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THE PATENTS ACT, 1977

IN THE MATTER OF
EP(UK) 0 113 031
of DEGUSSA AG.

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83111752.8).

SIGNED this 8th day of May 1988

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16

1 This invention relates to an apparatus for testing the
purity of noble metal mouldings, more especially noble metal
bars and noble metal discs, by imparting transverse vibra-
5 tions to the noble metal moulding using a vibration generator
and measuring the resonance frequency by means of a vibra-
tion pickup. Although it is particularly intended for
testing the purity of gold bars and gold coins, the
apparatus according to the invention may also be used for
testing moldings of other noble metals, such as silver or
10 platinum metals.

Forgeries of gold bars and gold coins are constantly
being discovered, consisting either completely of less noble
metals or of a core of base metals, particularly lead or
tungsten, covered only by a thin layer of noble metal. For-
15 geries such as these represent a considerable material loss
and, at the same time, reduce confidence in gold and other
noble metals as a reliable investment.

Accordingly, there are instruments with which the purity
of mouldings having certain dimensions can be determined,
20 for example in banks or jewellers, and of which the measure-
ment principle is based on non-destructive materials testing
techniques. Hitherto, ultrasonic and eddy-current instru-
ments have been used in practice for the identification of
materials. To couple the ultrasonic measuring head to the
25 test specimen, however, an oily transfer fluid has to be
applied to the test specimen in ultrasonic instruments,
preventing clean working. In addition, the measuring head
normally analyzes only part of the test specimen on account
of its small dimensions. Similarly, eddy-current instruments
30 do not analyze large sample volumes on account of the limited
depth of penetration of high frequency. Test instruments

- 1 which determine the thermal conductivity of the test speci-
men are also of only limited use because, where this prin-
ciple of measurement is adopted, the tolerances of the test
specimen dimensions have to meet very exacting requirements,
5 so that only special types of gold bars can be tested with
instruments of this type.

CH-PS 553 456 describes an apparatus for the detection
of forged coins, in which mechanical transverse waves are
applied to the coin via a loud speaker and the resonance
10 frequency of the coin is determined by a microphone. How-
ever, this apparatus is attended by the disadvantage that it
is only suitable for coins and, because of the accessories
required, is elaborate and bulky. In addition, it is not
very accurate.

- 15 The same applied to the apparatus described in GB-PS
1,011,472. In this case, longitudinal vibrations are applied
to the test specimens, an air gap having to be formed be-
tween the test specimens and the vibration generator and
between the test specimen and the vibration detector.

- 20 Accordingly, the object of the present invention is to
provide an apparatus for testing the purity of noble metal
mouldings, particularly noble metal bars and noble metal
discs, by imparting transverse vibrations to the noble metal
moulding using a vibration generator and measuring the
25 resonance frequency by means of a vibration pickup, which
may be universally used, is capable of testing any mouldings,
provides for clean working and is simple and handy in its
construction. In particular, forgeries based on tungsten
with a gold coating are intended to be readily detectable.

- 30 According to the invention, this object is achieved in
that the vibration generator and the vibration pickup are
formed by piezoelectric transducers and are directly coupled
to the moulding to be tested and in that one or more supports
are present for the molding to be tested.

- 35 By means of this apparatus, test specimens of different

1 dimensions can be non-destructively tested for their composition throughout their entire volume without any test residues. Any elastic body can be made to vibrate characteristically, the modes of vibration being confined to the fundamental mode and the harmonic mode. For a given method of
5 suspension or mounting of the mouldings, these vibration frequencies depend upon the dimensions, the elasticity modulus E and the density ρ of the test specimen. If, for example, bar-like test specimens lie on two knife edges,
10 they are capable of making transverse flexural vibrations when deflected from their rest position by an external force. The frequency of the fundamental vibration of a bar is dependent according to known equations on the thickness and length of the bar, on the elasticity modulus of its constituent material and on the density of that material. If
15 the external force acts on the bar, for example at the fundamental frequency, the bar resonates, i.e. vibrates at maximum amplitudes of vibration. If various vibrations are applied to the bar, it is possible to determine the resonance
20 frequency which, where the dimensions are known, is a characteristic parameter of the constituent material of the bar and may be used for its identification.

Bars or discs are preferably placed on a flat plate consisting of an elastic material or on two knife edges or
25 on three support points and are made to vibrate transversely by a piezoelectric transducer of which the frequency is continuously variable. The piezoelectric transducer may be coupled to the test specimen by a thin wire approximately 1 mm in diameter which is lightly pressed onto the test
30 specimen or onto which the test specimen is lightly pressed. The amplitude of vibration is also determined by a piezoelectric transducer. Its maximum value indicates the resonance frequency from which - given known dimensions - the ratio of elasticity modulus to density can be read off.

35 Since the resonance frequency is characteristic for

- 1 example of any type of fine gold bar, the measurement result can be compared with a table value. Forgeries can readily be detected because there is no material or combination of materials which has the resonance frequency of fine gold.
- 5 In particular, it is possible to identify inclusions of tungsten in gold which, although having the same density, differ in their elasticity modulus by a factor of 5.

To test the noble metal mouldings, it is preferred to use apparatus in which the support is in the form of a horizontal, flat plate of an elastic material. This elastic plate must be larger than the possible test specimen which is placed on the plate and which is pressed lightly against a needle-shaped vibration generator arranged at the edge of the plate. The materials used for the elastic plate are materials which allow vibration deflections of the test specimens of the order of a few micrometers without significant impediment. Felt, cork, velvet, velour fabrics, rubber and foam plastics have proved to be suitable. Coarse-pored, foamed polyethylene characterized by very low vibration damping values has proved to be particularly effective. The thickness of the elastic support plate is not crucial, although it should be greater than 1 mm.

Test specimens of any shape and any weight, i.e. any type of noble metal bars and noble metal coins, may be tested on this elastic support.

For testing, electronic signals are produced and processed in the apparatus. There are two embodiments for the electronic function of the apparatus, namely: generation of the vibrations to be imparted by the test specimen itself or by a frequency generator in the apparatus.

As in an electrical oscillation circuit, it is possible with a vibrating test specimen to build up a vibrating system of which the frequency-determining element are the resonance frequencies of the test specimen. To this end, the total amplification has to be greater than 1 while the

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1 phase displacement has to be zero. This is achieved by
amplifying the signal of the piezoelectric vibration pickup
(optionally phase-displaced) and feeding it to the piezo-
electric vibration generator. This oscillation circuit
5 oscillates at a resonance frequency of the test specimen
(self-excitation).

Advantages of the self-excitation measuring circuit
include its simple, inexpensive electronic construction.
However, self-excitation testing calls for certain skill on
10 the part of the operator because, in addition to the funda-
mental vibration, harmonics can also develop in dependence
upon the place at which the vibration pickup is attached to
the test specimen. A discrete sequence of resonance
frequencies may then be measured on the same test specimen,
15 making the result of measurement difficult to interpret for
the layman.

Accordingly, it is generally of advantage to generate
the frequencies required for application to the test specimen
within the apparatus itself by an oscillator which is capable
20 of generating any frequencies. The oscillator signal is
transmitted to the test specimen by the piezoelectric vibra-
tion generator. The frequency of vibration and amplitude of
vibration are measured and indicated by the vibration pickup.
Since fundamental vibrations and harmonics are successively
25 indicated in resonance in the event of continuous variation
of the frequency of the oscillator, the operator is again
confronted by the above-mentioned problems of interpretation.
In the interests of simple handling, therefore, it is desir-
able to store only one resonance frequency of any given
30 test specimen. This is achieved by the oscillator generating
certain characteristic frequencies which are allocated to
characteristic test specimens (manufacturer, type, quantity,
etc.) and can be recalled. In this way, the apparatus can
be made more user-friendly.

35 To test noble metal bars, particularly gold bars, it is

- 1 also possible to use apparatus in which the supports for the test specimen are formed by two edges which can be varied in their position symmetrically to the centre of the moulding.

To centre the moulding to be tested, two stops are
5 likewise fixed to a spindle, a vibration generator being arranged on one of the stops and a vibration pickup being situated on a movable lever arm over the centre of the moulding to the tested. The edges and the stops are preferably made of polyacrylates.

- 10 To test the purity of noble metal coins, it is also possible to use apparatus in which the test specimen is placed on three radially displaceable supports in the form of cones and the vibration generator and the vibration
15 pickup are situated adjacent one another on a movable lever arm over the centre of the moulding to be tested. The resonance frequency is measured in the antinode of the developing vibration situated in the centre or at the edge of the coin. Centring of the coin is not difficult and may be done by eye.

- 20 Figures I to IV diagrammatically illustrate some examples of embodiment of apparatus for testing the purity of noble metal mouldings, figure I showing an apparatus with a flat support plate, figure II an apparatus with two edges as supports and figure III an apparatus with three points as
25 support. Figure IV shows details of the radial displacement of the support.

- An apparatus suitable for bars, discs and other shapes consists of a housing (28) in which the oscillator and the other electronics are accommodated. The support (2) for
30 receiving the test specimen (1) is in the form of a flat plate made of an elastic material. The test specimen (1) is pressed lightly against the vibration generator (10) which is arranged at the edge of the support (2) and projects into the air space above the support (2). The resonance fre-
35 quencies characteristic of standard commercial shapes (bars,

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1 coins) may be fed into the oscillator through a keyboard (29)
The vibration pickup (11) is removed from its holder and
placed on the middle of the test specimen (1). The maximum
amplitude value of the frequency, i.e. the resonance fre-
5 quency, may be accurately adjusted by means of a tuning
button (30) and read off from a display window (31).

An apparatus with which bars of various dimensions can
be tested is described in detail with reference to figure II.
To ensure that the fundamental vibration of the free bar
10 can preferentially develop, the bar has to be mounted in the
two nodes of the stationary vibration which, under physical
laws, must each be at a distance of 0.22 times the bar
length from the middle of the bar. To this end, the
distance between the two supports (2), which are in the form
15 of edges, may be varied symmetrically to the centre of the
test specimen by means of a spindle (5) with a left-hand
thread and a right-hand thread. The supports (2) are guided
in bearings on two guide axes (7). The test specimen (1) is
centred in relation to the middle of the interval between the
20 two supports (2) by means of two stops (3,4) which are also
designed for symmetrical displacement by another spindle (6).
The two spindles (5,6) are driven by a servo motor (8) with
reduction gears (9). The thread leads of the two spindles
are in a ratio of 1:1.27, so that the interval between the
25 support (2) and the stop (3 or 4) is always $0.22 \times$ the bar
length. The stops (3,4) are used not only for clamping the
test specimen (1), but also as a centring aid during loading
of the apparatus. During the measurement process, the test
specimen (1) and the stops (3,4) are separated by a fine gap
30 so that the vibration develops without damping. This gap is
produced by increasing the interval between the two stops
(3,4) immediately before the beginning of measurement by
turning the spindle (6) slightly backwards. The edges are
prevented from moving apart from one another by a freewheel
35 on the threaded spindle (5) which only responds after the

- 1 gear has been turned backwards, for example through 120° .

The material from which the supports (2) and the stops (3,4) are made must differ in its sound wave resistance of the test specimen to minimize the transmission of vibration energy from the bar to the structure of the apparatus. For gold bars, therefore, the supports (2) and the stops (3,4) are preferably made of polyacrylic glass.

- The vibration is generated laterally at one end of the bar by a vibration generator (10) mounted on a stop (4).
10 Suitable vibration generators are piezoelectric transducers which transmit an appropriate range of frequencies. The preferred embodiment is characterized by the use of a piezoelectric sound pickup of the type used in the audio field for playing records. After a bolt has been released, the
15 sound pickup is moved horizontally about a centre of rotation towards the test specimen (1) by a spring to couple the sound head to the bars.

- The amplitude of vibration is determined at the middle of the bar by a lever arm (12) with a vibration pickup (11)
20 being placed on the test specimen (1). The lever arm (12) is provided with a balancing weight (13) for establishing the supporting force. Any type of piezoelectric transducer may be used as the vibration pickup. A piezoelectric acceleration pickup of minimal weight is preferably used.

- 25 The test process begins with the entry of the bar to be tested through a keyboard. This keyboard controls the servo motor (8) so that the edges are adjusted to the interval corresponding to the particular type of bar. The bar is placed between the stops (3,4) on the supports (2), the
30 vibration generator (10) is coupled through release of the lock and the pickup (11) is placed on the bar. The excitation frequency is varied over a range by a frequency generator and the resonance frequency determined. This measured value is compared with the desired value stored in
35 the input unit for the corresponding types of bar. Any

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1 forgery can immediately be detected in this way.

 The effectiveness of this test is demonstrated using a
100 g fine-gold bar. The resonance frequency 5.18 kHz is
measured. Bars having the same dimensions, but of different
5 metals, may be identified through a different resonance
frequency: $f(\text{Al}) = 14.0 \text{ kHz}$, $f(\text{Cu}) = 10.2 \text{ kHz}$, $f(\text{Pb}) =$
3.8 kHz, $f(\text{W}) = 13.3 \text{ kHz}$. Forged fine gold bars containing
inclusions of foreign metals are also recognized by a
resonance frequency differing from that of the genuine bar.

10 Figures III and IV diagrammatically illustrate an
apparatus for testing the purity of coins.

 Vibration is generated and the vibration amplitude
measured at the centre of the test specimen (1). To this
end, the vibration generator (15) and vibration pickup (16)
15 are placed adjacent one another on a lever arm (17) onto the
test specimen (18). The supporting force may be adjusted
through a counterweight (19) on the lever arm (17). For
example, piezoelectric sound pickups are used for the vibra-
tion generator and piezoelectric vibration pickups for
20 determining the amplitude of vibration.

 By means of this apparatus, coins of different size
can be tested for their purity. To this end, the coins are
placed horizontally on three conical supports (20) in a disc-
shaped base plate (21). The base plate (21) comprises three
25 radially arranged slots (22) arranged at an angle of 120° to
one another. The supports (20) may be guided in these slots
during their radial displacement. To vary the radial posi-
tions of the supports (4), another disc (23) is arranged
centrally beneath the base plate (21). The disc (23) con-
30 tains spiral slots (24) which extend from the centre of the
disc (23) to its edge. A pin-like extension (25) of the
supports (20) projects into each of these three spiral
slots (24). By turning the base plate (21) and the discs
(23) relative to one another, the supports (20) may be
35 synchronously moved in the radial direction. By virtue of

1 this construction, coins of different diameter may be mounted
in the vibration node. In one preferred embodiment, the
disc (23) is fixed while the base plate (21) is moved into
the required position by a stepping motor (26). The step-
5 ping motor (26) is mounted beneath the two discs in the
direction of the axis of rotation. Power is transmitted
by a square nut (27) which engages in the base plate (21).

The effectiveness of the purity testing apparatus is
demonstrated by way of example on gold krugerrands. The
10 fundamental vibration frequency of the genuine coins is
9.1 kHz. Tungsten discs of the same dimensions have
resonance frequencies of 17.0 kHz. If tungsten discs are
coated with a 200 μ m thick layer of gold, their resonance
frequency falls to 16.1 kHz. This coated modification is
15 visually indistinguishable from genuine gold discs although
the resonance frequencies are distinctly different from one
another. Further tests with discs of different light and
heavy metals also show significant differences in the natural
vibration frequencies. This shows that, despite the minimal
20 outlay on apparatus which it involves, the resonance fre-
quency method is a conclusive purity test.

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CLAIMS

1. An apparatus for testing the purity of noble metal mouldings, more especially noble metal bars and noble metal discs, by imparting transverse vibrations to the noble metal moulding using a vibration generator and measuring the resonance frequency by means of a vibration pickup, characterized in that the vibration generator (10) and the vibration pickup (11) are formed by piezoelectric transducers and are directly coupled to the moulding (1) to be tested and in that one or more supports (2) are present for the moulding (1) to be tested.

2. An apparatus as claimed in claim 1, characterized in that the support (2) is formed by a horizontal flat plate consisting of an elastic material.

3. An apparatus for testing the purity of bars as claimed in claim 1, characterized in that the supports are formed by two edges which can be varied in their position symmetrically to the centre of the moulding (1) to be tested by means of a spindle (5), in that for centring the moulding (1) to be tested two stops (3,4) are likewise fixed to a spindle (6), a vibration generator (10) being arranged on one (4) of the stops, and in that the vibration pickup (11) is situated on a movable lever arm (12) over the centre of the moulding to be tested.

4. An apparatus for testing the purity of discs as claimed in claim 1, characterized in that the supports consist of three radially displaceable cones (14) and in that the vibration generator (15) and vibration pickup (16) are situated adjacent one another on a moveable lever arm (17) over the centre of the moulding to be tested.