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OR 2,366,658

Jan. 2, 1945. A. SVOBODA 2,366,658

ANALYZER

Filed Nov. 10, 1942 2 Sheets-Sheet 1

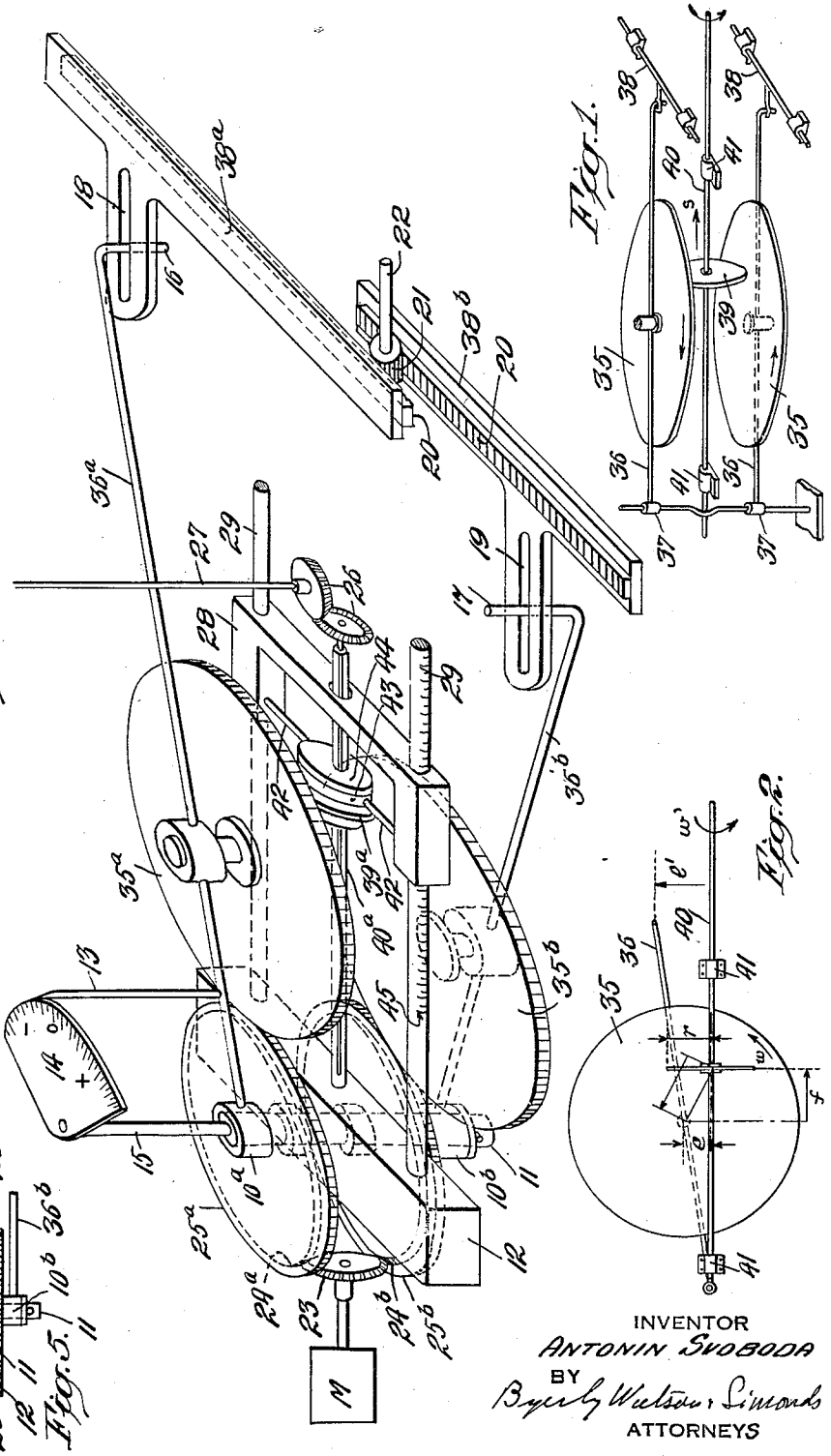


Fig. 3.

Fig. 1.

Fig. 2.

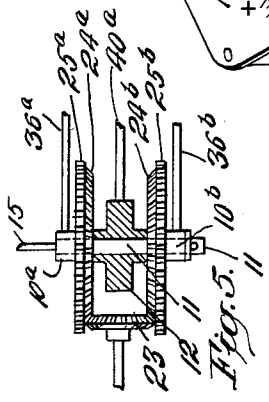


Fig. 5.

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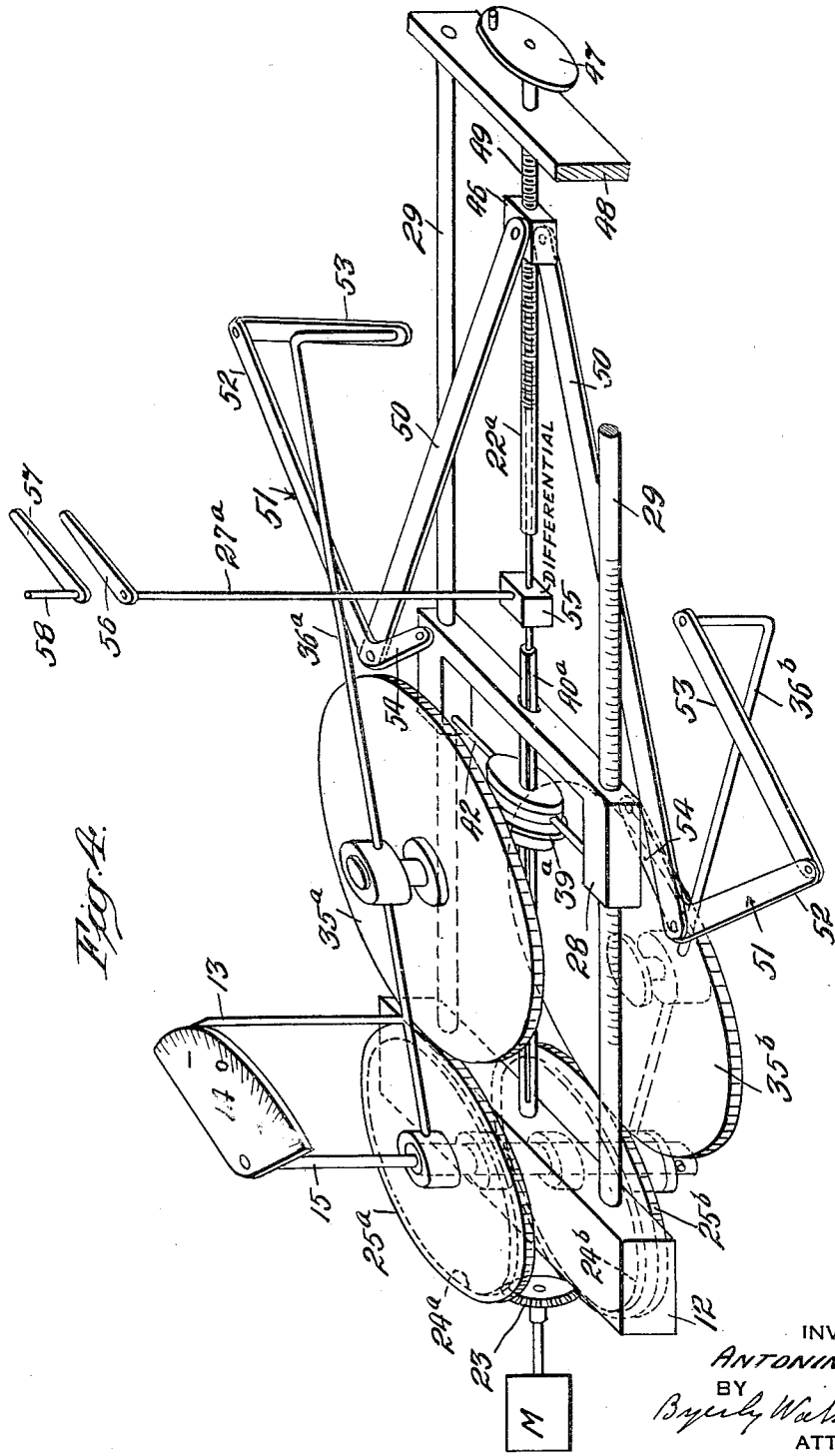


Fig. 4.

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235. REGISTERS
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UNITED STATES PATENT OFFICE

2,366,658

ANALYZER

Antonin Svoboda, Forest Hills, N. Y.

Application November 10, 1942, Serial No. 465,157
In Czechoslovakia December 31, 1938

8 Claims. (Cl. 235—61.5)

This invention relates to an analyzer for analyzing movements to indicate the first and second time derivatives thereof. As hereinafter indicated, the analyzer is susceptible of use as a variable-speed transmission.

In fire director apparatus, it is frequently necessary to analyze the movement of a target. My analyzer may be used for this purpose by connecting it with a telescope or other sight in which the target is followed. When so connected, the analyzer provides a desirable means for transmitting the movement of a motor to the sight so that the sight may be mechanically driven.

The analyzer consists of a driven friction wheel between two driving discs which are mounted on scissors levers in such manner that when the discs are rotated at a constant speed the axial movement of the wheel is equal to the first time derivative of the rotary movement of the wheel, and the second time derivative of this movement is indicated by the position of the scissors levers.

In describing the principle and construction of the analyzer, I shall refer to the accompanying drawings in which:

Figs. 1 and 2 are diagrams indicating the principle of operation, Fig. 1 being a perspective view, and Fig. 2 a plan view with the upper disc removed;

Fig. 3 is a perspective view showing the construction of the analyzer and including connecting parts and scales which are not shown in the diagrams;

Fig. 4 is a perspective view showing the analyzer provided with a follow-up control; and

Fig. 5 is a fragmentary vertical section in the plane of the axis of the pivot of the scissors levers and the axis of the motor shaft.

The principle of the analyzer will first be described with reference to Figs. 1 and 2. The driving member consists of two friction discs **35** which are rotated in opposite directions at equal speeds. The shafts of the driving discs **35** are journalled on scissors levers **36** mounted on coaxial pivots **37**. The free ends of the levers **36** are connected to slides **38**. These two slides are connected to a control handle in such manner that any movement given to the control handle moves the slides **38** equal distances in opposite directions.

The driven member is a friction wheel **39** located between the driving discs **35** with its periphery in engagement with each of them. The driven wheel **39** is free to move axially as well as rotatably. This is indicated in Fig. 1 by showing the shaft **40** on which the wheel **39** is mounted as extending through bearings **41** in which it may both rotate and slide.

The geometrical arrangement of the apparatus is such that in the "zero position" of the apparatus, that is, when the slides **38** are positioned to close the scissors levers and place the axes of the driving discs in coincidence, as shown in Fig. 1, the axis of the driven wheel **39** intersects the common axis of the driving discs at right angles and is located in the same plane as the levers **36**, so that the wheel is driven at a uniform velocity which is proportional to its distance from the common axis of the driving discs.

The operation of this transmission is such that, when the scissors levers are opened from their zero position in either direction, the axial displacement of the driven wheel **39** is equal to the first time derivative or velocity of the turning movement of the driven wheel **39**, while the movement of the slides **38** is equal to the second time derivative or acceleration of the turning movement of the driven wheel **39**. The reason for this is apparent from geometry of the arrangement as shown in Fig. 4.

Fig. 2 shows parts of the apparatus after the slides **38** have been moved in opposite directions from their zero position so as to turn the levers **36** to symmetrical positions at opposite sides of the axis of the wheel **39**. This separating movement of the levers **36** gives the driven wheel **39** an axial movement in the direction of the arrow *s* (Fig. 1) which increases its distance from the axes of the driving discs **35** and, therefore, increases its rate of rotation. From Fig. 2:

$$\omega' = \omega \cdot \frac{f}{r} = h_1 f \tag{1}$$

$$\frac{df}{dt} = \omega e \tag{2}$$

$$\frac{d\omega'}{dt} = \frac{\omega}{r}\frac{df}{dt} = \frac{\omega^2}{r} e = h_2 e' \tag{3}$$

where ω is the angular speed of the driving discs **35**, ω' is the angular speed of the driven wheel **39**, and h_1, h_2 are constants of the apparatus depending on the value of ω and the dimensions of the apparatus. Equations 1 to 3 are derived directly from the geometric relation of the dimensions shown in Fig. 4. With respect to Equation 2, it should be noted that

$$\frac{df}{dt}$$

is the rate of displacement of the driven wheel **39** along its axis, and this is the component of

the speed of the point of contact of the disc in a direction parallel to its shaft **40**.

As the extent of the turning movement q of the driven wheel **39** is the integral of its rate of rotation, it follows that

$$q=k\int\omega' dt \quad (4)$$

The first time derivative of q is then apparent from Equation 1 above:

$$\dot{q}=k\omega'=kh_1 f \quad (5)$$

and the second derivative of q is apparent from Equation 3 above:

$$\ddot{q}=k\frac{d\omega'}{dt}=kh_2 e' \quad (6)$$

so that the first time derivative of q is proportional to the distance f and the second time derivative of q is proportional to the distance of e'. The distance f is the axial displacement of the driven wheel **39** and of its shaft **40**. The distance e' is proportional to the movement of the slides **38**. It is thus apparent that the device described provides elements moved proportionally to a plurality of time derivatives of the movement of the driven member.

It should be noted that Fig. 2 shows an opening of the scissors levers in such direction that each lever is moved from its zero position in the direction in which the outer periphery of the driving disc nearest it is moving. Thus the lower lever **36** shown in Fig. 2 has been moved from its zero position in the direction in which the outer or right-hand side of the periphery of the lower disc **35** shown in Fig. 2 is moving. Under these circumstances, the friction wheel moves outwardly, that is, towards the right and increases in velocity, and the acceleration is positive. When the scissors levers are opened from their zero position in the opposite direction, it is evident that the wheel will move inwardly and decrease in velocity, that is, the acceleration will be negative. Equation 6 will, therefore, hold in either case, provided that the distance e' is regarded as positive when measured in the direction of the movement of the outer side of the periphery of the driving disc mounted on the lever to which the distance is made.

Fig. 3 shows a convenient method of connecting the parts shown in the diagrams Figs. 1 and 2 and indicating their movements. The scissors levers **36***a*, **36***b* have their ends fixed in collars **10***a*, **10***b* which are rotatably mounted on a post **11** fixed in a supporting block **12**. The value of e' is indicated by means of a pointer **13** and a dial **14**. The pointer **13** is fixed to the lever **36***a* while the dial **14** is carried by a rod **15** fixed in the post **11** and may have a uniform graduation from which the value of

$$K\tan^{-1} e'$$

may be read, or, more desirably a tangent graduation from which the value of e' may be read directly.

The outer ends of the scissors levers **36***a*, **36***b* have bent or vertical extensions **16**, **17** which engage slots **18**, **19** in slides **38***a*, **38***b*. Each slide has on its inner face a rack **20** and the two racks engage opposite sides of a pinion **21** fixed on a control shaft **22** which is mounted in fixed bearings so that turning the control shaft **22** moves the scissors levers **36***a*, **36***b* equal distances in opposite directions.

The driving discs **35***a*, **35***b* are driven in opposite directions from a constant speed motor M. A bevel gear **23** on the shaft of the motor engages bevel gears **24***a*, **24***b* independently rotatable on the post **11**. Spur gears **25***a*, **25***b* attached to the bevel gears **24***a*, **24***b* engage gear teeth formed on the peripheries of the driving discs **35***a*, **35***b*. The friction wheel **39***a* is splined on the shaft **40***a* which is journalled in the block **12**. The shaft **40***a* is connected by bevel gears **26** to the output or driven shaft **27** of the apparatus. Axial movements of the friction wheel are transferred to a slide **28** mounted on rods **29** fixed in the block **12**. The friction wheel **39***a* is connected to the slide **28** by rods **42** which are fixed in the slide and in a ring **43** rotatably mounted on the hub **44** of the friction wheel **39***a*. One of the rods **29** is provided with a scale **45** for reading axial displacements of the friction wheel.

When the apparatus shown in Fig. 3 is used to analyze the movements of a target, the output shaft **27** may be connected to move a sight in which the target is followed and the movements of the sight may be controlled by a hand wheel mounted on the control shaft **22**. When this is done the sight is driven by the motor M under control of the shaft **22** and the first and second time derivatives of its movement are indicated on the scales **45** and **14**.

The manipulation of the device so as to cause the output shaft to follow the movement of a target or any other movement to be analyzed is greatly facilitated by providing the device with a follow-up control as shown in Fig. 4. In the arrangement shown in Fig. 4 the slides **38***a*, **38***b* are replaced by linkages connecting the scissors levers to a nut **46** moved by a hand wheel **47** on a control shaft **22***a*. This control shaft is journalled in a bar **48** fixed to the ends of the rods **29**. A worm **49** is fixed on the control shaft **22***a* to engage the nut **46** so that turning of the control shaft moves the nut along this shaft which, as shown, is in line with the shaft **40***a* of the friction wheel. Links **50** are pivoted on the nut **46** at one of their ends and at their other ends to two bell crank levers **51** at the elbows of these levers. The one arm **52** of each bell crank lever is connected by a link **53** to the outer end of one of the scissors levers **36***a*, **36***b*, while its other arm **54** is pivoted on the slide **28** which moves with the axial movements of the friction wheel.

The friction wheel shaft **40***a* and the control shaft **22***a* enter a differential **55** which adds their movements and transmits the sum to the output shaft **27***a* when the shafts **40***a* and **22***a* are turned in the same direction, and transmits the difference between their turning movements when these shafts are turned in opposite directions.

Turning of the output shaft **27***a* may easily be controlled by the hand wheel **47** to make something connected with this shaft follow the movements of a target or any other movement to be analyzed. For the sake of illustration, Fig. 4 shows a pointer **56** fixed on the output shaft **27***a* and an adjacent pointer **57** fixed on an independently moved shaft **58** which is coaxial with the output shaft **27***a*. To analyze the movement of the shaft **58** the handle **47** is manipulated so as to keep the pointer **56** in coincidence with the pointer **57**. The operation of the device in accomplishing this is as follows:

When the pointer **57** falls behind the pointer **56**, the hand wheel **47** is turned in a clockwise direction (looking from the right in Fig. 4) until the pointer **56** is again coincident with the pointer **57**. When the hand wheel is thus turned, the turning movement of the control shaft **22***a* is in the opposite direction from the turning movement

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of the shaft **40***a*, so that the turning movement of the shaft **22***a* applied through the differential **55** to the output shaft **27***a* immediately slows the output shaft, causing the pointer **56** to drop back into coincidence with the pointer **57**. At the same time the turning movement of the control shaft has the effect of moving the nut **46** to the left swinging the bell crank levers **51** about their ends which are pivoted to the slide **28** to cause an opening movement of the scissors levers **36***a*, **36***b* in a "negative" direction, that is, each lever is moved in the opposite direction from that in which the outer side of the periphery of the driving disc nearest it is moving. This movement of the scissors levers causes the friction wheel **39***a* to move to the left and decrease its rate of rotation. When the slide **28** is moved to the left by the friction wheel, the bell crank levers **51** are turned about the points at which they are fulcrumed to the links **50**, thus swinging the scissors levers towards each other until an equilibrium is obtained at the point where the value of *e* indicated by the position of the levers is equal to the deceleration of the shaft **58**.

Whenever the pointer **57** gets ahead of the pointer **56**, coincidence is restored by turning the control wheel **47** in an anti-clockwise direction, and an operation similar to that already described restores the scissors levers to a position of equilibrium. In this operation the movement of each part is, of course, in the direction opposite from that which occurred when the control wheel was turned in a clockwise direction.

It is thus a simple matter to manipulate the control wheel **47** so as to make the pointer **56** follow the movement of the pointer **57**, and, when this is done, the first and second time derivatives of the turning of the shaft **58** are indicated (with a slight time lag) on the scales **45** and **14**.

As before explained, the output shaft **27***a* may be connected to move a sight, and, in this case, the control wheel **47** is manipulated to cause the sight to follow a target and the first and second time derivatives of the movements of the sight which correspond to those of the target may be read from the scales of the apparatus. In this case, the analyzer constitutes a variable-speed friction drive connecting the motor M with the sight. For this purpose and other uses as a friction drive, the analyzer possesses important mechanical advantages over the friction drives heretofore used in fire-control apparatus. for the danger of slippage is minimized by the fact that the friction wheel is driven at two opposite points of its periphery and may be firmly clamped between the two driving discs, which may be resiliently urged towards each other.

This application is a continuation in part of my application Serial No. 286,650, filed July 26, 1939.

What I claim is:

1. A variable-speed transmission which indicates a number of time derivatives of the movement of a driven member, comprising a pair of pivoted levers, controlling means for swinging said levers in opposite directions outwardly at equal speeds from a zero position in which the levers lie in a common plane, a driving disc mounted on each of said levers, said discs, when said levers are in said common plane. being coaxial and mounted for rotation in planes parallel to the planes of movement of said levers and rotated at constant equal speeds in opposite directions, a driven shaft slidably and rotatably mounted between the driving discs in the zero plane of the levers and mounted perpendicular to the axes of the driving discs, and a driven disc fixed on said driven shaft with its periphery in frictional engagement with both of the driving discs, so that movement of the controlling means is proportional to the second time derivative of the turning movement of the driven shaft while the degree of longitudinal movement of the driven shaft is proportional to the first time derivative of the turning movement of the driven shaft.

2. A variable-speed transmission and movement analyzer comprising a pair of levers, a pivot on which said levers are mounted, controlling means for swinging said levers in opposite directions outwardly at equal speeds from a zero position in which the levers lie in a common plane, a driving disc mounted on each of said levers, said discs, when said levers are in said common plane, being coaxial and mounted for rotation in planes parallel to the planes of movement of said levers, gear teeth at the peripheries of said driving discs, a pair of spur gears journalled on said pivot and engaging the gear teeth of the driving discs, bevel gears secured to said spur gears, a bevel pinion engaging said bevel gears and having its axis intersecting the axis of the pivot, a constant speed motor for driving said bevel pinion so as to turn the driving discs at equal speeds in opposite directions, a driven friction wheel axially-slidably and rotatably mounted with its axis between the driving discs in the zero plane of the levers and perpendicular to the axes of the driving discs and its periphery in frictional engagement with both of the driving discs.

3. A variable-speed transmission and movement analyzer comprising a pair of pivoted levers, controlling means for swinging said levers in opposite directions outwardly at equal speeds from a zero position in which the levers lie in a common plane, a driving disc mounted on each of said levers, said discs, when said levers are in said common plane, being coaxial and mounted for rotation in planes parallel to the planes of movement of said levers and rotated at constant equal speeds in opposite directions. a driven shaft rotatably mounted between the driving discs in the zero plane of the levers and mounted perpendicular to the axes of the driving discs, and a friction disc splined on said driven shaft with its periphery in frictional engagement with both of the driving discs, a slide mounted for movement parallel to the axis of the driven shaft and connected to the driven wheel so as to share the axial movement thereof, scale means for indicating the extent to which the levers have been opened to indicate the acceleration of the driven wheel, and scale means adjacent to said slide to indicate the velocity of the driven wheel.

4. A variable-speed transmission and movement analyzer comprising a pair of levers, a pivot on which said levers are mounted, controlling means for swinging said levers in opposite directions outwardly at equal speeds from a zero position in which the levers lie in a common plane, a driving disc mounted on each of said levers, said discs, when said levers are in said common plane, being coaxial and mounted for rotation in planes parallel to the planes of movement of said levers, gear teeth at the peripheries of said driving discs, a pair of spur gears journalled on said pivot and engaging the gear teeth of the driving discs, bevel gears secured to said spur gears, a bevel pinion engaging said bevel gears and having its axis intersecting the axis of the pivot, a

constant speed motor for driving said bevel pinion so as to turn the driving discs at equal speeds in opposite directions, a driven friction wheel mounted between the driving discs with its axis in the zero plane of the levers and perpendicular to the axes of the driving discs and with its periphery in contact with their opposed faces, a shaft on which said friction wheel is splined, a driven shaft connected to said wheel shaft, a slide mounted for movement parallel to the axis of the wheel shaft and connected to the driven wheel so as to share the axial movement thereof, scale means for indicating the extent to which the levers have been opened to indicate the acceleration of the driven wheel, and scale means adjacent to said slide to indicate the velocity of the driven wheel.

5. A movement analyzer comprising a pair of pivoted levers, controlling means for swinging said levers in opposite directions outwardly at equal speeds from a zero position in which the levers lie in a common plane, a driving disc mounted on each of said levers, said discs, when said levers are in said common plane, being coaxial and mounted for rotation in planes parallel to the planes of movement of said levers and rotated at constant equal speeds in opposite directions, a driven friction wheel axially-slidably and rotatably mounted with its axis between the driving discs in the zero plane of the levers and perpendicular to the axes of the driving discs and its periphery in frictional engagement with both of the driving discs, a driven shaft connected to the wheel so as to share the rotary movement thereof, and follow-up control means comprising a controlling member, means for transmitting movement of the controlling member directly to the driven shaft, means so connecting the control member and the pivoted levers and the friction wheel that movement of the controlling member tends to move the pivoted levers in one direction, while the axial movement of the wheel caused by such movement of the levers tends to restore the pivoted levers to their original position.

6. A movement analyzer comprising a pair of pivoted levers, controlling means for swinging said levers in opposite directions outwardly at equal speeds from a zero position in which the levers lie in a common plane, a driving disc mounted on each of said levers, said discs, when said levers are in said common plane, being coaxial and mounted for rotation in planes parallel to the planes of movement of said levers and rotated at constant equal speeds in opposite directions, a driven friction wheel axially-slidably and rotatably mounted with its axis between the driving discs in the zero plane of the levers and perpendicular to the axes of the driving discs and its periphery in frictional engagement with both of the driving discs, a shaft on which said wheel is splined, a control shaft aligned with said wheel shaft, a driven shaft, a differential connecting the wheel shaft and the control shaft with the driven shaft, a slide movable parallel to the axis of the wheel shaft and connected to the wheel so as to share the axial movement thereof, a worm fixed on the control shaft, a nut mounted on said worm, bell crank levers having their extremities secured to the slide and to the pivoted levers, and levers connecting the nut with the fulcrum points of the bell crank levers.

7. A variable-speed transmission which indicates a number of time derivatives of the movement of a driven member, comprising a pair of pivoted levers, controlling means for swinging said levers in opposite directions outwardly at equal speeds from a zero position in which the levers lie in a common plane, a driving disc mounted on each of said levers, said discs, when said levers are in said common plane, being coaxial and mounted for rotation in planes parallel to the planes of movement of said levers and rotated at constant equal speeds in opposite directions, a driven friction wheel axially-slidably and rotatably mounted with its axis between the driving discs in the zero plane of the levers and perpendicular to the axes of the driving discs and its periphery in frictional engagement with both of the driving discs, so that movement of the controlling means is proportional to the second time derivative of the turning movement of the driven wheel while the degree of axial movement of the driven wheel is proportional to the first time derivative of the turning movement of the driven wheel.

8. A variable-speed transmission which indicates a number of time derivatives of the movement of a driven member, comprising a pair of pivoted levers, controlling means for swinging said levers in opposite directions outwardly at equal speeds from a zero position in which the levers lie in a common plane, a driving disc mounted on each of said levers, said discs, when said levers are in said common plane, being coaxial and mounted for rotation in planes parallel to the planes of movement of said levers and rotated at constant equal speeds in opposite directions, a driven shaft rotatably mounted between the driving discs in the zero plane of the levers and mounted perpendicular to the axes of the driving discs, and a friction disc splined on said driven shaft with its periphery in frictional engagement with both of the driving discs, so that movement of the controlling means is proportional to the second time derivative of the turning movement of the driven shaft while the degree of axial movement of the friction wheel is proportional to the first time derivative of the turning movement of the driven shaft.

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