May 22, 1962 KEIJIRO OTO 3,035,773

MULTIPLICATOR

Filed June 22, 1959

Fig. 1

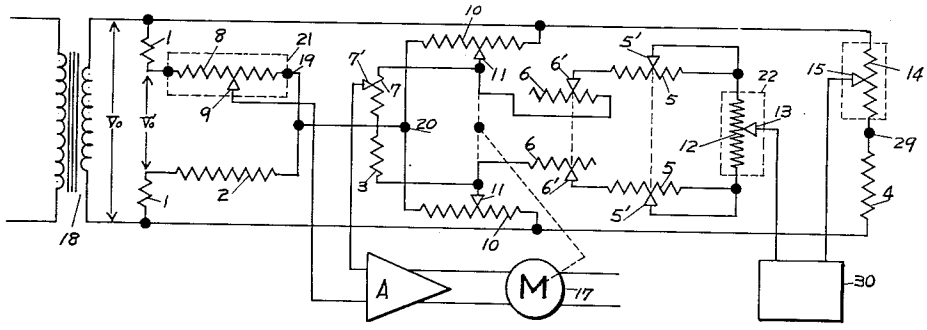


Fig. 2

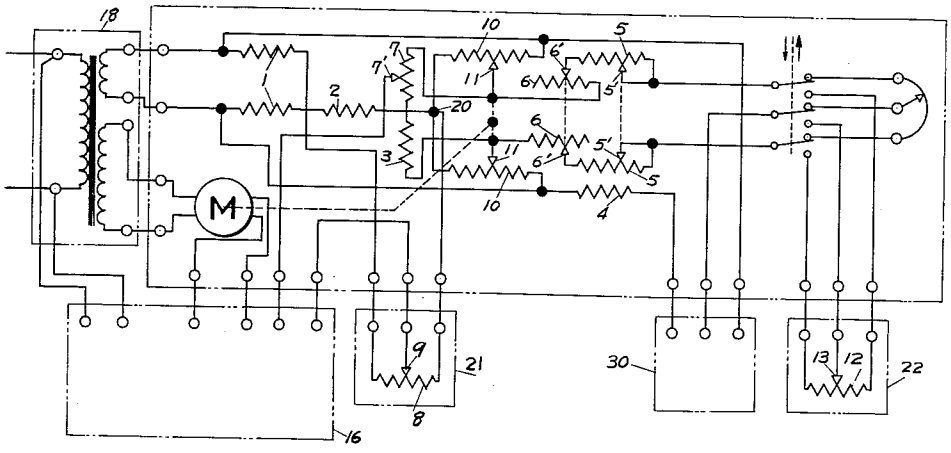
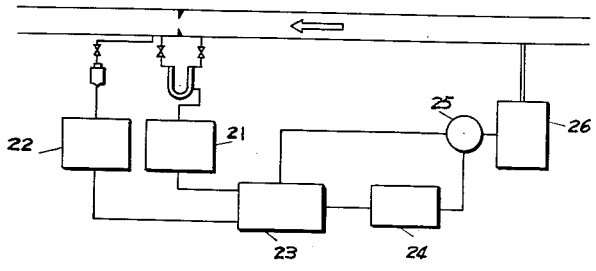


Fig. 3



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3,035,773

MULTIPLICATOR

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8 Claims. (Cl. 235—194)

This invention relates to an improvement in a multiplicator for and a method of calculating a product of two signals representing two variables.

One object of this invention is to provide a multiplicator which calculates a product of the kind described automatically and continuously.

Another object of this invention is to provide a method of calculating such a product as above.

Still another object of this invention is to provide an automatic and continuous controlling means for a continuous process.

Briefly stated in accordance with one aspect of this invention, there is provided a multiplicator comprising a servo-multiplying mechanism, and three pairs of potentiometers, the potentiometers of each pair being interlocked for conjoint operation. The three pairs include a pair of multiplying-factor controlling potentiometers and a pair of constant-term adding-or-subtracting potentiometers. The other pair interlocked potentiometers is used as potentiometers for feeding back to the servo-multiplying mechanism. By virtue of the above structure, a product of two input signals, derived from two signalling potentiometers built in two meters metering two different quantities, with each other is calculated automatically and continuously.

The invention will be better understood, and other objects and additional advantages of this invention will become apparent, upon perusal of the following description taken in connection with the drawings in which:

FIG. 1 is a schematic wiring diagram of an embodiment of this invention;

FIG. 2 is a more detailed wiring diargam of this embodiment in operation; and

FIG. 3 is a block diagram illustrating the application of the invention to a water treating system for controlling physical and/or chemical conditions of a boiler water.

Similar numerals refer to similar parts throughout the several views.

Referring now to drawings, there are four fixed resistances **1**, **2**, **3**, and **4**, and ten potentiometers **5**, **6**, **7**, **8**, **10**, **12** and **14**. Numerals **5** indicate a pair of two manually operable potentiometers for setting a multiplying factor in order to multiply a product of two detected variables by a constant and having conjointly operable contacts **5'** attached to a common controlling shaft. Numerals **6** indicate a pair of two manually operable potentiometers for adding a constant to, or subtracting the same from, a detected variable prior to multiplying the detected variable by another detected variable, and having conjointly operable contacts **6'** attached to another common controlling shaft. Numeral **7** indicates manually operable potentiometers for setting a multiplying factor, operating in the same manner as potentiometer **5**, in setting a multiplying factor. However, potentiometer **7** is provided for compensating a variation in scale of a multiplying factor depending upon the setting of potentiometer **12**, to be connected with the above-mentioned variable resistance for setting a multiplying factor. Numeral **8** indicates a signalling potentiometer having a contact **9** built in one meter **21** (such as a feed-water flow meter shown in FIG. 3) of two meters. Numerals **10** indicate a pair of potentiometers having contacts **11** conjointly operable with each other and mechanically connected to a balance motor **17**. Numeral **12** indicates a signalling potentiometer having a contact **13** built in the other meter **22** (such as a meter for measuring a physical and/or chemical property of the feed-water shown in FIG. 3) of two meters. Numeral **14** indicates a potentiometer having a contact **15** attached to a means for indicating a product.

The potentiometers **8**, **12** and **14** are connected to a common voltage source **18**. When there is a potential difference between the contacts **9** and **7'**, amplification thereof is effected by an amplifying means **16** so that the motor **17** is energized to conjointly adjust the contacts **11** of the potentiometers **10** which divide the adjusted voltage between the multiplying factor setting potentiometer **7** and the fixed resistance **3**, the adjustment continuing until the potential difference between the contact **9** and the contact **7'** of the multiplying factor setting potentiometer **7**, becomes zero. In this adjustment, since an end **19** of potentiometer **8** and a junction point **20** of the potentiometers **10** are connected directly with each other electrically and are thus at the same potential, the motor **17** would be stopped when a potential difference between these equipotential points and the contact **9** has become equal to that between these equipotential points and the contact **7'** of the multiplying-factor setting potentiometer **7**. If the junction point **20** of the potentiometers **10** is considered a zero reference potential point, the potential of contact **11** is, therefore, the product of a potential of contact **9**, relative to the above zero reference point by a factor determined in accordance with the position of the contact **7'** of the multiplying-factor setting potentiometer **7**. That is, a balance would be given conditional on

$$V_2=kV_1$$

in which V_2 represents the potential of contact **11** with point **20** being the zero reference potential point, k represents a multiplying factor determined by the position of contact **7'** of potentiometer **7**, and $k \geqq 1$, and V_1 represents the potential of the contactor **9**. Any potential difference between the contacts **11** is applied to potentiometers **12** through the constant-term adding-or-subtracting potentiometers **6** and the second multiplying-factor setting potentiometers **5**. As a matter of convenience, it is considered hereinafter that the intermediate point **20** of the two slide wires **10** is the zero potential or reference point. Accordingly, a term "a" point potential is intended to mean a potential difference between the "a" point and the junction point **20**.

The potential of contact **13** may be varied depending upon the positions of the contacts **5'** of the second multiplying-factor setting potentiometers **5**, the contacts **6'** of the constant-term adding-or-subracting potentiometers **6** and the contacts **11**. The effective potential drops across the two multiplying-factor controlling potentiometers **6** may be varied by means of moving the contact controlling shaft thereof. An increase in the effective potential of one of the two constant-term adding-or-subtracting potentiometers **6** results in a corresponding decrease in the effective potential of the other thereof, or vice versa, and the sum of the two effective potentials remains constant by virtue of the electric connection as shown in FIGS. 1 and 2. The effective potentials of the two second multiplying-factor setting potentiometers **5** may be varied by means of moving the controlling shaft thereof resulting in an increase in one effective potential and a simultaneous and corresponding decrease in the other effective potential by virtue of the electric connection as shown in FIGS. 1 and 2. Therefore, the potential of contact **13** may be displaced by a constant value by means of conjointly adjusting the contact **6'** of the constant-term add-

ing-or-subtracting potentiometers 6 and may be multiplied or divided in a constant proportion by means of conjointly adjusting the contact 5′ of the second multiplying-factor setting potentiometers 5. The resistance of the potentiometer 14 is equalized to the resistance of the fixed resistance 4 so that the connecting point 29 between fixed resistance 4 and potentiometer 14 is a zero potential point.

A potential difference V_1 between the two contactors 11 in a balanced state is given by the equation

$$V_1=V_0\times\frac{r_8}{R_1+R_8}\cdot\frac{R_7}{r_7}=V_0\times\frac{R_8}{R_1+R_8}\cdot\frac{r_8}{R_8}\cdot\frac{R_7}{r_7}$$

where R_1 represents the fixed total resistance 1, R_8 represents the resistance of potentiometer 8, r_8 represents the resistance of that part of potentiometer 8 between the zero potential point and the contactor 9, R_7 represents the total resistance of the multiplying-factor setting potentiometer 7, r_7 represents the resistance of that part of potentiometer 7 between the junction thereof with the fixed resistance 3 and the contact 7′, and V_0 represents the output voltage of the power source 18. The potential V_2 of the contact 13 is given by the equation

$$V_2=\frac{V_1}{R_6+2r_5+R_{12}}\times\left\{r_{12}+\left(\frac{r_{6.2}-r_{6.1}-R_{12}}{2}\right)\right\}$$

Substituting for

$$V_1,\ V_0\times\frac{R_8}{R_1+R_8}\cdot\frac{r_8}{R_8}\cdot\frac{R_7}{r_7}$$

I get

$$V_2=V_0\times\frac{R_8}{R_1+R_8}\cdot\frac{R_7}{r_7}\cdot\frac{R_{12}}{R_6+2r_5+R_{12}}\cdot\frac{r_8}{R_8}\times\left(\frac{r_{12}}{R_{12}}+\frac{r_{6.2}-r_{6.1}}{2R_{12}}-1/2\right)$$

where R_6 represents the total resistance value of each of the respective potentiometers 6, which is divided into two parts by respective contacts 6′, one on the left side of the contactor 6′ and the other on the right side thereof, $r_{6.2}$ represents the resistance value of the former, $r_{6.1}$ represents the resistance value of the latter so that $r_{6.2}+r_{6.1}=R_6$, R_{12} represents the total resistance value of the potentiometer 12, r_{12} represents the resistance value between the lower end of the potentiometer 12 and the contact 13, R_5 represents the maximum resistance value of each of the potentiometers 5, and r_5 represents the effective potentiometer value of each resistance 5, that is, the resistance value of the non-short circuited portion of each resistance 5 between the left end of each of the potentiometers 5 and the corresponding contact 5′. Since the terms r_8 and r_{12} are variables varying in proportion to displacements of contacts 9 and 13 of the signalling potentiometers 8 and 12 built in the two meters 21 and 22, respectively, the potential of the contact 13 represents a value in proportion to a product of a metered value of one meter 21 and a sum of a metered value of the other meter 22 and a constant. The above equation is rewritten as follows, if r_8/R_8 is X, r_{12}/R_{12} is Y,

$$V_0\times\frac{R_8}{R_1+R_8}\times\frac{R_7}{r_7}\times\frac{R_{12}}{R_6+2r_5+R_{12}}\text{ is }A$$

and

$$\frac{r_{6.2}-r_{6.1}}{2R_{12}}-1/2\text{ is }B$$

$$V_2=A.X.(Y+B)$$

where r_8/R_8 and r_{12}/R_{12} are proportions of detected resistances to the whole resistances of the signalling potentiometers 8 and 12 provided in the meters 21 and 22, respectively. As to the potential V_2 of the contact 13 with respect to the electrically zero potential point in the system of circuits, if R_1, R_8, R_6, and R_{12} are fixed, the term A is varied depending upon the proportion establishing term R_7/r_7, and the proportional band establishing term $R_{12}/(R_6+2r_5+R_{12})$. Hence a variation in r_7 or r_5 has

influence on the term A only. The terms X and Y are varied depending upon variation in r_8 and r_{12}, respectively, and the term B is varied depending upon $r_{6.2}$ only. This means that, when the constant terms A and B are adjusted, they are not related with each other. Therefore, it is possible to operate a control strictly in accordance with the above equation. One of the essential points of this invention consists also in the above fact.

Now in order to remove the potential difference between the contacts 13 and 15, it is sufficient to adjust the contact 15 until its potential is equal to the potential V_2 of the contact 13, for example, by inserting an electronic relay such as called "Spetrol" 30 between the two contacts 13 and 15, it becomes possible to indicate the term V_2 as an extent of a displacement in space. "Spetrol" is the registered name of an electronic relay which detects the potential difference between a control voltage and a feedback voltage and responds in accordance with the polarity of the difference, to control conventional relays which control the electric power applied to the reversible servomotor in order to operate it in such a direction as to provide a feedback voltage approaching the control voltage. The conventional relays will be deenergized when the two voltages become equal to each other. In this case, the potential of contact 13 is the control voltage and the potential of contact 15 is the feedback voltage. The "Spetrol" actuates the relay to continue energization of the servomotor until the two voltages are balanced. Thus the contact 15 as well as the servomotor shaft closely follow the control voltage. The shaft drives the device which changes the condition of a controlled process. According to this invention, it is possible either to read directly a result of a calculation by means of a scale divided correspondingly to resistances of various points of the potentiometer 14, or to operate an appropriate operating means automatically in proportion to a product of two metered values by means of providing the potentiometer 14 so as to correspond to the operating range in scale (angle and length) of the operating means.

Referring now to FIG. 3 in which an embodiment of this invention is applied to a water-treating system for controlling the physical and/or chemical properties of boiler water, there are a feed-water flow meter 21 and a meter 22 for metering a physical and/or chemical property of the feed-water, having signalling potentiometers 8 and 12, respectively. Numeral 23 indicates a multiplicator in accordance with this invention. Numeral 24 indicates a servo-amplifier. Numeral 25 indicates a servomotor whereby a manipulated variable controller in a manipulating section 26 is driven. A potentiometer which generates a feed back signal in proportion to the manipulated variable is provided in the manipulating section 26. The last-named potentiometer corresponds to the slide wire 14 shown in FIG. 1. In this embodiment, there is provided a plunger pump having a variable stroke for injecting chemicals, which corresponds to the above-mentioned manipulating section 26.

In case the concentration of a certain component of the feed-water is metered by meter 22 and it is intended to remove the component by means of injecting into the main pipe for the feed-water a chemical of which a quantity of k times by weight combines with the component, it is necessary to satisfy the following equation

$$k.S_x.Q=A.S_c.q$$

where S_x represents the concentration, Q represents the quantity of flow of the feed-water, q represents the output of the pump, S_c represents the concentration of the chemical, and A represents a proportional constant of a manual control corresponding to a multiplying-factor of the manipulated variable. In the case of a variable-stroke plunger pump, q becomes a linear function of the stroke L. Therefore,

$$q=q_0\times L/L_0$$

where q_0 indicates the output in case the pump acts with

the whole stroke and L_0 indicates the whole stroke. Substituting for the equation showing the injecting condition this equation, there is obatined

$$k.S_x.Q=A.S_c.q_0.L/L_0$$

Therefore, it becomes necessary to satisfy conditions $k=A.S_c.q_0/L_0$ and $S_x.Q=L$.

There are many cases where it is necessary to inject not only just the right quantity of a chemical to combine with the metered component of the feed-water so as to remove the component from the water but also an excess quantity so as to retain an excess having a predetermined concentration within the boiler. However, the excess remaining within the boiler may be lost by continuous blows. Therefore, it becomes necessary to inject the chemical in such an excess quantity as to be proportioned to a product of the flow of the blows and the concentration predetermined for the remaining chemical. In general, it may be deemed that the quantity of flow of the feed-water is substantially proportional to the quantity of the continuous blows. Therefore, it becomes satisfactory for supplementing the remaining excess to provide variations in the stroke proportional to variations in the quantity of flow of the feed-water. Accordingly the invention attains this objective in a water-treating system as shown in FIG. 3, by using an injecting means which satisfies the following condition,

$$k.(S_x+B).Q=A.S_c.q_0.L/L_0$$

where B represents a proportional constant required for supplementing the remaining excess. That is, the object may be achieved completely and easily by the function of the multiplicator in accordance with this invention.

While particular embodiments of this invention have been illustrated and described, modifications thereof will readily occur to those skilled in the art. It should be understood therefore that the invention is not limited to the particular arrangements disclosed but that the appended claims are intended to cover all modifications which do not depart from the true spirit and scope of the invention.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A multiplicator, for deriving the product of two variables, comprising, in combination, a first potentiometer providing a first potential corresponding to the value of the first variable; a second potentiometer providing a second potential corresponding to the value of the second variable; a pair of third potentiometers each having a first fixed terminal and said first fixed terminals being interconnected to each other and to a fixed terminal of said first potentiometer and providing a feedback potential; a fourth potentiometer connected between the adjustable contacts of said third potentiometers and manually adjustable to preset a multiplying factor for said first potential; a servomotor operable to conjointly adjust the contacts of said third potentiometers; means operable to apply to said servomotor a potential corresponding to the differential between said first potential and said feedback potential to operate said servomotor to adjust the contacts of said third potentiometers in a direction to equalize said first and feedback potentials; circuit means connecting the fixed terminals of said second potentiometer to the adjustable contacts of said third potentiometers to apply across said second potentiometer the sum of the potentials across said third potentiometers; and means, operatively associated with said second potentiometer, and operable to measure the product of said second potential as multiplied by said first potential multiplied by said factor.

2. A multiplicator as claimed in claim 1, including a pair of fifth potentiometers each included in said circuit means and connected between the respective fixed terminals of said second potentiometer and a respective adjustable contact of said third potentiometers, said fifth potentiometers being conjointly manually adjustable in opposed directions to pre-set the proportion of such sum of the potentials of the third potentiometers applied across said second potentiometer.

3. A multiplicator as claimed in claim 2 including a pair of sixth potentiometers, each connected in series with a respective fifth potentiometer, and conjointly manually adjustable in opposed directions to further preset the proportion of said sum of the potentials of the third potentiometers applied across said second potentiometers.

4. A multiplicator as claimed in claim 1, including a pair of fifth potentiometers each included in said second circuit means and connected between the respective fixed terminal of said second potentiometer and the respective adjustable contacts of said third potentiometers, said fifth potentiometers being conjointly manually adjustable in opposed directions to pre-set a multiplying factor for said second potential.

5. A multiplicator as claimed in claim 4, including a pair of sixth potentiometers, each connected in series with a respective fifth potentiometer, and conjointly manually adjustable in opposed directions to add a constant increment of potential to said second potential.

6. A multiplicator as claimed in claim 1 in which said last-named means comprises a feedback potentiometer adapted to provide a second feedback potential in opposition to said second potential; servo means operable to adjust said feedback potentiometer; and means operable to apply to said servo-means a potential corresponding to the differential between said second potential and said second feedback potential, to operate said servo-means to adjust said feedback potentiometer in a direction to equalize said second potential and said second feedback potential.

7. A multiplicator as claimed in claim 1, including a fixed resistance connected in series with said fourth potentiometer; the sum of the potentials across said third potentiometers being divided between said fourth potentiometer and said fixed resistance.

8. A multiplicator as claimed in claim 6, including a fixed resistor connected in series with said feedback potentiometer, the overall value of the resistance of said feedback potentiometer being equal to the value of said fixed resistance; whereby the junction of said fixed resistance and said feedback potentiometer becomes a reference point for adjustment of said feedback potentiometer.

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