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CENTRIFUGE WITH EFFICIENCY MEASURING DEVICE

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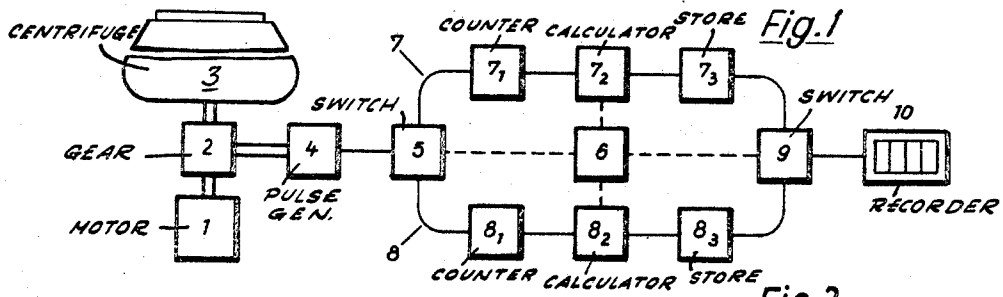


Fig.1

Fig.2

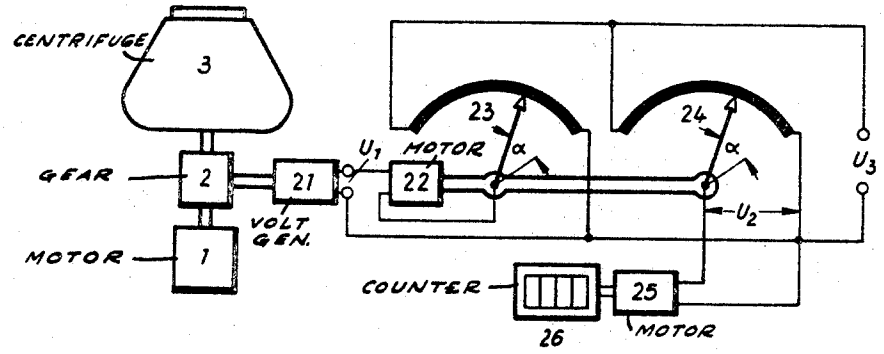


Fig.3

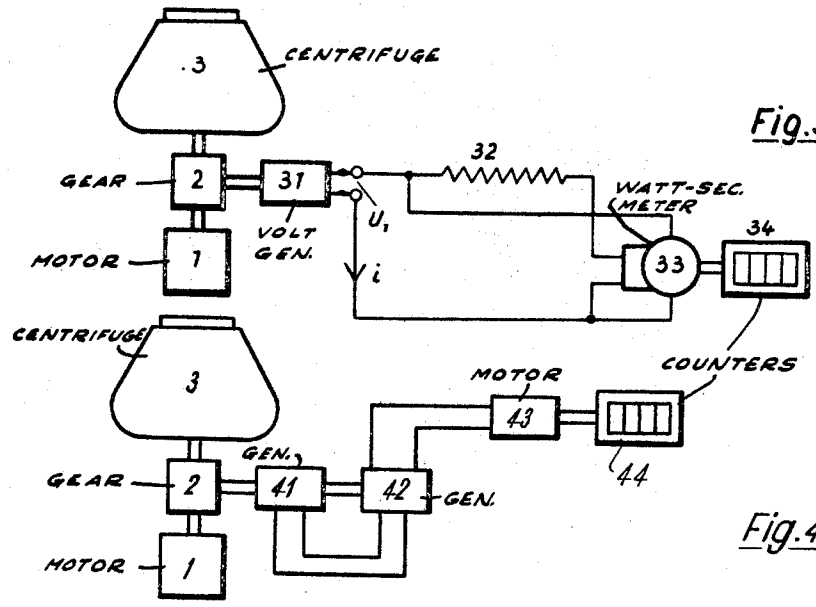


Fig.4

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CENTRIFUGE WITH EFFICIENCY MEASURING DEVICE

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The present invention relates to centrifuges.

It is a preferred object of the centrifuging technique to separate particles which are suspended in a liquid, according to their migration speed in a centrifugal field, or to deposit such particles. The field of forces effective in the rotor of the centrifuge is proportional to the square of the speed of the rotor in accordance with a fundmental physical law.

The length of the path through which the particles travel in the suspension in a certain time—and thus also the quantity of particles which have reached the bottom of the centrifuge beaker during this time, is proportional to the time integral over the square of the speed.

This relationship is true for so-called preparative centrifuges in which a single rotor filling is centrifuged until the required effect is obtained and the lighter fraction can be separated from the heavier fraction or sediment, as well as also for so-called separators in which the required separation of the sedimenting particles from the non-sedimenting liquid is obtained in continuous through-put during the through-put period.

Furthermore, when operating with a so-called analytical ultra-centrifuge to determine the sedimentation coefficient the path through which the substance under observation travels within a certain period must be related to the time integral over the square of the speed.

In all these problems the action of the centrifuge is not proportional to the speed n but to n^2, the square of the rotor speed and the action G of the centrifugal field during a certain time interval $\Delta t = t2 - t1$ is given by the time integral over the square of the speed. Thus

$$G = \int_{t1}^{t2} n^2 dt$$

This quantity G is referred to below as "centrifugal action."

The centrifugal action of known centrifuges was calculated heretofore in such manner that a constant speed was assumed, that this speed was squared and then multiplied by centrifuging time. If the effects of the starting and stopping periods of the centrifuge, during which the speed changes are also to be taken into account, the assumption is generally made that the acceleration after starting and the deceleration during stopping are uniform and the centrifugal action can then be calculated approximately by taking one-third of the acceleration and deceleration times into account.

The disadvantage of this calculating method practised heretofore is that a considerable amount of calculation is required and particularly that constancy of speed and of acceleration after starting and during stopping must be assumed. However, these conditions are ensured only approximately. Fluctuations in the speed or deviations from uniformity of the acceleration on starting and of the deceleration on stopping can be taken into account only with a great amount of calculations.

The invention avoids these disadvantages. The invention consists in a centrifuge which is provided with a measuring device which is adapted to indicate the value of the time integral over the square of the rotory speed of the rotor.

Apart from the avoidance of the above-mentioned disadvantages, the centrifuge according to the invention has the additional particular advantage that the centrifugal action is measured continuously during operation from a defined starting-point onwards.

The measuring device can be used advantageously also for performing certain control functions. For example, a counting device thereof can be provided with a pre-selection device whereby switch contacts can be activated when adjustable values of the counting device are attained.

Since, as mentioned above, the quantity of the sedimenting substance depends upon the centrifugal action, a preferred embodiment can be constructed so that the measuring device which measures the centrifugal action switches the driving motor off when an adjustable amount has been attained, and causes the centrifuge to come to stand still.

When operating with an analytical ultra-centrifuge it is often desirable that the first registration after starting is effected when the centrifugal action has attained a certain value. Particularly in this case it is hardly possible to obtain an approximately exact value by means of the methods known heretofore, since during the runup of the rotor after starting the speed generally does not change in a manner which can be assessed exactly.

If, however, an analytical ultra-centrifuge has a measuring device according to the invention which indicates the centrifugal action continuously, this measuring device can be easily modified in a further embodiment of the invention in such a manner that when an adjustable value is attained a registration device, e.g. a photographic device, is activated for detecting the concentration distribution in the centrifuge cell.

Some embodiments of the invention will now be described in more detail with reference to the accompanying drawings, in which:

FIG. 1 is a block diagram of a first embodiment, and FIGS. 2, 3 and 4 are block diagrams of further embodiments.

In the embodiment of the invention illustrated in FIG. 1 a centrifuge is indicated on the left hand side of FIG. 1. A driving motor **1** drives a centrifuge rotor **3** by means of a driving gear **2**. The driving gear **2** controls synchronously a pulse transmitter **4** which, in a manner known per se, delivers a certain number of pulses during each rotation of the rotor **3**. These pulses are applied to a first two-way device **5** which is switched by a timing device **6** at adjustable and exactly defined time intervals alternately to branch paths **7** and **8**.

When the pulse transmitter **4** is connected by the two-way device **5** to the branch path **7** the pulses delivered by the transmitter are counted by a counting device 7_1 during the respective time interval. At the beginning of the next time interval the two-way device **5** is switched by the timing device **6** to the branch path **8** and the following pulses are received by a counting device 8_1. Meanwhile, the number of pulses recorded in the counting device 7_1 during the last time interval is multiplied by itself by a calculating device 7_2 in the branch path **7** and the result is stored in a storage device 7_3. Upon the next switching action of the timing device a further two-way device **9** is set so that the number of pulses recorded in the storage device 7_3 is cumulatively added to the number recorded in a result device **10**. Simultaneously, the pulses arriving from the pulse transmitter are also received again by the counting device 7_1 and the number received in the counting device 8_1 during the last time interval is squared in a calculating device 8_2 and recorded in a storage device 8_3. Upon the next switching action of

the timing device 6 the storage device 8_3 is connected by way of the further two-way device 9 to the result device 10 and the number stored in the storage device is cumulatively added to the number already stored therein in the result device; the process is then repeated. In this manner the pulses can be received, squared and stored in the two switched branch paths and delivered to the result device 10. The number appearing in the result device 10 is proportional to the centrifugal action.

A second embodiment of the invention operates in accordance with an analog calculating method and is diagrammatically illustrated in FIG. 2. The motor 1 of the centrifuge drives the rotor 3 by way of the driving gear 2. Moreover, a measuring generator 21 producing a voltage U_1 which is proportional to the speed of the rotor 3 is also driven by the driving gear 2 in a suitable speed ratio. This voltage is adjusted applied in a known manner to a servo-motor 22 which displaces the slider of a rotary potentiometer 23 so that the rotary angle α of the potentiometer is proportional to the voltage U_1.

The rotary potentiometer has a linear characteristic and its spindle is connected to the spindle of a second rotary potentiometer 24 which has a square characteristic so that the voltage taken off the latter increases with the square of the rotary angle α. The appropriate ends of both potentiometers 23 and 24 are connected to a fixed voltage source U_3. A voltage U_2 tapped off by the slider of potentiometer 24 is thus proportional to the square of the rotary angle and is consequently proportional to the square of the speed of the rotor.

The voltage U_2 is applied to a measuring motor 25 the speed of which is proportional to the applied voltage U_2 and this measuring motor 25 drives a counting device 26. The value indicated by the counting device 26 is proportional to the centrifugal action.

A variation of the above embodiment can be obtained when the potentiometer 23 has a root dependent characteristic and the potentiometer 24 a linear characteristic. A potentiometer has a root dependent characteristic when the root of the voltage tapped off the potentiometer is proportional to the rotary angle α.

A further embodiment is illustrated in FIG. 3. A rotor 3 is driven by a motor 1 by means of a driving gear 2. Furthermore, a measuring generator 31 producing a voltage U_{31} which is proportional to the speed of the rotor 3 is driven at a suitable speed ratio by the driving gear 2.

A current which is also proportional to the rotary speed flows in a current circuit which is connected to the measuring generator and which has a fixed external resistor 32. The power dissipated in the resistor 32 is proportional to the product of current strength and applied voltage and is thus proportional to the square of the speed of the rotor. This power is measured by means of a watt-second measuring device 33, e.g. an electrodynamometer, which drives a counting device 34. The value indicated by the latter is proportional to the centrifugal action.

A still further embodiment of the invention is illustrated in FIG. 4 and comprises two measuring generators 41 and 42 which are driven synchronously by the driving gear 2 which also drives the rotor 3. The measuring generator 41 is excited in a constant manner, e.g. a magnetic field thereof is produced by a permanent magnet and it generates in a known manner a current which is proportional to the rotary speed of the rotor 3.

The measuring generator 42 is excited electromagnetically by means of a field winding which is fed with the current produced by the generator 41, whereby a magnetic field strength is produced which is proportional to the speed of the rotor.

Thereby the voltage which is induced by the generator 42 and which is proportional to the product of speed and excitation, becomes proportional to the square of the speed of the centrifuge rotor 3. A measuring motor 43 is driven with this voltage and drives a counting device 44 associated therewith, the value indicated by the latter is proportional to the centrifugal action. In a preferred variation of this embodiment the two measuring generators described above are constructed to form a unit having a common shaft.

The counting device of the measuring device may alternatively be re-settable to zero. The invention can also be realised with other circuit arrangements than the arrangements mentioned herein with reference to the block diagrams.

The embodiments described in the examples are constructed from known elements of control and measuring engineering and do not require any further explanation.

I claim:

1. A centrifuge comprising a centrifuge rotor, a driving motor, driving gear means operatively interposed between the motor and the rotor for driving the rotor at a required rotary speed, means for producing an electrical signal proportional to the instantaneous rotary speed of said rotor, converter means for producing during a given time interval a signal proportional to the square of said electrical signal, and means for indicating said squared quantity summed over the time of operation of the centrifuge, wherein said means for producing an electrical signal comprises pulse transmitter means coupled to the rotor for producing electrical pulses at a frequency proportional to said rotor speed, said converter means comprising counting means for counting pulses, timing means for applying said pulses to said counting means during said given time intervals, calculating means connected to said counting means for producing a signal proportional to the square of the value of said counted pulses, said indicating means including further counting means, and means for applying said squared quantity to said further counting means.

2. A centrifuge comprising a centrifuge rotor, a driving motor, driving gear means operatively interposed between the motor and the rotor for driving the rotor at a required rotary speed, means for producing an electrical signal proportional to the instantaneous rotary speed of said rotor, converter means for producing during a given time interval a signal proportional to the square of said electrical signal, and means for indicating said squared quantity summed over the time of operation of the centrifuge, wherein said means for producing an electrical signal is a measuring generator means driven at a speed proportional to the rotor speed for producing a voltage proportional to the rotor speed, and wherein the converter means is a measuring value converter means including a servo-motor connected to the output of said measuring generator means and a potentiometer arrangement driven by said servo-motor and producing an output voltage proportional to the square of a voltage applied thereto, means for applying said first mentioned voltage to said measuring value converter means, said indicating means including a measuring motor and a counting means connected thereto and means for applying said squared output voltage to said measuring motor driving said counting means for indicating said squared voltage.

3. A centrifuge comprising a centrifuge rotor, a driving motor, driving gear means operatively interposed between the motor and the rotor for driving the rotor at a required rotary speed, means for producing an electrical signal proportional to the instantaneous rotary speed of said rotor, converter means for producing during a given time interval a signal proportional to the square of said electrical signal, and means for indicating said squared quantity summed over the time of operation of the centrifuge, wherein said means for producing an electrical quantity is a measuring generator means driven at a speed proportional to the rotor speed for producing a voltage proportional to the rotor speed, said converter means comprising a current circuit, means for applying said voltage to said current circuit to produce a current therein proportional to said voltage, and watt-second counter

means for measuring the power dissipated in said current circuit to provide a value proportional to the time integral of the square of said voltage.

4. A centrifuge comprising a centrifuge rotor, a driving motor, driving gear means operatively interposed between the motor and the rotor for driving the rotor at a required rotary speed, means for producing an electrical signal proportional to the instantaneous rotary speed of said rotor, converter means for producing during a given time interval a signal proportional to the square of said electrical signal, and means for indicating said squared quantity summed over the time of operation of the centrifuge, wherein said means for producing an electrical signal is a first measuring generator driven at a speed proportional to the rotor speed and energized in a constant manner, said electrical signal being a voltage produced by said first generator proportional to the rotor speed, and wherein the means for producing a signal proportional to the square of said electrical signal is a second measuring generator having a field winding and being driven at the same speed as the first generator, means being provided for applying the voltage produced by the first generator to said field winding of said second generator said indicating means including a measuring motor and a counting means connected thereto and means for applying the voltage produced by said second generator to said measuring motor driving said counting means for indicating said squared value.

5. In a centrifuge having a rotor driven in rotation, measuring means for measuring the value of the square of the instantaneous rotary speed of the rotor, and indicating means connected to said measuring means for indicating numerically the sum of the instantaneous values measured during the time of operation of the centrifuge, wherein said measuring means includes a pulse transmitter coupled to said rotor providing pulses at a frequency proportional to the speed of the rotor and a calculating device coupled to the output of said pulse transmitter providing a signal whose value represents the square of the frequency of said pulses per given time period, and said indicating means includes means for summing the values of said signals for consecutive time periods and a counter for indicating the summed values.

6. In a centrifuge having a rotor driven in rotation, measuring means for measuring the value of the square of the instantaneous rotary speed of the rotor, and indicating means connected to said measuring means for indicating numerically the sum of the instantaneous values measured during the time of operation of the centrifuge, wherein said measuring means includes a measuring generator driven at a speed ratio fixed relatively to the rotor speed and producing a primary voltage proportional to the rotary speed and converter means including a potentiometer arrangement adjusted in accordance with said primary voltage providing an output voltage corresponding to the square of said primary voltage.

7. In a centrifuge having a rotor driven in rotation, measuring means for measuring the value of the square of the instantaneous rotary speed of the rotor, and indicating means connected to said measuring means for indicating numerically the sum of the instantaneous values measured during the time of operation of the centrifuge, wherein said measuring means includes a generator coupled to said rotor to provide a voltage proportional to the rotary speed thereof and a current circuit connected to the generator providing a current in response to said voltage which is proportional to the rotary speed of said rotor, and a watt-second measuring device and a counter connected in series to said current circuit and providing a signal proportional to the time integral of the square of the rotary speed of said rotor.

8. In a centrifuge having a rotor driven in rotation, measuring means for measuring the value of the square of the instantaneous rotary speed of the rotor, and indicating means connected to said measuring means for indicating numerically the sum of the instantaneous values measured during the time of operation of the centrifuge, characterised in that said measuring means includes two measuring generators driven at a rotary speed which is in a definite ratio to the speed of the rotor, one generator being energised in a constant manner and having its output voltage applied to the field winding of the second generator, and the output voltage of the second generator being applied to said indicating means including a measuring motor which drives a counting device.

9. A centrifuge as claimed in claim 8, characterised in that the counting device of the measuring device for the time integral of the square of the rotary speed is resettable to the value of 0.

10. A centrifuge as claimed in claim 9, characterised in that the counting device of the measuring device for the time integral of the square of the rotary speed is provided with a pre-selection device by which switch contacts can be actuated when adjustable values of the counting device are attained.

References Cited

UNITED STATES PATENTS

2,465,437	3/1949	Engelhardt	324—70
1,715,446	6/1929	Bossart	324—70
2,295,118	9/1942	LeClair	324—70
2,443,668	6/1948	Tagg	324—70
2,882,717	4/1959	Brown	233—1
2,949,774	8/1960	Cox	324—142
3,018,978	1/1962	Graneau	324—69
3,244,363	4/1966	Hein	233—1

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