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[54] **DRIVE SYSTEM FOR THE IMAGE SECTION OF AN X-RAY APPARATUS**

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[52] **U.S. Cl.** **250/449,** 250/525, 318/628, 318/2

[51] **Int. Cl.** **G01n 21/34**

[58] **Field of Search** 250/525, 449, 444; 318/628, 2

[56] **References Cited**

UNITED STATES PATENTS

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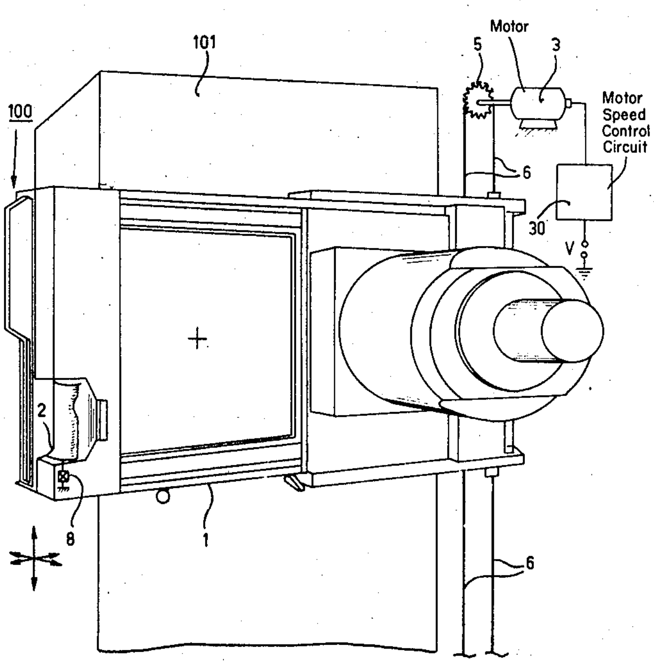
[57] **ABSTRACT**

A drive system for the displacement of the image section of an X-ray apparatus. The drive system is constructed such that the acceleration of the image section by the motor is proportional to the force produced by the user. To this end, a force which is exerted on a grip is converted into an electrical signal which is integrated, the speed of the motor being proportional to this integral.

11 Claims, 3 Drawing Figures



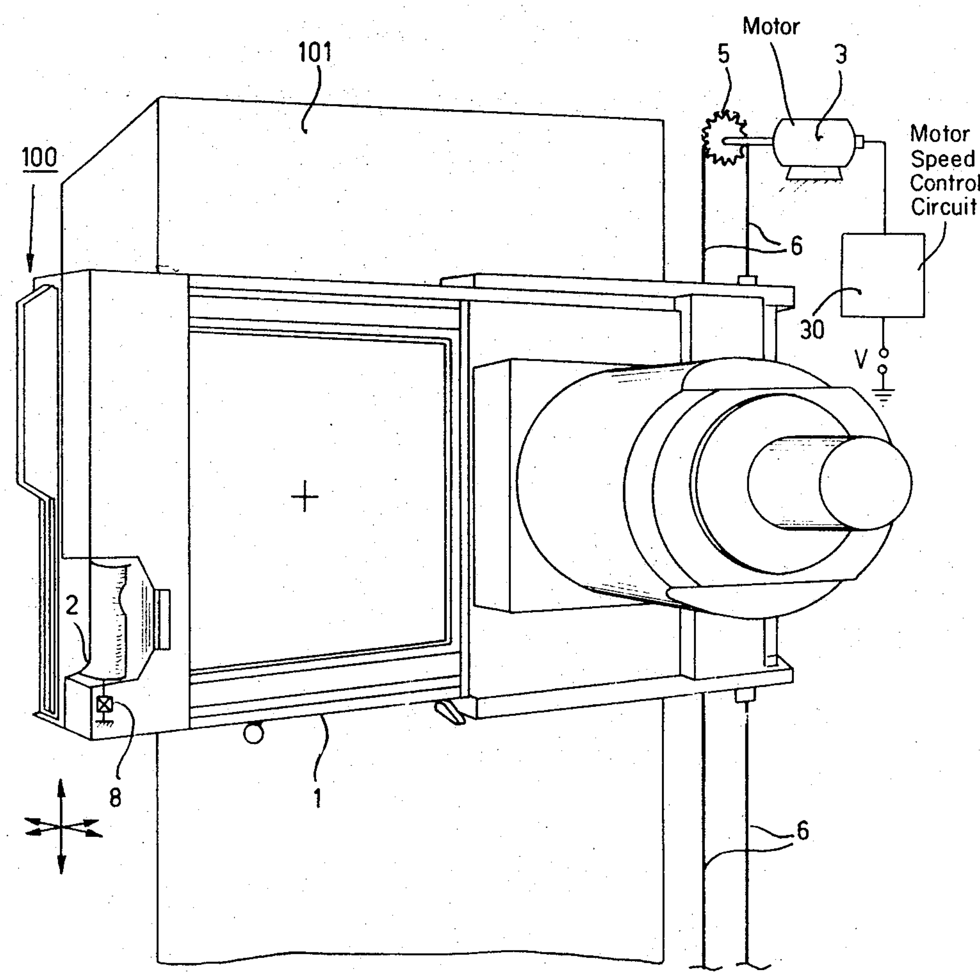


Fig. 1

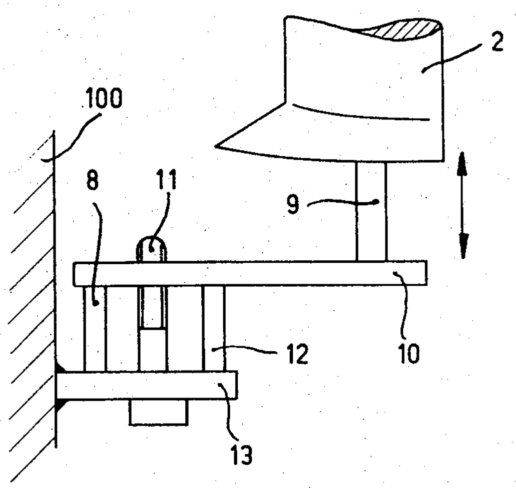

2
100
8
11
9
12
10
13

Fig. 2

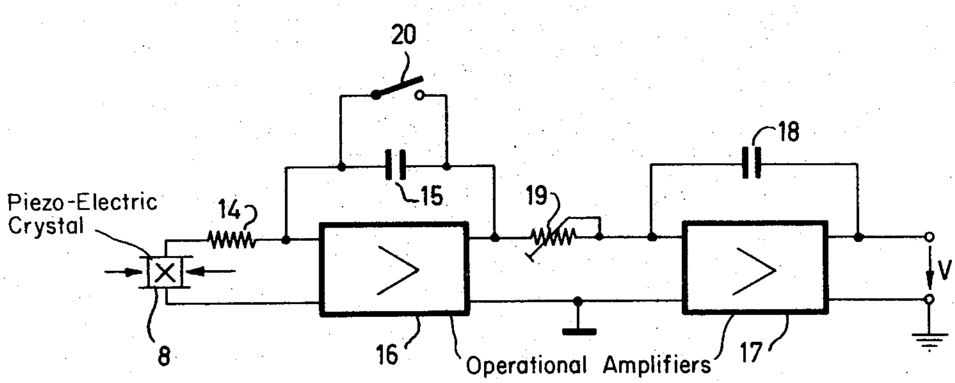

20
18
Piezo-Electric
Crystal
14
15
19
V
8
16
Operational Amplifiers
17

Fig. 3

DRIVE SYSTEM FOR THE IMAGE SECTION OF AN X-RAY APPARATUS

The invention relates to a drive system for the displacement of the image section of an X-ray apparatus for medical purposes, comprising a converter provided with a generator element for converting a force exerted by a user into an electric voltage which controls a drive motor such that the speed of the motor, and hence the displacement of the image section is, dependent of the force exerted by the user.

A drive system of this kind is known, for example, from German Patent Application M 25099. A drawback of this known device is that when a constant force is exerted, the speed of the image section substantially suddenly accelerates from zero to a given value. The acceleration, consequently, is initially very high, and as a result the user at first has the feeling that he brings a very small mass into motion. If the force exerted by the user thereafter remains constant, the speed does not change. The acceleration is then substantially zero, so that the user has the feeling that he brings a very large mass into motion. This movement behaviour is experienced as annoying by the user.

In another known drive system (see German Auslegeschrift 1,566,119), comprising a converter for converting the force exerted by the user into an electric voltage, the motor is controlled such that the acceleration of the image section by the motor is proportional to the force exerted by the user. The said drawback is thus eliminated. The proportionality between the acceleration of the image section and the force exerted by the user is then obtained by means of a control slide which is provided in a grip by means of which the image section is displaced by the user. By means of this control slide the damping of an oscillator can be influenced, the output voltage of the said oscillator being rectified and controlling a magnetic coupling provided between the motor drive and the image section. The shape of the control slide, the electric parameters of the oscillator and the characteristic of the magnetic coupling must then be such that the desired linear relationship is obtained. It was found in practice that it is difficult to achieve the given values in view of the tolerances of these elements. Variation of the ratio of the force exerted by the user and the force delivered by the motor is particularly difficult at a later stage.

The invention has for its object to provide a construction of a drive system of this kind such that, in spite of the manufacturing tolerances present, there is always a linear relationship between the force exerted by the user and the force delivered by the motor, and also such that the ratio of these two forces can be changed at a later stage without the linear relationship between the two forces being affected.

To this end, the drive system according to the invention is characterized in that the output voltage of the converter is substantially proportional to the force exerted by the user, the output of the converter being connected to the input of an integrator, the output voltage of which is proportional to the time integral of the voltage on its input, the speed of the motor being proportional to the output voltage of the integrator.

In a further embodiment according to the invention, the converter comprises a piezo-electric crystal as the generator element.

In a drive system of this kind, usually two converters must be provided for converting the force exerted by the user which can act in two opposite directions. However, one converter suffices if according to a further embodiment of the invention the generator element of the converter is mechanically biassed and arranged such that a force exerted on the grip by the user causes a decrease or an increase of the bias. Generally suitable means must then be privided to ensure that the output voltage of the converter is zero when only the mechanical bias acts on the generator element. As will be demonstrated hereinafter, this requirement is automatically satisfied when use is made of a piezo-electric generator element.

It may be desirable to effect the displacement of the image section in two or in even three mutually perpendicular directions by means of a motor. The drive systems required for this purpose are controlled in a further embodiment according to the invention in that at least one converter is associated with each drive system, the said converter being arranged such that the speed of the associated motor is influenced if the force exerted by the user contains a component in the direction in which said motor can displace the image section.

The displacements of the image section of an X-ray apparatus for medical purposes in the three mutually perpendicular directions (in the vertical direction, in the lateral direction and in the compression direction) usually involves the acceleration of different masses; for example, in the case of a displacement of the image section in the compression direction, only the mass of the image section itself and that of a possibly present counterweight must be put into motion, whilst in the case of a movement in the vertical direction the tube carriage and the associated counterweight must also be moved. However, the radiologist would like to obtain the same acceleration in each direction when a given force is applied. Therefore, in a further embodiment according to the invention, the integrators for integrating the voltages on the output of the converters are constructed such that the speed which is produced when a given force is exerted on the grip is the same for all motors.

The invention and its advantages will be described in detail hereinafter with reference to the drawing.

FIG. 1 shows an image section of an X-ray apparatus for medical purposes, comprising a drive system according to the invention for the displacement in the vertical direction,

FIG. 2 shows the arrangement of a converter which is capable of taking up forces in two opposite directions, and

FIG. 3 shows a circuit arrangement to be used for a converter comprising a piezo-electric generator element for generating a voltage which is proportional to the exerted force, and for integrating this voltage.

FIG. 1 shows the image section **100** of an X-ray apparatus **101** for medical purposes, the said image section being movable in the desired direction by means of a grip **2**, a generator element **8** being loaded to a greater or lesser extent in the case of movement in the vertical direction. So as to assist the movement of the image section **100** in the vertical direction, a motor **3** is provided which drives a gearwheel **5** and a chain **6** which is coupled thereto; the image section is connected to this chain. The speed of the motor **3** is increased to a desired value by means of a speed control unit **30**; for this purpose an electric voltage V is used which is proportional to the desired speed to be obtained and which is dependent of the force, and of the duration thereof, which is exerted on the grip **2**. Conversion of this voltage into a porportional speed is known per se (see German Auslegeschrift 1,936,915, FIG. **2**); therefore, this will not be elaborated herein.

FIG. **2** shows the arrangement of a piezo-electric generator element **8** (for example, a rod of barium titanate) which is capable of taking up forces in two opposite directions. In comparison with generator elements which are provided with springs and which are used in the known motor drive systems for X-ray apparatus, the piezo-electric generator element has the advantage that the grip **2** on which the force of the user is exerted is not displaced with respect to the image section **100**. The piezo-electric crystal is clamped between two rods **10** and **13**, the rod **13** being rigidly connected to the image section **100** and the rod **10** being connected, by way of a pin **9**, to the grip **2**. The rods **10** and **13** are pressed against the piezo-electric crystal **8** and against a pin **12** by means of a screw **11**; this pin **12** serves to prevent excessive tilting of the rods with respect to each other. If a downwards directed force is exerted on the grip **2**, the pressure on the crystal decreases, whilst in the case of an upwards directed force the pressure on the crystal increases. As is known, a linear relationship exists between the variations of the force exerted on the grip **2** and the variation of the surface charge on the crystal **8**.

FIG. **3** shows the block diagram of a circuit arrangement for generating a voltage V for controlling the speed of the motor **3** on the basis of the variations of the charge on the crystal **8**. The electrodes of the crystal **8** are connected, via a resistor **14** of 56 kΩ, to the high-ohmic input, provided with field-effect transistors, of an operational amplifier **16**, the output of which is connected to the input via a capacitor **15** of 100 nF. The charge on the crystal **8** decreases at a rate determined by the time constant given by the resistor **14** and the capacitance of the crystal, the current then flowing charging the capacitor **15**, with the result that the voltage across this capacitor or - because the voltage on the input of the amplifier **16** amounts to approximately zero as a result of the high amplification - the voltage on the output of the amplifier **16** is proportional to the charge previously present on the crystal **8**. If the pressure on the crystal and hence the charge changes, the voltage on the output of the amplifier changes accordingly. Because this voltage is proportional to the sum of all charge variations and because the charge variation is proportional to the variation of the force, the voltage on the output of the amplifier **16** is proportional to the force acting on the grip **2**. This voltage is applied to an integrator, consisting of an operational amplifier **17**, the output of which is connected via a capacitor **18** of 1.5 nF to the input which, moreover, is connected to the output of the amplifier **16** via a variable resistor **19** of approximately 100 kΩ. The voltage V on the output of the integrator is proportional to the time integral of the voltage on the output of the charge amplifier **16**, and hence to the time integral of the force exerted on the grip **2**. The speed of the motor **3** is adjusted in known manner (see German Auslegeschrift 1,936,915) to a value which is proportional to the voltage V on the output of the integrator (**17, 18, 19**).

The relationship between the force produced by the user and that delivered by the motor **3** can be adjusted by means of the variable resistor **19**, because the larger the resistance thereof, the smaller the voltage V on the input of the integrator and the smaller the variation of the speed of the motor. Instead of the variable resistor **19** of the integrator, a potentiometer connected to the output of the integrator could alternatively be used for this purpose, it then being possible to derive the voltage V for controlling the speed of the motor **3** from the slide contact of said potentiometer. For reversal of the direction of rotation of the motor **3**, the polarity change of the voltage on the output of the integrator can be utilized.

Connected parallel to the capacitor **15** is a switch **20** which short-circuits the capacitor as soon as the user releases the grip **2**. To this end, the grip could be constructed, for example, as a rotating grip which returns to a rest position after having been released, thus closing the switch **20**. Because the capacitor **15** is thus each time discharged in the intervals between two displacements of the image section **100**, drifting of the zero point of the charge amplifier **16** is prevented, with the result that the voltage on its output is always zero when no force is exerted on the grip **2**.

If the user releases the grip **2** before the image section has come to a standstill, the voltage on the output of the charge amplifier **16** becomes zero, but the value of the voltage V on the output of the integrator **17, 18, 19** is maintained, i.e., the motor **3**, or the image section **100**, continues its movement at constant speed. The movement of the image section **100** is therefore that of an accelerated, frictionlessly guided body. So as to introduce friction, i.e., so as to ensure that the image section **100** does not continue to move indefinitely after the release of the grip **2**, a resistor (not shown) can be connected parallel to the capacitor **18**, the said resistor discharging the capacitor with the result that the voltage V, and hence the speed, decreases to zero. It is even more advantageous to connect a switch parallel to the capacitor **18**, the said switch shortcircuiting this capacitor after the grip **2** has been released; this is similar to the short-circuiting of the capacitor **15** by the switch **20**.

A particular advantage of the drive system according to the invention is that the acceleration of the image section is exclusively dependent of the force exerted on the grip **2** by the user. Consequently, for example, a counterweight for the image section **100** and the tube carriage which is connected thereto (not shown) could be dispensed with, without the user having to exert more force for the upward movement of the image section than for the downward movement (in this case the drive would have to be effected via a self-braking transmission which prevents the image section from moving downwards when the grip is released).

This characteristic of the drive system according to the invention, moreover, facilitates the provision of corresponding drive systems for the two other directions (lateral and compression direction). It merely must be ensured that the proportionality factors between the force exerted on the grip and the voltage on the output of the charge amplifier **16** and between the time integral of this voltage and the voltage V on the output of the integrator are the same for all drive systems. The radiologist will then have the feeling that he accelerates the same mass in every direction, even though as a result of the different weight-compensation systems for the different directions of movement different masses are accelerated. The generator elements required for these drive systems can be arranged in the same way as shown in FIG. 2 for the generator element for driving in the vertical direction, i.e., such that the speed of the associated motor is influenced when the force produced by the user contains a component in the direction in which the associated motor drive is active.

What is claimed is:

1. A drive system for power assisting an individual in displacing a mass which is free to move, such that the mass moves in response to manually applied forces as if it had a lower than actual mass, comprising for each direction in which such power assisting is desired:

- means for sensing the amount of force manually applied to said mass in such direction;
- integrating means responsive to said sensed amount of force for generating a voltage proportional to the time integral thereof;
- a variable speed electric motor coupled to said mass to assist in moving said mass in such direction, the velocity of said mass in such direction being proportional to the speed of said motor;
- a motor speed control circuit responsive to said generated voltage proportional to the time integral and electrically connected to said motor to drive said motor at a speed proportional to said generated voltage, whereby said motor so assists in moving said mass in such direction that said mass moves in response to said manually applied force in such direction as if it had a lower than actual mass.

2. A drive system as defined in claim **1** wherein said means for sensing generates a voltage proportional to the amount of force manually applied to said mass in such direction, said integrating means being responsive to said voltage proportional to the amount of force for generating a voltage proportional to the time integral thereof.

3. A drive system as defined in claim **2** wherein said means for sensing comprises a piezo-electric crystal to receive force manually applied to said mass in such direction, and an integrator sensitive to charge build up on said crystal resulting from changes in force applied to said crystal, said charge sensitive integrator generating a voltage proportional to the sum of said charge build up, said generated voltage thereby also being proportional to the force manually applied to said mass in such direction.

4. A drive system as defined in claim **3** and further comprising a handgrip, said piezo-electric crystal being positioned between said handgrip and said mass to receive forces manually applied to said mass in such direction via said handgrip.

5. A drive system as defined in claim **4** wherein said piezo-electric crystal is mechanically loaded in order to be responsive to changes in both positive and negative forces manually applied to said mass in such direction via said handgrip.

6. A drive system as defined in claim **5** wherein said integrator sensitive to charge build up on said crystal is automatically reset when no force is applied to said handgrip.

7. A drive system as defined in claim **1** wherein said voltage generated by said integrating means responsive to said sensed amount of force gradually decays when no amount of force is sensed, thereby simulating friction.

8. A drive system as defined in claim **1** and further comprising means for adjusting the proportionality constant between at least one pair of quantities defined as being proportional.

9. A drive system for power assisting an individual in displacing the image section of an X-ray apparatus, such that the image section moves in response to manually applied forces as if it had a lower than actual mass, comprising for each direction in which such power assisting is desired:

- means for sensing force manually applied to said image section in such direction and for generating a first voltage proportional thereto;
- integrating means responsive to said first voltage for generating a second voltage proportional to the time integral thereof;
- a variable speed electric motor coupled to said image section to assist in moving said image section in such direction, the velocity of said image section in such direction being proportional to the speed of said motor;
- a motor speed control responsive to said second voltage and electrically connected to said motor to drive said motor at a speed proportional to said second voltage, whereby said motor so assists in moving said image section in such direction that said image moves in response to said manually applied force in such direction as if said image section had a lower than actual mass.

10. A drive system as defined in claim **9** wherein said means for sensing comprises a piezo-electric crystal positioned to receive force manually applied to said image section in such direction, and an integrator sensitive to charge build up on said crystal resulting from changes in force applied to said crystal, said charge sensitive integrator generating said first voltage proportional to the sum of said charge build up, said generated first voltage thereby also being proportional to the force manually applied to said image section in such direction.

11. A drive system as defined in claim **9** wherein power assistance is desired in more than one direction and the proportionality constants between quantities which are defined to be proportional are so selected that the same rate of acceleration of said image selection results when the same amount of force is applied to said image section in any of said desired directions, whereby the lower effective mass of said image is the same in any of said desired directions.

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