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(71) Applicant: **UNICORN INDUSTRIES plc**
285 Long Acre
Nechells Birmingham B7 5JR(GB)

(72) Inventor: **Barnard, John Malcolm**
39 Sheppard Way Minchinhampton
Stroud Gloucestershire(GB)

(74) Representative: **Carter, Gerald et al**
Arthur R. Davies & Co. 27 Imperial Square
Cheltenham GL50 1RQ Gloucestershire(GB)

(54) Improvements in or relating to the dressing of grinding wheels.

(57) In a method of dressing a grinding wheel 14 to form thereon a peripheral surface of a required cross-sectional profile, the grinding wheel is rotated at a predetermined speed, and rotated about a parallel axis is a dressing wheel (10) having a hard peripheral forming surface the cross-sectional profile of which is the complementary inverse of said required cross-section profile. The peripheral surface of the grinding wheel 14 is brought into pressing engagement with the peripheral surface of the dressing wheel 10, and while maintaining the pressing engagement the speed of rotation of the dressing wheel is controlled in a manner to provide a difference in speed between the engaging peripheral surfaces. The speed of rotation may be controlled by direct control of an electric servo-motor 12 driving the dressing wheel 10, or by controlled braking of the dressing wheel. For a given composition of grinding wheel and dressing wheel the surface characteristics of the finished wheel may thus be determined in a predictable fashion by pre-setting an appropriate predetermined speed of rotation for the dressing wheel.

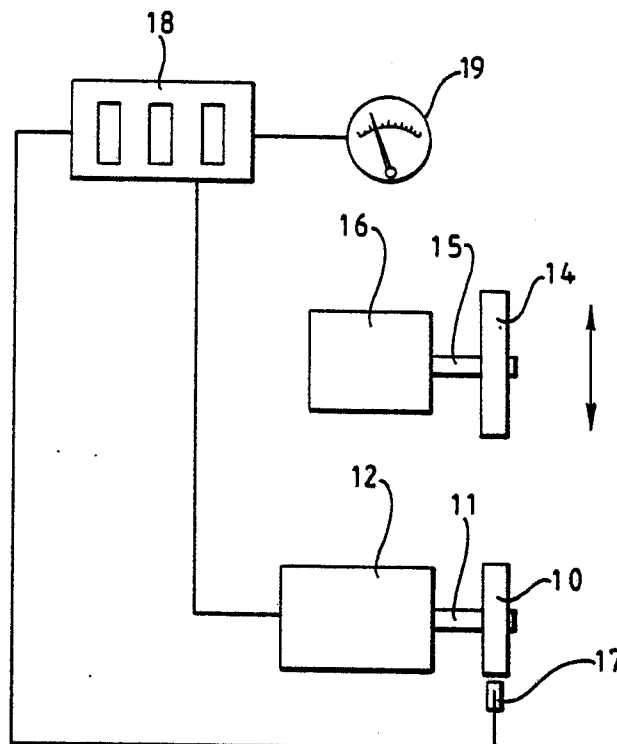


FIG 1

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"Improvements in or relating to the dressing of grinding wheels"

The invention relates to the dressing of grinding wheels, by which is meant the shaping of the outer peripheral surface of a grinding wheel to ensure that the wheel is perfectly circular and to provide its peripheral surface with an accurate cross-sectional profile having the desired surface characteristics. The process of making the grinding wheel perfectly circular is normally referred to as "trueing" and the process of providing the required surface characteristics of the periphery of the grinding wheel is normally referred to as "conditioning".

The invention is particularly applicable to the dressing of so-called "superabrasive" grinding wheels, as will be described hereinafter, but it may also be applied with advantage to the dressing of conventional grinding wheels.

Profiled grinding wheels are used for the accurate shaping of many different types of rotary machine parts, such as engine camshafts. A grinding wheel which has been dressed to perform a certain operation will become worn in the course of its use and may require redressing many times during its working life to remove worn abrasive material and metal particles from the peripheral surface of the wheel as well as to restore the required exact cross-sectional profile to the peripheral surface.

Grinding wheels are normally manufactured from grains or particles of abrasive material held together and moulded into disc form by a bonding agent. Typical abrasive materials are aluminium oxide and silicon carbide. Various bonding agents are used such as synthetic resins, metals or vitrified materials.

The peripheral surface of the dressing wheel must obviously be formed from material which can cut or abrade, without undue wear itself, the hard surface of the grinding wheel. Typically, therefore, dressing wheels consist of diamond particles embedded in a hard material such as nickel, tungsten carbide or other hard matrix.

It has become increasingly common, in some applications, to use superabrasive grinding wheels in which the abrasive material is diamond or cubic boron nitride, for example in a vitrified bonding agent, and difficulties have arisen in conditioning such wheels using conventional methods. In the case where the profile of the grinding wheel is flat, i.e. where the peripheral surface of the wheel is perfectly cylindrical, acceptable conditioning of the surface has been achieved by traversing the inter-engaging surfaces of the two wheels relatively to one another in the axial direction while they are rotated in engagement with one another. The sur-

face characteristics of the grinding wheel, that is to say its conditioning, may then be varied by varying the relative rate of traverse, as well as the force between the wheels and their relative rates of rotation. However, where the grinding wheel is required to have a non-cylindrical profile relative traversing movement is not possible and the shaping of the grinding wheel profile is effected by a generally crushing or rotary dressing action of the dressing wheel. While such processes achieve the necessary trueing and shaping of the grinding wheel it is difficult to control in a predictable manner the conditioning of the surface of the grinding wheel.

The present invention sets out to provide a new method and apparatus for dressing a grinding wheel, providing a further parameter which may be varied to vary the conditioning of the surface of the grinding wheel.

According to one aspect of the invention, therefore, there is provided a method of dressing a grinding wheel to form thereon a peripheral surface of a required cross-sectional profile, the method comprising rotating the grinding wheel at a predetermined speed about its central axis, rotating about a parallel axis a dressing wheel having a hard peripheral forming surface the cross-sectional profile of which is the complementary inverse of said required cross-sectional profile, effecting relative movement between the dressing wheel and grinding wheel in a direction perpendicular to their axes of rotation to bring the peripheral surface of the dressing wheel into pressing engagement with the peripheral surface of the grinding wheel, maintaining said pressing engagement, and controlling the speed of rotation of the dressing wheel in a manner to provide a difference in speed between said engaging peripheral surfaces of the dressing wheel and grinding wheel. Preferably the dressing wheel is controlled in such manner that its peripheral speed is less than the peripheral speed of the grinding wheel.

It is found, using this method, that the surface conditioning of the grinding wheel may be varied by adjusting the speed of rotation of the dressing wheel and thereby varying the speed difference between the engaging surfaces of the wheels. Accordingly, for a given composition of grinding wheel and dressing wheel, the surface characteristics of the finished wheel may be determined in a predictable fashion by setting an appropriate predetermined speed of rotation for the dressing wheel. The effect of the surface speed difference will be to cause rotational "scuffing" of the surface of the dressing wheel relatively to the surface of the grinding wheel, in addition to the normal action.

It is this scuffing, the extent of which depends, for given wheels, on the predetermined value of the speed of rotation of the dressing wheel, which determines the surface characteristics of the finished wheel.

As previously mentioned, the invention is particularly applicable where the grinding wheel is a superabrasive wheel comprising, for example, cubic boron nitride or diamond in a vitrified bonding agent, and at least the peripheral surface of the dressing wheel may comprise diamond particles embedded in a bonding material, such as nickel or tungsten carbide.

The speed of rotation of the dressing wheel may be controlled by driving the wheel by means of a speed-controllable electric servo-motor. The speed of rotation of the servo-motor may then be continuously controlled so as to maintain the speed of rotation of the dressing wheel at a substantially constant predetermined value. Alternatively, the speed of rotation of the servo-motor, and hence of the dressing wheel, may be varied in a cyclic fashion.

In an alternative arrangement according to the invention, the speed of rotation of the dressing wheel may be controlled by applying thereto a braking load when the speed of rotation of the dressing wheel is greater than a predetermined value, the magnitude of the braking load being variable and being such as to tend to reduce the speed of rotation of the dressing wheel towards said predetermined value.

The pressing engagement between the peripheries of the grinding wheel and dressing wheel may be maintained, in known manner, by feeding one wheel towards the other at a predetermined rate. In accordance with a further feature of the present invention, however, this feed rate may be controlled in accordance with the speed of rotation of the dressing wheel, in such manner that the feed occurs at a first rate when the speed of rotation of the dressing wheel is below said predetermined value, and at a second, lower rate when the speed of rotation is above said value. Thus, the speed of rotation of the dressing wheel will be at or below the predetermined value before the wheels are brought into engagement and the wheels may thus be fed towards each other comparatively rapidly. However, as soon as the wheels come into engagement the grinding wheel will accelerate the dressing wheel above the predetermined rate of rotation with the result that the feed rate will be switched to a lower value appropriate for the wheels being in operative engagement.

The invention also provides apparatus for dressing a grinding wheel comprising means for rotating the grinding wheel at a predetermined speed about its central axis, means for rotating a

dressing wheel about a parallel axis, means for effecting relative movement between the dressing wheel and grinding wheel in a direction perpendicular to their axes of rotation, means for sensing the speed of rotation of the dressing wheel, and control means for controlling the speed of rotation of the dressing wheel in accordance with signals from said speed sensing means in a manner to tend to return the speed of rotation towards a predetermined value when it departs from said value.

In the case where the speed of rotation of the dressing wheel is controlled by brake means, the means for rotating the dressing wheel about its central axis may comprise a rotatably mounted shaft having means for mounting the dressing wheel coaxially thereon, the brake means being operable on said shaft or a part rotatable therewith. For example, the brake means may comprise a disc brake mechanism, the disc of which is mounted on the shaft or part rotatable therewith.

The brake mechanism may be pneumatically actuated, and in this case said control means may include an air control valve which controls the supply of pressurised air to the brake mechanism.

The control means may further include a differential control device for comparing signals from the speed sensor with a pre-set datum indicative of said required predetermined speed, and actuating said air control valve in a manner to reduce the difference between said signals and the datum.

Preferably the air control valve is solenoid operated and is actuated by electrical signals from said differential control device.

The means for rotating the dressing wheel about its central axis may include an electric motor drivingly connected to the shaft on which the dressing wheel is mounted. In this case the differential control device is preferably also connected to the electric motor and is arranged to switch off the motor when the speed of rotation of the dressing wheel rises above the aforesaid predetermined value.

The following is a more detailed description of embodiments of the invention, by way of example, reference being made to the accompanying drawings in which:

Figure 1 is a diagrammatic representation of one form of apparatus in accordance with the invention,

Figure 2 is a similar representation of an alternative form of apparatus, and

Figure 3 is a sectional view through apparatus in accordance with Figure 2 for mounting, driving and braking the dressing wheel.

Referring to Figure 1, a dressing wheel 10 is mounted on the end of a rotary shaft 11 which is driven by an electric servo-motor 12 through a suitable coupling.

The grinding wheel 14 to be dressed is mounted on a rotatable shaft 15 driven by an electric motor 16. The dressing wheel 10 and grinding wheel 14 are rotatable about parallel axes and the assembly comprising the grinding wheel and its motor is so mounted that the grinding wheel may be fed towards the dressing wheel in a direction perpendicular to the axes of rotation of the two wheels. The feeding mechanism, which is electrically driven, may be of any well known kind and will not be described in further detail.

Adjacent the periphery of the dressing wheel 10 is a speed sensor 17 which is electrically connected to a differential control device 18 to which it sends signals indicative of the speed of rotation of the dressing wheel. A revolution counter 19 is connected to the control device to indicate the speed of rotation. The differential control device is connected to the electric servo-motor 12 driving the dressing wheel 10 and is arranged to maintain the speed of rotation of the dressing wheel at a predetermined value. This value is adjustable and may be pre-set in the differential control device. Alternatively, the control device may be such that it can be pre-programmed to vary the speed of rotation of the dressing wheel in cyclic fashion.

The arrangement is such that when the speed of rotation of the dressing wheel 10 departs from the value pre-set in the differential control device, as determined by the device comparing signals from the speed sensor 17 with the pre-set value, the servo-motor 12 is automatically controlled in a manner to restore the speed of the dressing wheel to the pre-set value. Servo-motors and control systems to operate in this fashion are readily available commercially and the control system will not therefore be described in detail.

In operation, the electric motors 12 and 16 are initially switched on. The dressing wheel 10, while it is not subjected to any external load, then rotates at the predetermined speed set in the differential control device which may, for example, be 750 rpm. The grinding wheel 14 may, for example, be rotating at a speed of a 1000 rpm.

Once the dressing wheel and grinding wheel are rotating the grinding wheel 14 is fed towards the dressing wheel until the peripheries of the two wheels come into contact. When contact occurs the grinding wheel increases the speed of rotation of the dressing wheel above 750 rpm. (The relative diameters of the wheels may be such that if the dressing wheel were freely driven by the grinding wheel it would reach a speed of something over 3000 rpm). However, as soon as the speed of

rotation of the dressing wheel exceeds the predetermined 750 rpm the differential control device 18 responds to reduce the speed of the servo-motor and hence of the dressing wheel.

The speed sensor 17 may be of any suitable form. For example, it may operate by optical sensing of a shaft encoder or by optical sensing of the wheel periphery using a stroboscope. Alternatively the sensor may use one or more transducers such as accelerometers, piezo-electric strain gauges or capacitive transducers arranged so that the signals therefrom vary in accordance with the speed of rotation of the dressing wheel.

The differential control device is also arranged to control the rate of feed of the grinding wheel towards the dressing wheel so that the feed rate drops, as soon as the dressing wheel speeds up over 750 rpm, from an initial rapid indexing rate to a lower operating rate.

Alternatively, or additionally, the rate of feed of the grinding wheel may be controlled in accordance with the positions of the axes of rotation of the grinding wheel and dressing wheel, the rate of feed being reduced when the axes of the wheels reach a position where the peripheries of the wheels will be in contact. The relative positions of the axes of rotation of the wheels may be sensed, for example, by using an optical grating, linear voltage differential transformer (LVDT), capacitive transducers, inductosyn transducers, or the like. The signals from such devices are then used to control the rate of feed of the grinding wheel, so that the feed rate is reduced when a predetermined relative position of the wheels is reached.

During continued operation the grinding wheel 14 constantly tries to rotate the dressing wheel 10 at a speed greater than the predetermined 750 rpm, and the servo-motor 12 is constantly controlled to maintain the pre-set speed.

As the grinding wheel 14 is fed towards the dressing wheel 10, the dressing wheel acts on the periphery of the grinding wheel with a crushing/dressing action so as to "true" the wheel, i.e. render it perfectly circular, and to shape the profile of the peripheral surface of the wheel in accordance with the profile of the peripheral surface of the dressing wheel.

At the same time, however, the lower peripheral speed of the dressing wheel provides a scuffing action between the peripheral surface of the dressing wheel and the peripheral surface of the grinding wheel urged against it. The surface characteristics of the grinding wheel produced by this combined crushing and scuffing action vary according to the extent of the scuffing action, and this in turn depends on the pre-set rotational speed of the dressing wheel. Accordingly, for a given type of dressing wheel and grinding wheel, and a given

rotational speed of the grinding wheel, the surface characteristics of the finished grinding wheel can be varied in a predictable fashion by adjusting the pre-set rotational speed of the dressing wheel or by varying the speed in a cyclic fashion.

The invention thus allows predictable conditioning of the grinding surface of a grinding wheel where the profile of the surface, and/or the material of the wheel, makes such predictable conditioning difficult or impossible using conventional methods.

In the alternative arrangement of Figure 2 the speed of rotation of the dressing wheel 10 is controlled by a brake mechanism 13 connected between the electric motor 12 and the shaft 11 of the dressing wheel, and not by direct control of the electric motor 12. Corresponding components of the two arrangements are indicated by the same reference numerals.

In the Figure 2 arrangement the differential control device 18 is again connected to the electric motor 12 driving the dressing wheel 10 and is arranged to switch off the motor when the speed of rotation of the dressing wheel reaches or exceeds a predetermined value. As before, this value is adjustable and may be pre-set in the differential control device.

In the modified arrangement of Figure 2, however, the differential control device 18 also controls a solenoid actuated air control valve 20 which controls the supply of air from an air supply source 21 through a regulator 22 to a manifold 23 which distributes the air supply to a number of pneumatically operated brakes in the coupling and brake apparatus 13 associated with the drive to the dressing wheel 10. The pneumatically operated brakes, of which there may be any suitable number, are indicated diagrammatically at 24.

The arrangement is such that when the speed of rotation of the dressing wheel 10 is greater than the value pre-set in the differential control device, as determined by the device comparing signals from the speed sensor 17 with the pre-set value, the air control valve 20 is operated so as to actuate the brakes 24 and thus reduce the speed of the dressing wheel 10.

In operation, the electric motors 12 and 16 are initially switched on. The dressing wheel 10, while it is not subjected to any external load, then rotates at the predetermined speed set in the differential control device which may, as in the previous embodiment, be 750 rpm. The grinding wheel 14 may, as before, be rotating at a speed of a 1000 rpm.

Once the dressing wheel and grinding wheel are rotating the grinding wheel 14 is fed towards the dressing wheel until the peripheries of the two wheels come into contact. When contact occurs the grinding wheel increases the speed of rotation of the dressing wheel above 750 rpm. However, as

soon as the speed of rotation of the dressing wheel exceeds the predetermined 750 rpm the differential control device 18 responds and switches off the electric motor 12 and operates the valve 20 to actuate the pneumatic brakes and apply a braking load to the dressing wheel.

As in the previous embodiment, the differential control device is also arranged to control the rate of feed of the grinding wheel towards the dressing wheel so that the feed rate drops as soon as the dressing wheel speeds up over 750 rpm, from an initial rapid indexing rate to a lower operating rate. Also, as in the previous embodiment, the rate of feed of the grinding wheel may also be controlled in accordance with the positions of the axes of rotation of the wheels.

During continued operation the grinding wheel 14 constantly tries to rotate the dressing wheel 10 at a speed greater than the predetermined 750 rpm, and the brakes are constantly applied to the dressing wheel to reduce its rotational speed. The control of the brakes is such that the braking force increases in dependence on the excess speed of the dressing wheel.

The braking of the dressing wheel, and the hunting effect of the dressing wheel being constantly braked towards the pre-set rotational speed, provides the aforementioned scuffing action between the peripheral surface of the dressing wheel and the peripheral surface of the grinding wheel urged against it. Accordingly, for a given type of dressing wheel and grinding wheel, the surface characteristics of the finished grinding wheel can again be varied in a predictable fashion by adjusting the pre-set rotational speed of the dressing wheel.

Figure 3 shows in greater detail a typical construction for the driving and braking apparatus for the dressing wheel in the embodiment of Figure 2.

Referring to Figure 3, the dressing wheel 10 is mounted on one end of the shaft 11 the opposite ends of which are rotatably mounted in bearings 25 and 26 in a casing 27.

The end of the shaft 11 opposite to the dressing wheel 10 is connected by a coupling 28 to the output shaft of the aforementioned electric motor 12. Adjacent the coupling 28 there is mounted on the shaft 11 the disc plate assembly of a pneumatically actuated disc brake mechanism. One of the pneumatically actuated brake pad mechanisms of the disc brake is indicated at 30 and a suitable number of such brake pad assemblies are disposed around the periphery of the disc. The brake mechanism may be of a kind which is commercially available where the number of brake pad assemblies may be selected according to the brak-

ing power required. As previously mentioned, the brake mechanism is preferably of a kind where the braking torque is proportional to the operating air pressure.

Claims

1. A method of dressing a grinding wheel to form thereon a peripheral surface of a required cross-sectional profile, the method comprising rotating the grinding wheel (14) at a predetermined speed about its central axis, rotating about a parallel axis a dressing wheel (10) having a hard peripheral forming surface the cross-sectional profile of which is the complementary inverse of said required cross-sectional profile, effecting relative movement between the dressing wheel and grinding wheel in a direction perpendicular to their axes of rotation to bring the peripheral surface of the dressing wheel into pressing engagement with the peripheral surface of the grinding wheel, and maintaining said pressing engagement, characterised by the step of controlling the speed of rotation of the dressing wheel in a manner to provide a difference in speed between said engaging peripheral surfaces of the dressing wheel and grinding wheel.

2. A method according to Claim 1, characterised in that the dressing wheel (10) is controlled in such manner that its peripheral speed is less than the peripheral speed of the grinding wheel (14).

3. A method according to Claim 1 or Claim 2, characterised in that at least the peripheral surface of the dressing wheel (10) comprises diamond particles embedded in a bonding material.

4. A method according to Claim 3, characterised in that the bonding material is selected from nickel and tungsten carbide.

5. A method according to any of Claims 1 to 4, characterised in that the speed of rotation of the dressing wheel (10) is controlled by driving the wheel by means of a speed-controllable electric servo-motor (12).

6. A method according to Claim 5, characterised in that the speed of rotation of the servo-motor (12) is continuously controlled so as to maintain the speed of rotation of the dressing wheel (10) at a substantially constant predetermined value.

7. A method according to Claim 6, characterised in that the speed of rotation of the servo-motor (12), and hence of the dressing wheel (10), is varied in a cyclic fashion.

8. A method according to any of Claims 1 to 4, characterised in that the speed of rotation of the dressing wheel (10) is controlled by applying there-to a braking load when the speed of rotation of the

dressing wheel is greater than a predetermined value, the magnitude of the braking load being variable and being such as to tend to reduce the speed of rotation of the dressing wheel towards said predetermined value.

9. A method according to any of Claims 1 to 8, characterised in that the pressing engagement between the peripheries of the grinding wheel (14) and dressing wheel (10) is maintained by feeding one wheel towards the other at a predetermined rate, the feed rate being controlled in accordance with the speed of rotation of the dressing wheel, in such manner that the feed occurs at a first rate when the speed of rotation of the dressing wheel is below said predetermined value, and at a second, lower rate when the speed of rotation is above said value.

10. A method according to any of Claims 1 to 9, characterised in that the pressing engagement between the peripheries of the grinding wheel (14) and dressing wheel (10) is maintained by feeding one wheel towards the other at a predetermined rate, the feed rate being controlled in accordance with the relative positions of the axes of rotation of the grinding wheel and dressing wheel, in such manner that the feed occurs at a first rate as the wheels approach a predetermined relative position, and at a second, lower rate after the wheels have reached said position.

11. Apparatus for dressing a grinding wheel comprising means (16) for rotating the grinding wheel (14) at a predetermined speed about its central axis, means (12) for rotating a dressing wheel (10) about a parallel axis, and means for effecting relative movement between the dressing wheel and grinding wheel in a direction perpendicular to their axes of rotation, characterised in that means (17) are provided for sensing the speed of rotation of the dressing wheel, and in that control means (18) are provided for controlling the speed of rotation of the dressing wheel (10) in accordance with signals from said speed sensing means in a manner to tend to return the speed of rotation towards a predetermined value when it departs from said value.

12. Apparatus according to Claim 11, characterised in that the means (12, Fig.2) for rotating the dressing wheel (10) about its central axis comprise a rotatably mounted shaft having means for mounting the dressing wheel coaxially thereon, brake means (13) being operable on a part rotatable with said shaft.

13. Apparatus according to Claim 12, characterised in that the brake means (13, Fig.2) comprise a disc brake mechanism (30, Fig.3), the disc of which is mounted on the shaft.

14. Apparatus according to Claim 13, characterised in that the brake mechanism (13) is pneumatically actuated, said control means including an air control valve (20) which controls the supply of pressurised air to the brake mechanism.

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15. Apparatus according to Claim 14, characterised in that the control means further include a differential control device (18) for comparing signals from the speed sensor (17) with a pre-set datum indicative of said required predetermined speed, and actuating said air control valve (20) in a manner to reduce the difference between said signals and the datum.

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16. Apparatus according to Claim 14, characterised in that the air control valve (20) is solenoid operated and is actuated by electrical signals from said differential control device (18).

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17. Apparatus according to Claim 15, characterised in that the means for rotating the dressing wheel (10) about its central axis include an electric motor (12) drivingly connected to the shaft on which the dressing wheel is mounted, and the differential control device (18) is also connected to the electric motor and is arranged to switch off the motor when the speed of rotation of the dressing wheel rises above the aforesaid predetermined value.

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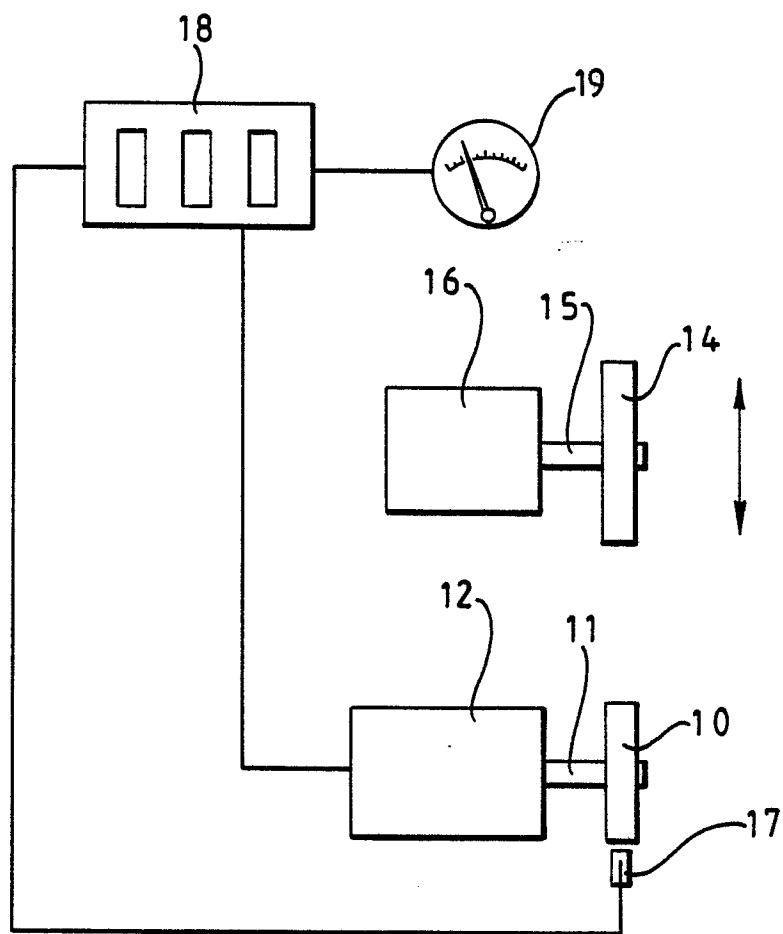
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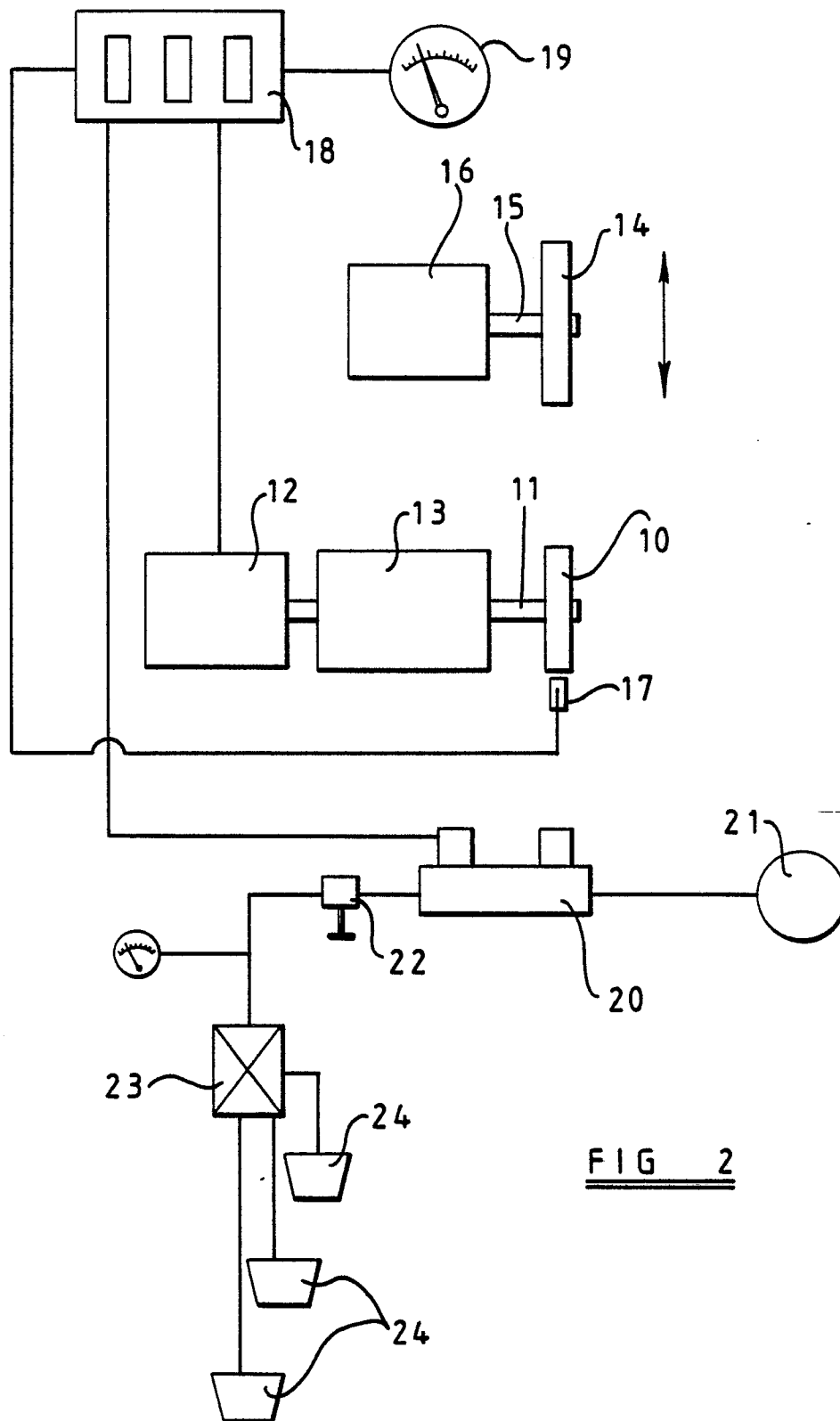
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FIG 1

FIG 2

