of the coin having the particular metallic makeup sought to be acted upon by the coil **28**. The center frequency of the other band pass filter is selected such that it coincides with the dominant or resonant frequency of a coin having another metallic makeup.

Since the strobed comparator output occurs at a time when the coin has traveled just a short distance and is not yet in a suitable position for physical sorting by coil **28**, the determination which has been made must be stored until the coin is in a proper location in its trajectory. The storage or memory capability is a function of a reset pulse generator **150**.

The reset pulse generator **150** produces a level output which is zero if the comparator output at the strobe time is positive and is approximately +20 volts when the output of comparator **148** is in its normally negative mode. However, when the output of reset pulse generator **150** drops to zero it remains zero until it is reset by a signal derived from the interruption by the coin of second photocell **94**.

Photocell **94** is in a position such that the coin is centered over the coil **28** when the beam is broken. The signal from the photocell is processed thru a pulse shaper **156** in order to produce a fast rise pulse of the proper magnitude. This pulse is transmitted to a SCR driver **152**.

The SCR driver **152** produces an output when a pulse is received from pulse shaper **156** and the level from the reset pulse generator **150** is zero. When a pulse is produced by SCR driver **152**, another pulse is also produced which returns the level of the reset pulse generator **150** to the +20 volt positive level.

The output pulse of SCR driver **152** is transmitted to the gate of a high voltage silicon controller rectifier **160** through an isolating SCR drive transformer **158**. When SCR **160** is gated "ON", the stored charge in a capacitor bank **162** is discharged through the electromagnetic coil **28**. The coil induces currents in the coin as it passes over the coil when the capacitor bank is discharged. These currents in the coin are in such a direction as to set up a magnetic field counter to the one emanating from the coil, thereby producing a repulsion force between the coil and the coin. When this occurs, the normal trajectory of the coin is altered such that it now assumes a higher trajectory. The difference in trajectories can be adjusted to get the desired physical separation by adjusting the voltage to which the capacitor bank is charged.

The switch of SCR **160** reopens when the anode voltage thereof drops below the cathode voltage, approximately 200 microseconds after the SCR started to conduct. This is due to overshoot of the capacitive/inductive circuit.

When the switch of the SCR is so opened, capacitor bank **162** can be recharged from a variable three phase high voltage power supply through a limiting resistance **166**. The power supply includes a three phase input **168**, a variable auto transformer **170**, a delta-wye power transformer **172** and a full wave rectifier **176**.

Circuit **30** can also operate to separate "good" coins from defective ones. It has been determined that coins that are defective in poor bonding of heterogenous layers, blisters on the

outside layer, missing heterogenous components (i.e., entire layers missing), partial delamination, etc., cause a change in the fundamental mode of the natural frequency of vibration. Generally this change is such that the frequency is significantly lower.

The technique for detecting delaminated coins, blanks, or planchets is essentially the same as that for separating two types of good coins as previously explained. The singular difference is that instead of the output of two filter/amplifier/integrator channels being compared, only one filter/amplifier/integrator output is compared against a fixed level. Thus switch **146** is connected to its contact **146***a*. In order that the machine operate in fail safe manner (i.e., machine failure causes inspected pieces to be rejected) the output of amplifier/integrator **138** is fed to the noninverting input of comparator **148**.

To summarize, the output of buffer amplifier **130** passes thru band pass filter **134**. The center frequency of the filter **134** is that at which a "good" coin oscillates when it is in its fundamental mode of vibration. The filter output feeds the comparator noninverting input.

A DC fixed bias **144** is fed into the inverting input of the comparator. The voltage level of this bias is experimentally determined by "ringing" good planchets or coins, observing the output of amplifier/integrator **138** at the time of the strobe pulse and setting the bias level slightly below that level.

The rest of the machine logic is identical to that as used for separation in theory and hardware.

We claim:

1. A method of separating metal objects, which comprise the steps of:

causing a metal object to vibrate;

determining whether said metal object is vibrating in a predetermined frequency range; and

projecting a magnetic field in response to the determination that the metal object is vibrating in said predetermined frequency range, said magnetic field inducing a counter magnetic field in the metal object and thus causing the repulsion of the metal object toward a collection area.

2. A method according to claim **1** wherein the step of determining whether said metal object is vibrating in a predetermined frequency range comprise the steps of:

transducing the ringing of the metal object into an electric signal;

filtering the signal;

amplifying and integrating the signal;

selecting a fixed signal level source that produces a signal level just below that produced by a filtered, amplified and integrated signal from a metal object vibrating in the predetermined frequency range; and

comparing the level of the filtered, amplified and integrated signal from the vibrating metal object to the fixed signal level.

3. Apparatus for separating metal objects, which comprises:

means for causing a metal object to ring at its natural frequency;

transducer means for changing the ringing of the metal object to an electrical signal;

filter means for filtering out all signals except those of a predetermined frequency;

means for comparing the level of said filtered electrical signal with a fixed signal level;

an electromagnetic coil; and

means for activating the electromagnetic coil upon detection by the comparing means of a predetermined filtered signal level.

4. Apparatus according to claim **3**, wherein: said coil is activated by a silicon controlled rectifier; and the silicon controlled rectifier is triggered by the detection of a metal object over the center of the coil.