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[33] **France**

[31] **62732**

[51] Int. Cl. **G06g 7/12**

[50] Field of Search **235/151.2,**
184, 185, 150.2, 179

[56] **References Cited**

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[54] **COMPOSITE MIXTURE BATCHING**
27 Claims, 13 Drawing Figs.

[52] U.S. Cl. **235/151.2,**
235/184, 235/69

ABSTRACT: The present disclosure is directed to a method of using an analogue computing device for proportioning a plurality of components of a batch mixture in obtaining a composition exhibiting desired physical properties.

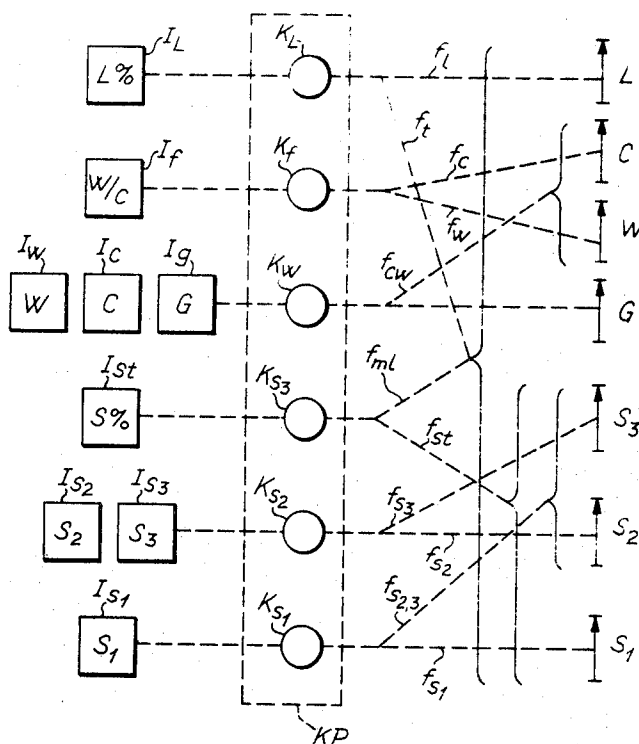
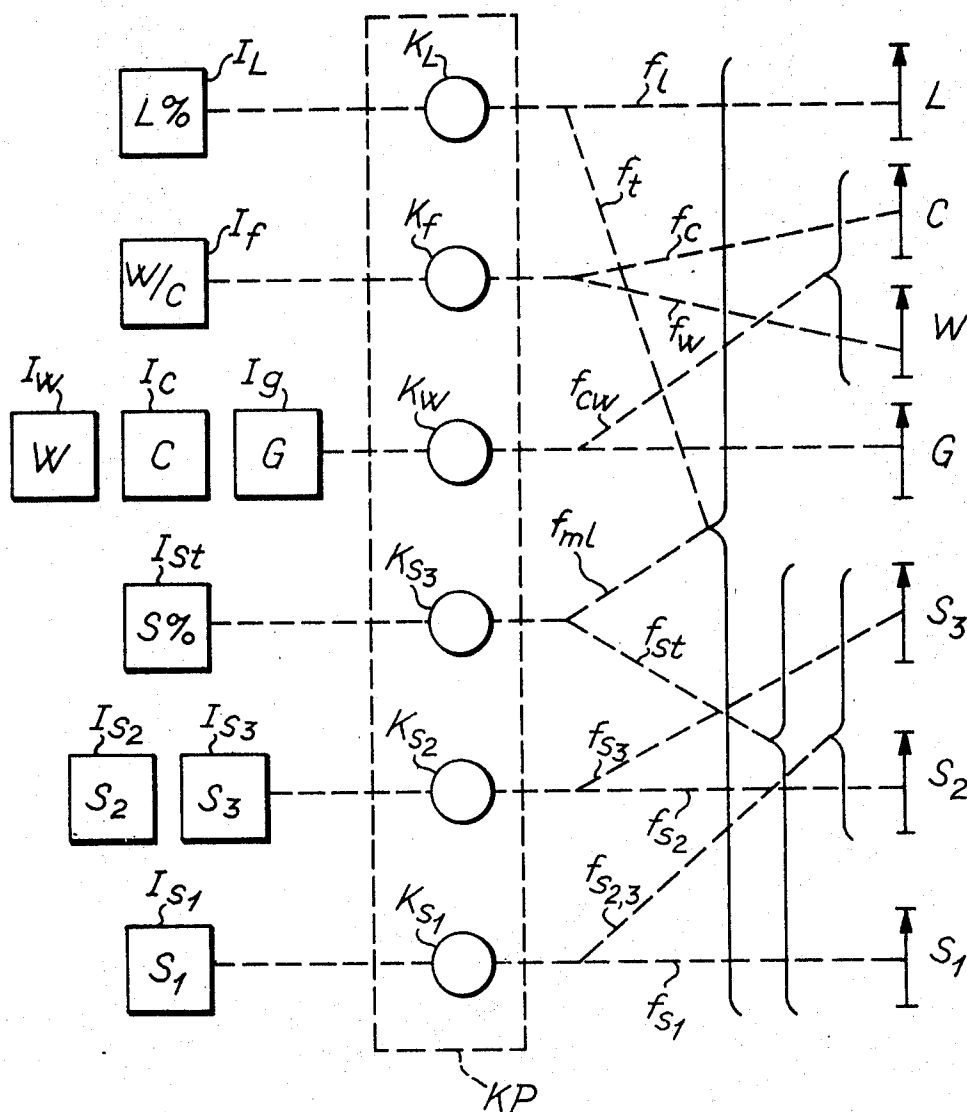


Fig. 1.



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Fig. 4.

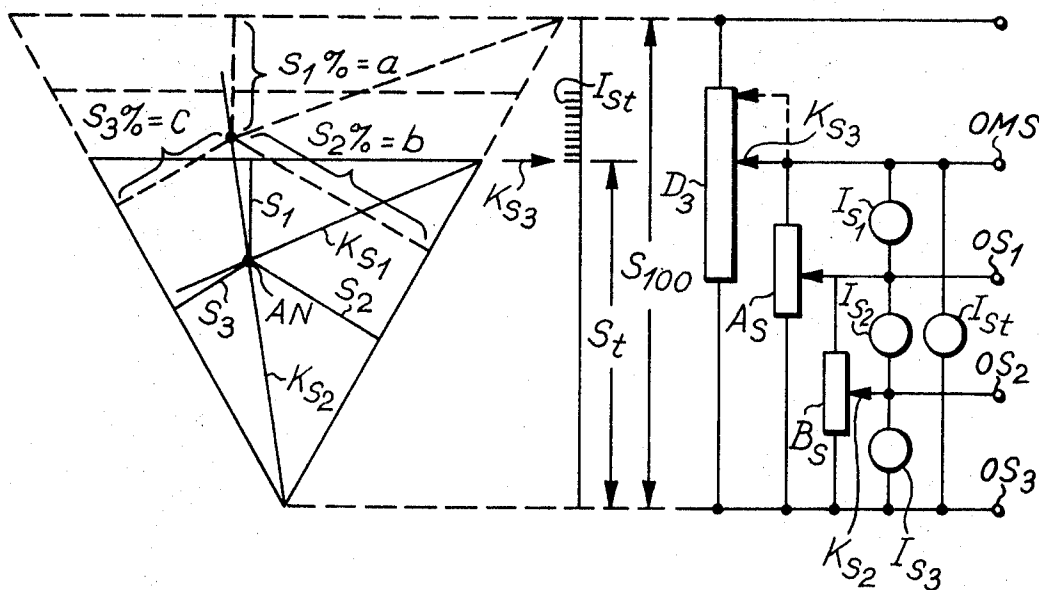


Fig. 5.

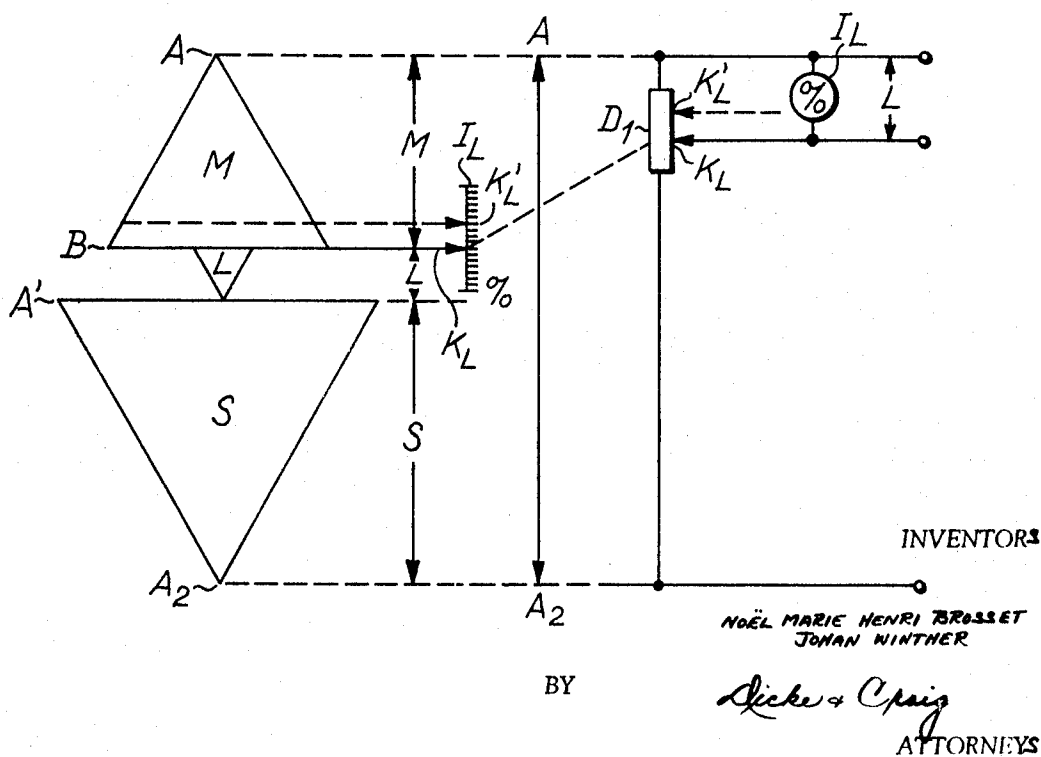
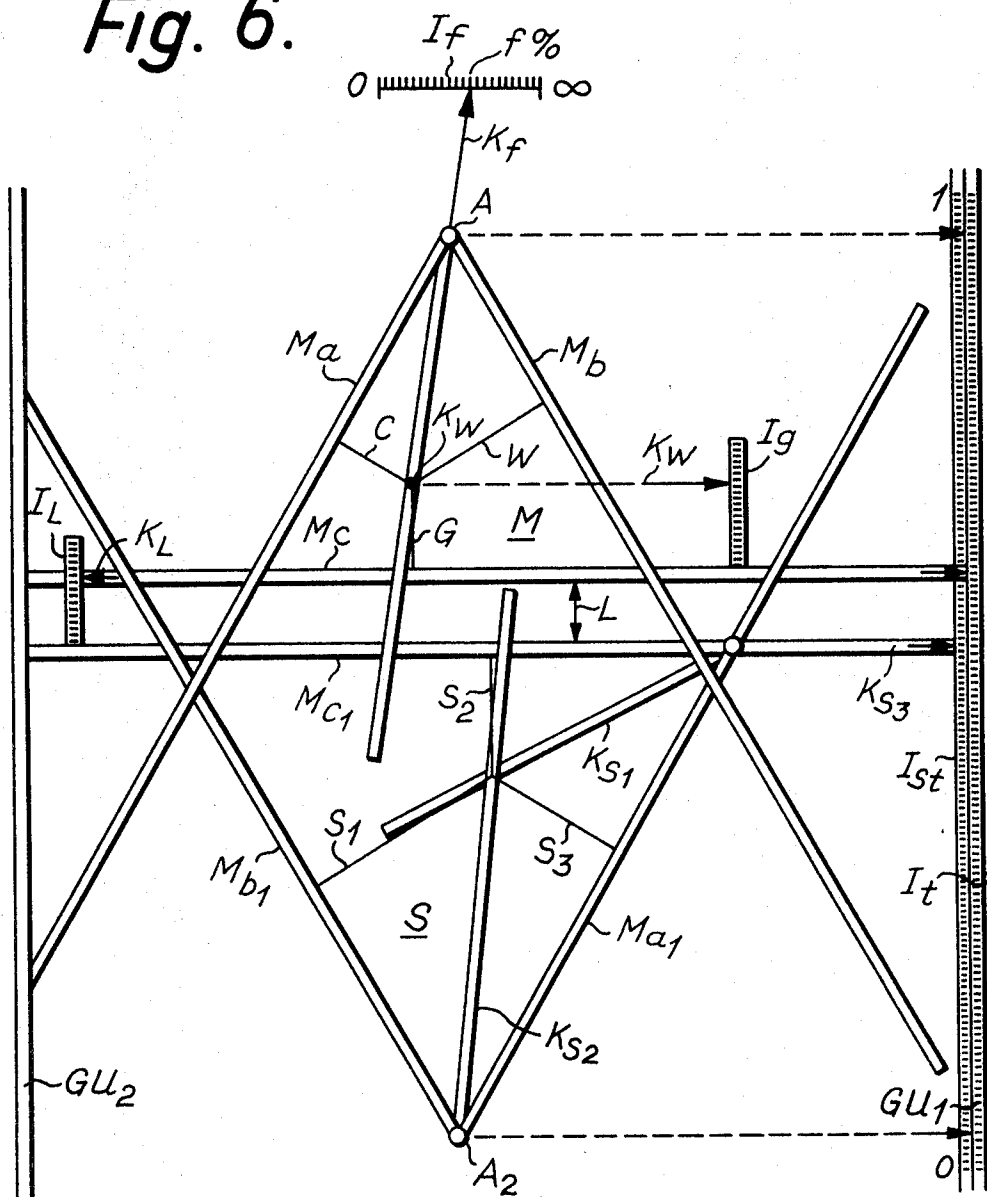


Fig. 6.



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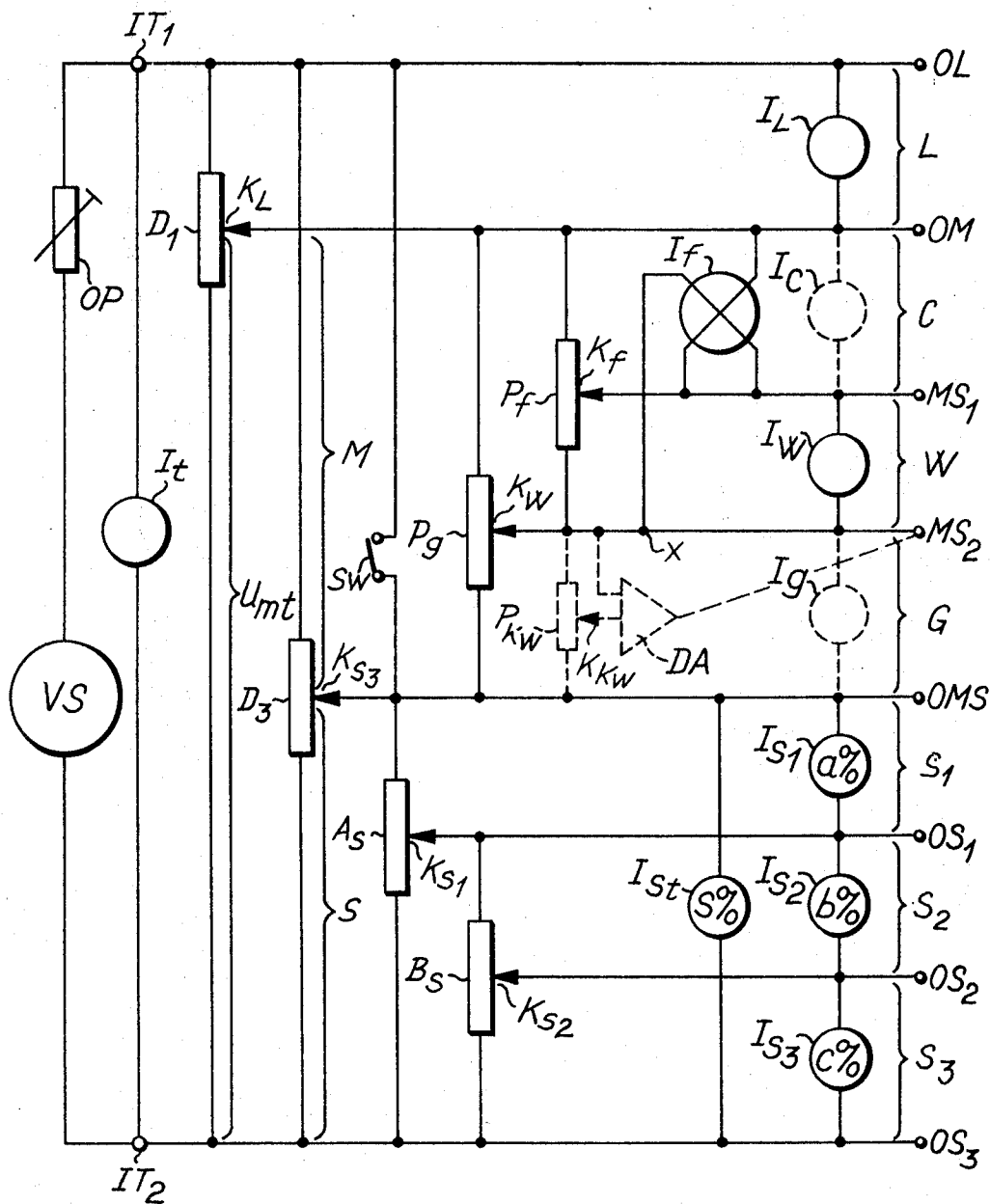
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Fig. 7.



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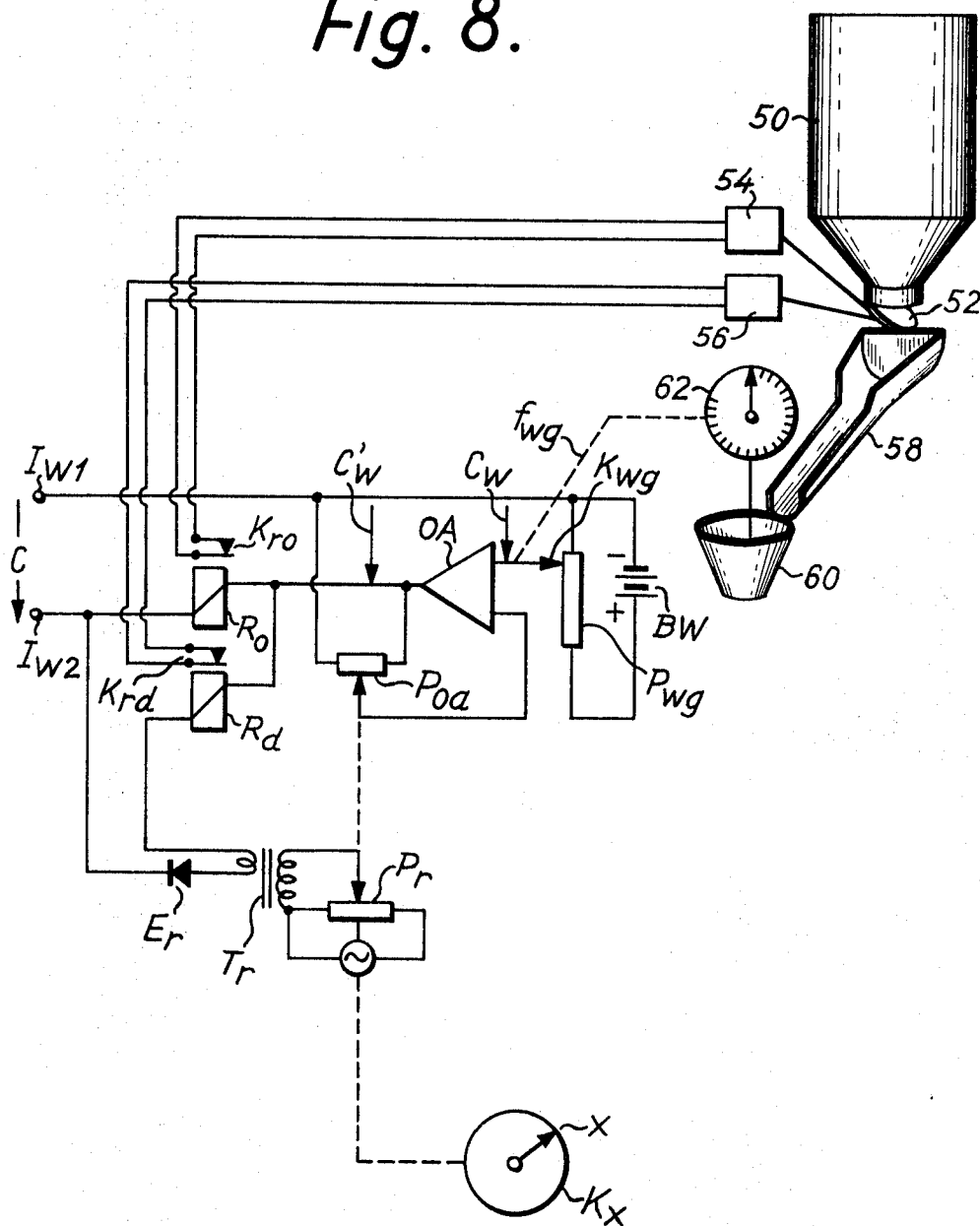
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Fig. 8.



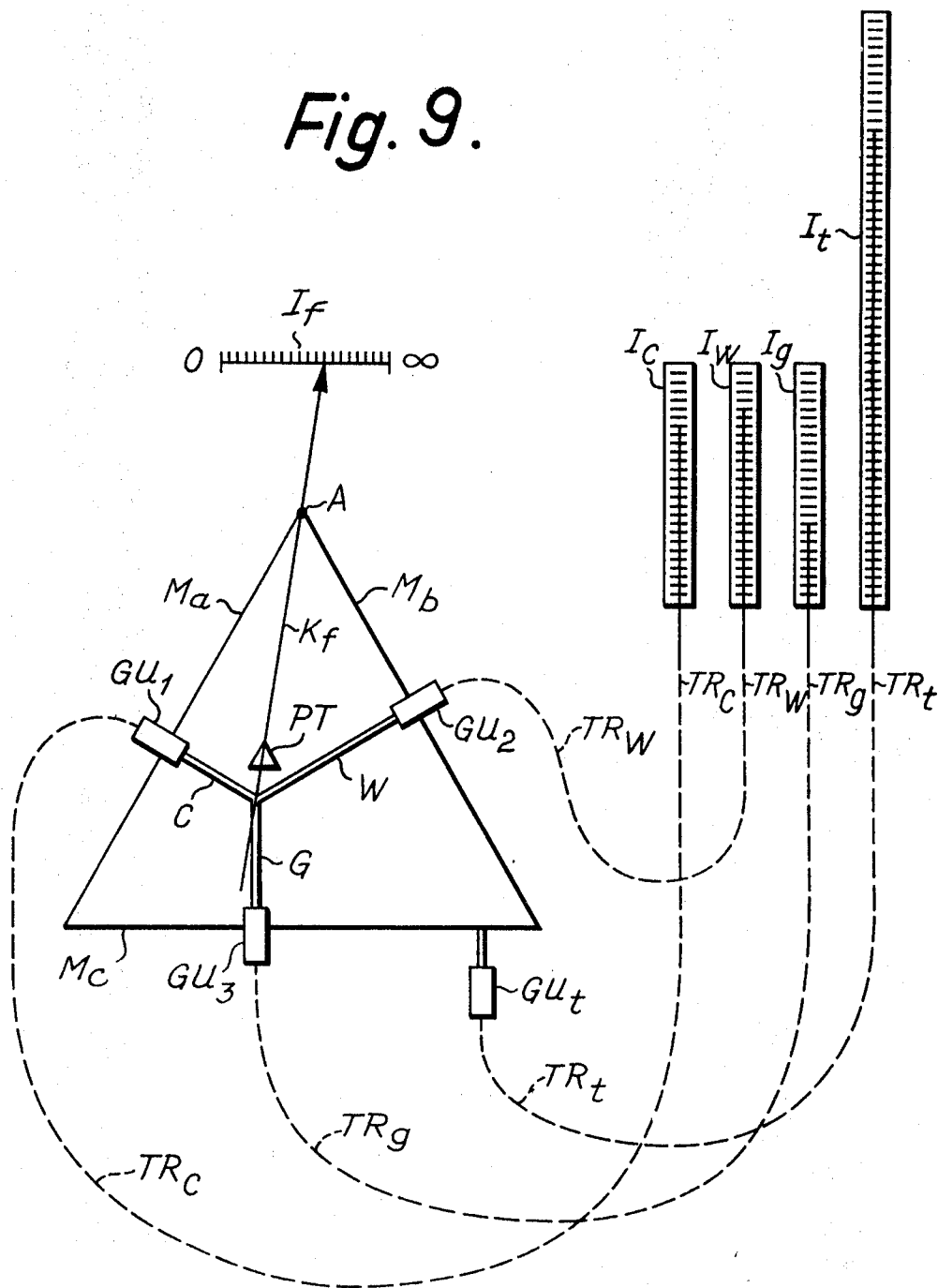
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Fig. 9.



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Fig. 10.

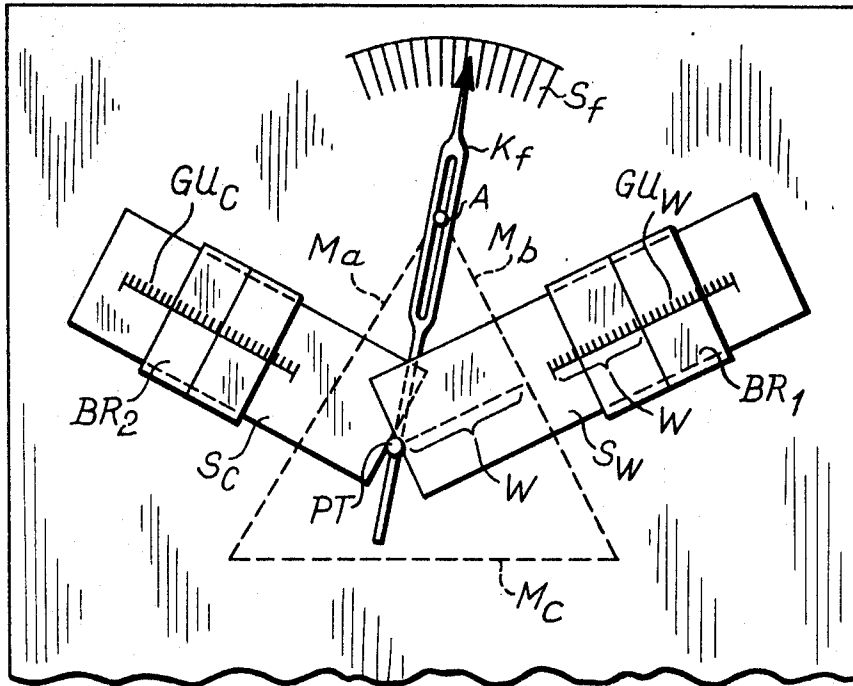
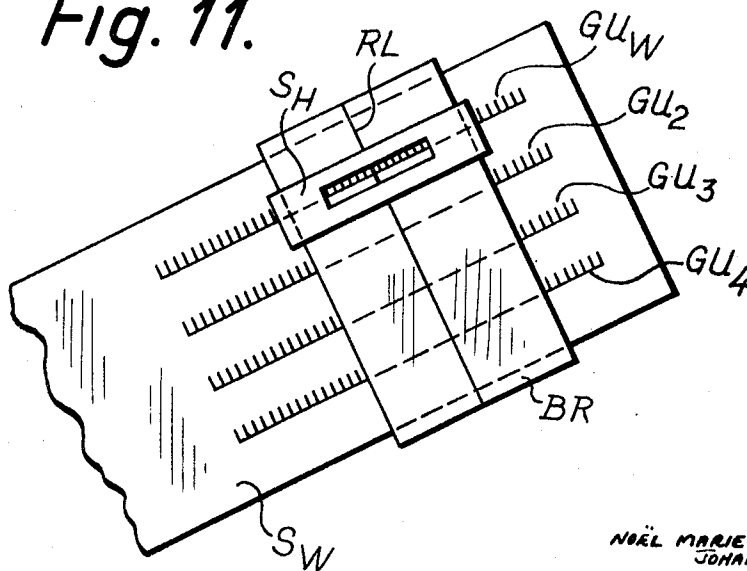


Fig. 11.



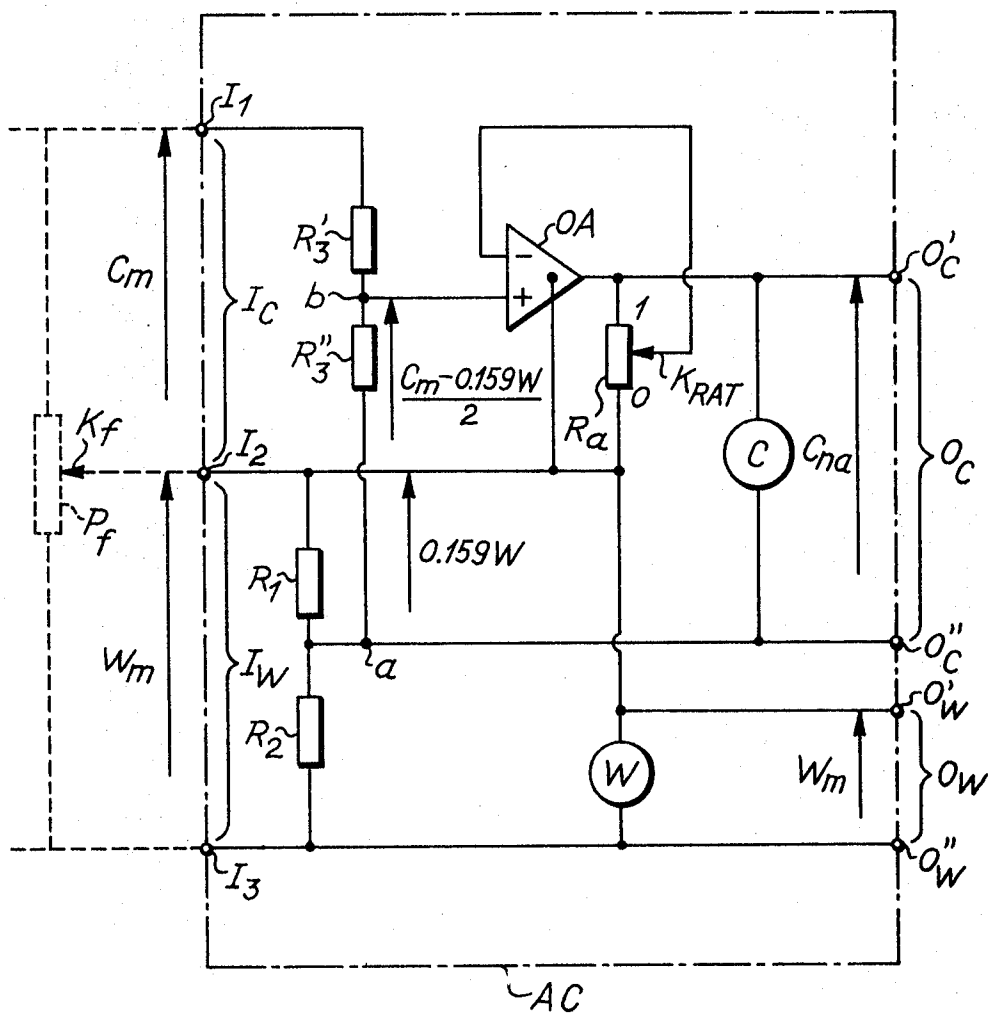
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Fig. 12.



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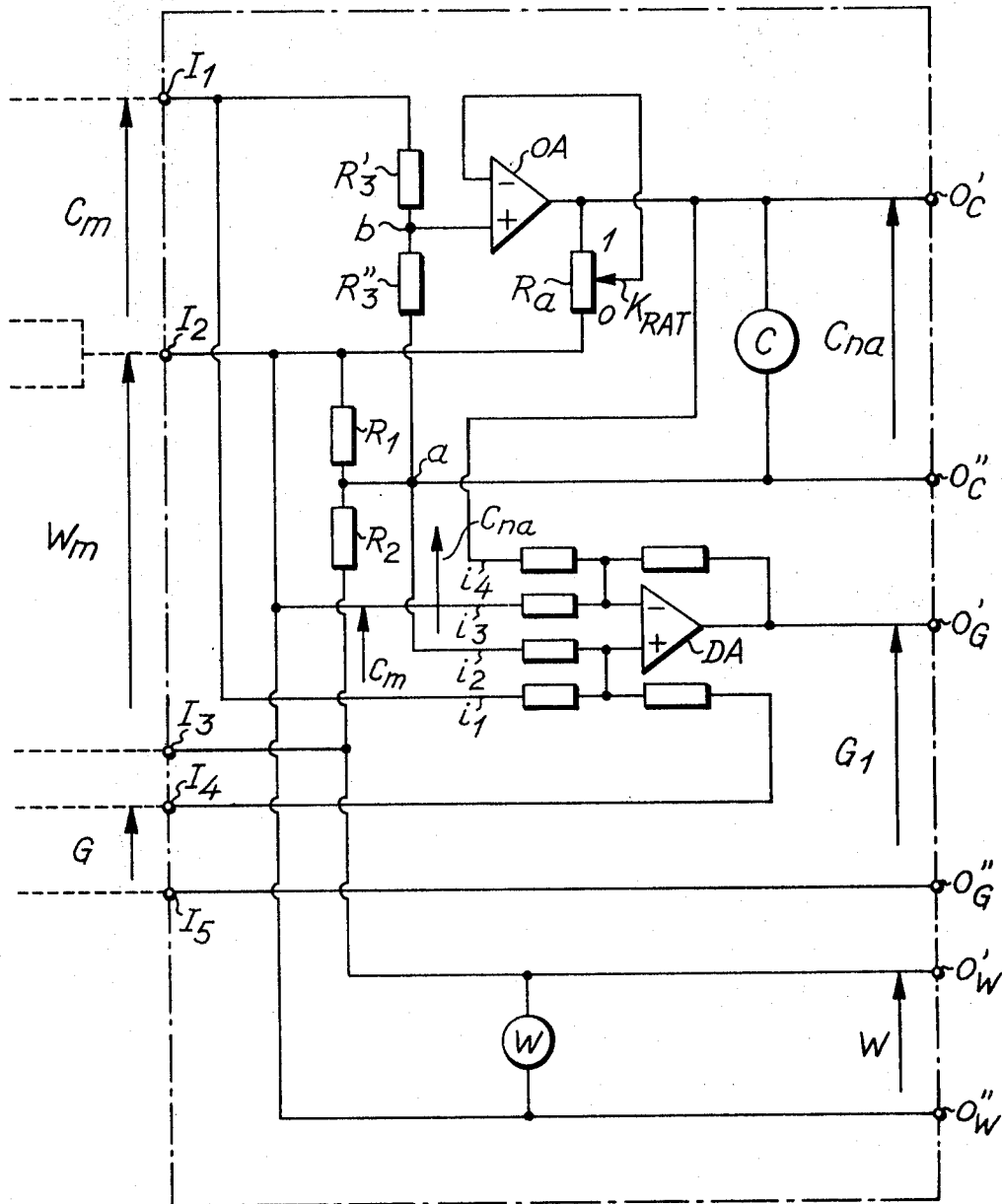
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Fig. 13.



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COMPOSITE MIXTURE BATCHING

In batch blending it is often the case that one physical property of the mixture is determined by the ratio between two of the components, while another physical property is determined by the amount of one of the components.

A typical example of such a mixture is concrete. In addition to the skeleton, concrete comprises cement and water and as well known by those skilled in the art, the ratio between cement and water determines the concrete strength while the amount of water determines the slump.

In most concrete mixing stations a plurality of precalculated standard mixtures are available for immediate delivery. The calculation of such standard mixtures requires the use of tabulations and formulas known to those skilled in concrete technology.

It happens, however, several times daily in most concrete mixing stations that immediate delivery of a mixture is specified with a proportioning which differs from any of the standard mixtures.

Though the ready-mix operator is a qualified man with practical experience, he is not skilled in calculating the correct blending of a new batch according to individual requirements and even if he was, such a recalculation would not be feasible under practical conditions because it would require much more time than available when a lorry driver pulls in and requests a modified batch to be taken back to a building site.

The mix-operator knows, however, that if the customer wants a mixture with more water than in standard mixture then it is necessary to add more cement to make sure that the mixture keeps its strength, and for that reason mix-operators all over the world are inclined to overproportion the cement in such individually specified mixtures.

Since the cement is the most expensive component in ready-mixed concrete, the result is that in a mixing station a substantial amount of cement is given away or wasted each year. Furthermore the addition of an arbitrary amount of cement to make up for an extra amount of water also changes the total volume.

This waste could be avoided, provided a method and an apparatus can be found for quickly determining the correct amount of cement to be used in an individually specified concrete mixture to give the required strength of the mixture.

Corresponding conditions prevail in other technical fields and even though the invention will be described hereinafter basically with reference to concrete mixtures, it will be understood that the invention is not limited to concrete but can be used in other technical fields where similar conditions are found, namely that the ratio between two components of a mixture determines one physical property and the amount of one of the two components determines another physical property.

It is an object of the invention to provide a simple method which enables a quick and safe proportioning of the correct amount of the components to ensure the first mentioned physical property with a specified amount of the second of the two components which determines the second physical property.

According to the invention this is achieved by using an analogue computing device which is programmed for reading in the analogue values of two of the components and which is also provided with means for dividing an analogue value which is the sum of an analogue value corresponding to the two components the ratio between which determines the first physical property and means for indicating that ratio. This analogue computing device is used in such a manner that the ratio between said two last mentioned components is first adjusted to the value which determines the first physical property whereafter the amounts of that amount of the one of the two components which determines the other physical property is adjusted until a predetermined analogue value can be read out whereafter the analogue values are used for proportioning the batch.

It has been suggested to use analogue computing devices in various embodiments in connection with batch blending, for example to solve such complicated problems as minimum costs blending, using the method of steepest ascents.

In such cases, however, the analogue computer has not been preprogrammed and the programming of such a computer is obviously far beyond what can be done by the mix-operator of a ready-mix concrete station. In addition, the problems to be solved by such a specially programmed analogue computer are entirely different from the problems which are solved according to this invention.

It has also been proposed to store a substantial amount of data relating to a plurality of standard mixtures on punched cards or tape in a general purpose computer to enable the selection of an already calculated mixture of concrete among so many precalculated mixtures that practically all deviations from standard mixtures can be avoided.

This solution is, however, not feasible under practical conditions. First of all a computer of sufficient capacity to meet all practical requirements is a fairly expensive equipment which must be written off and the writing off must be calculated in the price of all the mixtures. In addition, the selection of the correct one of maybe several thousand standard mixtures stored in a computer requires a substantial training of the mix-operator far beyond what he normally has and with such a large amount of standard mixtures a mistake is very likely to occur. Thus even if the best standard mixture to meet a customer's specification may be No. 1237, the mix-operator may very well supply No. 1252.

The merits of the present invention are that it provides a very simple method and a correspondingly simple preprogrammed analogue computer which can be used by any mix-operator after short training without any knowledge of analogue computers because it is preprogrammed and the operation is limited to the adjustment of a few controls and the reading of a few indicators which even may be calibrated to indicate the desired physical properties directly.

The method is so simple that mistakes can be practically completely avoided.

The solution of the problem by a simple method also provides for construction of a simple analogue computer.

The simplest possible analogue computer according to the invention has the character of a slide rule and provides two rulers which are reciprocal in two directions with an angle of 120 therebetween into engagement with an abutment on an arm which is pivotable about the point of intersection between two sidelines of a hypothetical equilateral triangle in which the sides are perpendicular on the direction of reciprocation of the two rulers and with the position of the abutment relatively to the two sidelines of the triangle being readable on a scale.

By calibrating this scale to show the ratio between the components and calibrating the readings of the two rulers to show the distance from the abutment to each of the two sides in the hypothetical triangle, the well-known teaching that the sum of the distance from each point inside an equilateral triangle perpendicular to each of its three sides is equal to the height of the triangle enables the correct proportioning of the two of the components by first adjusting the pivotable arm to indicate the desired ratio and thereafter displacing the abutment in the direction of the arm until the reading on one of the rulers indicates the desired amount. By using a third ruler reciprocable perpendicular to the third side of the hypothetical triangle, the reading on the third ruler indicates the analogue value of the third component of the mixture, the total amount of which is the analogue value of the height of the triangle.

By calibrating the first two rulers into amounts corresponding to cement and water in a concrete mixture and the third ruler corresponding to gravel such a slide rule device can be used as a simple calculation aid for concrete proportioning.

A mechanical-geometrical system based on this principle can obviously be constructed by means of rails and reciprocal rulers and by using the reciprocating of the rulers, if desired, in connection with mechanical amplifiers the reciprocation of

the rulers can be used directly or indirectly to control the supply of the components in amounts corresponding to the analogue values readable on the rulers from automatic weighing devices.

It will also be possible to combine the rulers with electrical devices in such a manner that the reciprocation of each of the rulers controls the movement of a variable tapping on a voltage divider so as to thereby produce electrical voltages which represent analogue values of the readable analogue values of the rulers and thereby provide for electrical control of automatic dispensing of the individual components.

An analogue electrical system which enables the same simple method to be used can, however, be constructed by means of voltage dividers which provide an electrical analogue computer which is preprogrammed to use the method. In a mixture with three components it is only necessary to first adjust an analogue value which corresponds to the total amount of the batch, thereafter adjusting the ratio between the two of the components and eventually adjusting the desired analogue value of one of the two components, the ratio between which must be kept constant.

A simple analogue computer for proportioning three components of a batch comprises basically only two voltage dividers, each having an adjustable tapping. The first voltage divider is connected across the voltage source and thereby supplied with an input voltage which corresponds to the analogue value of the total amount of the batch. The other voltage divider is connected between the variable tapping of the first voltage divider and one end thereof. The adjustment of the tapping of the second voltage divider is made readable either by a graduation of a control member or by means of a suitable instrument. Output terminals are connected with each end of the first voltage divider as well as with the two variable tapings. An indicator is provided for reading out the voltage which corresponds to one of the portions into which the second voltage divider divides the potential thereacross so as to readout the analogue value of one of the components.

A simple analogue computer of this kind with two potentiometers can be used for carrying out the method whereby the variable tapping of the second potentiometer first is adjusted to the desired ratio between the two components until the indicator shows the ratio, whereafter the variable tapping of the first potentiometer is regulated until the desired analogue value of one of the two components is indicated between the outlets which are connected with the two variable tapings of the potentiometers.

In the case of concrete the first adjustment determines the ratio between cement and water, while the second adjustment regulates the ratio between gravel and cement plus water. During the last regulation the ratio is kept constant, and the amount of cement and water is readjusted with the ratio therebetween maintained until the desired amount of water can be read out of the computer.

It will often be found in a mixture that a third component of a mixture such as a filler has a content of one of the two other components. In concrete it is nearly always the case that the gravel is wet, i.e. a part of water is included in the gravel.

The invention also enables a correction for such a case. Obviously, if there is for example 10 percent water in the gravel, the amount of water used must be reduced correspondingly because otherwise the adjusted cement/water ratio will not be kept.

By the method according to the invention this can be compensated for by measuring the amount of one component which is contained in the other component and using an analogue computer which comprises an adjustable summator device which is operatively connected with the outputs for the two components. By adjusting the summator device according to the measured contents of one of the components in the other, it will in the case of for example water in the gravel automatically decrease the analogue value which corresponds to the contents of water with an amount corresponding to the water which is included in the gravel.

It will also often be the case that the quality of one of the components differs from one supply thereof to the next. It is well known that the quality of cement differs and it has therefore previously been necessary to dispense sufficient cement to ensure that cement of the poorest quality always will give the desired strength of the concrete. The strength of concrete is governed by the coefficient of variation, variations of the quality of the cement increase the coefficient of variation. The more uniform the cement quality is, the smaller becomes the coefficient of variation.

The invention also provides for automatically readjusting the dispensing of that one of the components of a mixture the quality of which varies from supply to supply in such a manner that in order to keep a substantially uniform physical property of the mixture and savings with respect to the components in question a relatively increased amount of the component is dispensed when the quality is poor, while a relatively smaller amount of the component is dispensed when the quality is better.

According to the invention this is achieved in that the analogue value of the component in question, the quality of which varies, is adjusted as a reference value derived from the physical properties of a reference mixture whereafter a test mixture is produced with a different quality of the component in question and the physical properties of the test mixture are derived whereafter a digital ratio between the two physical properties is calculated and an adjustable multiplication device which is connected with the analogue value of the component in question as adjusted according to the reference mixture is adjusted to the ratio calculated so as to thereby produce a corrected analogue value of the component in question which corresponds substantially to the amount of the component which with different quality will produce substantially the same physical property of the mixture in which the component of different quality is used.

With specific reference to concrete this method can be used in such manner that the reference value of the analogue amount of cement is adjusted according to a reference mixture for which the factor K in Bolomeys formula

$$\delta = K \left(\frac{C}{W} - 0.5 \right)$$

is calculated whereafter the strength of a test mixture in which a different cement quality is used is determined and the K-factor of the test mixture is calculated, whereafter the multiplication device is adjusted on the ratio between the two K-factors and the analogue value for the amount of cement of different quality is derived from the multiplication device.

Further details with respect to the method and the construction of geometrical mechanical analogue computers as well as equivalent electrical analogue computers will be described in the following with reference to the accompanying drawings in which

FIG. 1 is a diagrammatic illustration of controls, indicators and analogue values illustrating schematically the connections in order to explain the method and the principle of an analogue computer according to the invention,

FIG. 2 is a perspective illustration of a computing device according to the invention,

FIG. 3 is a schematic illustration of a mechanical geometrical system which provides a part of an analogue computer according to the invention with appertaining electrical equivalence for that part of the computer,

FIG. 4 is an illustration similar to that of FIG. 3 with respect to other parts of the computer,

FIG. 5 is a schematic combination of the systems of FIGS. 2 and 3,

FIG. 6 is a complete mechanical geometrical system constructed according to the principles of FIGS. 3 and 4 and 5,

FIG. 7 is the electrical equivalence of FIG. 6,

FIG. 8 is a schematic illustration of the control of dispensing one component by using the electrical analogue value of the amount of components as reference voltage,

FIG. 9 is a schematic illustration of a further modification of the principle of FIG. 3,

FIG. 10 is a schematic illustration of a simple calculating device based on the mechanical geometrical system,

FIG. 11 is a detail of the calculating device of FIG. 10.

FIG. 12 is a diagrammatic illustration of a part of an analogue computer according to the invention for automatically correcting the analogue value of one of the components, in response to variations of quality of the component, and

FIG. 13 is the circuit arrangement of FIG. 12 illustrating a further automatic correction of a third component in response to the variation of the analogue value of the component the quality of which varies.

FIG. 1 illustrates schematically the principles of an analogue computer for adjusting the desired amounts of seven analogue values L , C , W , G , S_1 , S_2 and S_3 , corresponding to the amounts of seven components of a composite product. The components will in the following be referred to by the same capital letters as their analogue values. It is supposed that the ratio between the analogue values or components C and W determines one physical property of the composite product and that the absolute analogue value or amount of W determines another physical property.

To begin with only the part of the computer which relates to the three components C , W and G will be considered.

The computing device has a first control member K_f which by means of connections f_c and f_w shown in dotted lines and symbolizing adjustments is connected with analogue outputs for the values C and W so as to adjust the ratio therebetween. The control K_f is also connected with a ratio indicator I_r operable to indicate the ratio W/C . The computing device furthermore has another control member K_w which through one connection f_g is connected with the analogue output G and through another connection f_{cw} is connected with the total analogue output $C+W$.

The control member K_w is furthermore connected with an indicator I_w which indicates the value of the analogue value W and preferably also with indicators I_c and I_g which indicate the values of C and G respectively.

The method of using this part of the computing device is as follows:

The ratio between the analogue values C and W is first adjusted by means of the control member K_f until the desired ratio is readable on the indicator I_r corresponding to the physical property of the composite product which is determined by the ratio W/C . The indicator I_r may within the scope of the invention be an instrument or a graduated scale or any other type of indicator.

Hereafter the ratio $(C+W):G$ is adjusted by means of the control member K_w . Obviously, the ratio W/C as previously adjusted by means of the control member K_f will not be influenced by the adjustment of the control member K_w but the analogue values W and C are changed, still with the same proportion between them. When, during the adjusting of the control member K_w the indicator I_w shows the desired amount of the component W which is required in the mixture in order to obtain the second physical property, all the three analogue values will be correctly adjusted and the components can be dispensed in accordance with the analogue values to provide a composite mixture in which the physical properties will be as determined by the ratio W/C as well as by the absolute amount of W .

Through the indicators I_c and I_g are not absolutely necessary we have found it convenient that also the analogue values of C and G can be indicated.

In the following it will be supposed that the mixture is concrete in which the analogue values C , W and G stand for the components, cement, water and gravel.

When the delivery of concrete of a predetermined strength is specified by a customer, the ready-mix operator of a concrete station knows that within practical limits the strength is determined by the ratio between water and cement and that the second physical property, namely the slump, is determined by the contents of water.

The part of the analogue computer briefly described hereinbefore provides for a method which avoids the danger of overdispensing cement and thereby wasting cement when the customer requires an individually composed mixture with a certain absolute amount of water in order to obtain a certain slump.

Obviously the method obtaining an immediate answer to the correct composition of a concrete mixture is that the water/cement ratio is first adjusted to obtain the desired strength by reading the ratio on the indicator I_r , whereafter the amount of water is adjusted until the desired amount is readable on the indicator I_w . By the last adjustment the analogue value C of cement is readjusted because the water/cement ratio is kept constant so that a mixture is always obtained with the desired strength as determined by the control member K_f and there is no risk of overdispensing the cement with waste as a result or of underdispensing with less strength as a result.

In the following the remaining part of the analogue computer device of FIG. 1 will be explained with reference to concrete technology.

In addition to cement/water and gravel, concrete usually contains entrained air L and skeleton composed of different modules aggregate or sizes of stones S_1 , S_2 and S_3 which in the following will be supposed to be small, medium and large sizes of stones.

The computer device has a control member K_{s1} with one connection f_{s1} operable to adjust the analogue value of S_1 , another connection $f_{s2,3}$ operable to adjust the analogue values S_2+S_3 and an indicator I_{s1} for the amount of stones S_1 . A further control member K_{s2} has connections f_{s2} and f_{s3} operable to adjust the ratio between the stones S_2 and S_3 as well as a connection to indicators I_{s2} and I_{s3} for indicating the values of these analogue values. A further control member K_{s3} is provided with connections f_{s4} and f_{sm} to adjust the ratio between the entire amount of stones $S_1+S_2+S_3$ and the entire amount of all the components in the mixture as well as an indicator I_s for indicating some of the analogue values $S_1+S_2+S_3$ in proportion to the sum of all the analogue values.

By initially setting the control member K_{s3} to read a unit value of the amount $S_1+S_2+S_3$ on the indicator I_s , such as for example 100 by volume and determining that for example the ratio between S_1 , S_2 and S_3 should be 50:30:20 it is possible to obtain the adjustment in the following manner:

The control member K_{s1} is operated until the indicator S_1 shows 50 whereafter the control member K_{s2} is operated until the indicators S_2 and S_3 show 30 and 20 respectively.

When thereafter the control member K_{s3} is operated and the analogue value of the total batch amount also is a unit value, for example 1,000, and it is desired to have for example 40 percent skeleton in the mixture, this can be adjusted directly by means of the member K_{s3} by calibrating the indicator I_s to show percent. Thereby the exact analogue values of the three amounts S_1 , S_2 and S_3 will be readjusted but the initially adjusted ratio will be kept constant.

The analogue value L for entrained air is adjustable relatively to the entire sum of analogue values by means of a member K_L by means of connections f_L and f_s as indicated, and the contents of entrained air as adjusted thereby can be read out in percent on the indicator I_L .

When the four adjustment herein described have been made, the total amount of cement, water and gravel is the difference between the entire batch amount and the sum of contents of air and skeleton.

The final step of determining the composition is thereafter to use the controls K_f and K_w as hereinbefore described to determine the water/cement ratio according to the desired strength and the amount of water according to the desired slump.

More specifically the strength is determined by the water/cement ratio according to Bolomeys formula

$$\sigma = K(C/V - 0.5)$$

in which σ is the strength and K is a constant which is determined by the quality of the cement.

It will be understood that it is possible to calibrate the indicator I_r directly in strength according to Bolomeys formula so as thereby to avoid the use of tabulations for determining the water/cement ratio as a function of strength.

Regarding the adjustment of the amount of water which determines the slump, it should be observed that the slump is also governed by the largest size of stones which must be smaller than the narrowest cross section of the mould. Since the stones already have been selected according to previous adjustments, the adjustment of K_w is the actual slump determination.

Obviously, if the amount of water is increased, this will cause an increase of the total amount of paste which is the sum of cement and water, and decrease the amount of gravel and alternatively, if the amount of water is decreased the amount of cement will be proportionally decreased and the amount of gravel increased.

It will be appreciated that the method of using the schematically shown computing device of FIG. 1 is extremely simple and provides for quickly obtaining the correct analogue values of an individually specified mixture. We have found that the method is so simple that it is possible with relatively short training to teach the mix-operator of a concrete station to use the method and obtain the correct answer in less than 1 minute.

A practical design of an analogue computing equipment according to the invention is illustrated in FIG. 1 in which 100 is a control panel on the front side of which the various control members K_{s1} , S_{s2} ... are shown in the form of control knobs and in which also the indicators are shown as readable instruments.

It will be understood that the control knob assembly which in FIG. 1 is referred to by KP represents means for adjusting the analogue values and ratios therebetween and once a predetermined batch of a composite product has been calculated and the analogue values adjusted, the computing device can be used to reproduce the same composition by retaining the controls.

In other words it is possible to completing the system of FIG. 1 with a plurality of preadjusted controls in groups corresponding to the group KP and selecting each one of said preadjusted groups of controls to select a corresponding one of a plurality of precalculated standard mixtures.

This possibility is indicated in FIG. 2 in which StI , $StII$... StX indicate each one of ten different groups of controls which by way of trimming are adjustable to respond to each one of ten different standard mixtures and can be selected individually by means of corresponding selector members SeI , $SeII$... SeX of a selector board 102 which is connected with the control panel 100 by means of a cable 104.

The arrangement of FIG. 2 is such that all the indicators are common to each of a selected one of control groups whether it is the group for individual adjustment KP as shown in FIG. 1 or any one of the standard mixture groups StI , $StII$...

The selector board 102 has in addition to the selectors SeI , $SeII$... a selector K_r for selecting the group of controls KP for individual batch mixing.

While the adjustment members of the group of selectors KP may be in the form of control knobs or the like which can be individually adjusted, the corresponding control members of the standard mixture controls should be designed in such a manner that they can only be readjusted by means of special tools or the like and only for the purpose of minor readjustments or trimmings. The groups of standard mixture controls however, correspond individually with respect to their connections with the instruments and the analogue value outputs to the control group KP of FIG. 1, and it will be appreciated that initially they have to be adjusted individually precisely in the manner described hereinbefore to correspond to selected standard mixtures.

In a concrete mixing station the selector board 102 may be arranged on the platform where the mix-operator can surbey the delivery and can select either a specified one of the stan-

dard mixtures by pushbutton control or the individual control selector group KP of FIG. 1 in the case where a mixture which deviates from any of the available standard mixtures is specified.

The control panel 100 of FIG. 2 has in addition to the controls hereinbefore described a pushbutton SW and two other controls K_{KH} and K_{RAT} , the function of which will be described in the following and the selector board 102 has a further control K_r the function of which also will be described in the following.

It is indicated that the selector board is connected with a cable 106 which is the output cable from the entire computer device and adapted to be connected with the dispensing equipment for automatic dispensing of the individual components according to the adjusted analogue values of each of them.

As will be appreciated from the foregoing the adjustment procedure is the same the whole way through and always starts with adjusting the ratio between two numerical values and after the first adjustment another adjustment of ratio between two numerical values is effected and so forth, all in accordance with a pattern which is related to the technology of the mixture to be produced.

This simple method provides for a simple construction and preprogramming of an analogue computing device, either in the form of a simple mechanical calculation device or an equivalent electrical computer as will be described in the following.

FIG. 3 illustrates a mechanical geometric system and the corresponding electrical equivalent for determining the analogue values of C, W and G.

The mechanical geometrical system comprises three rulers C_1 , W_1 and G_1 each of which extends perpendicularly to each one of three sidelines a , b and c of a hypothetical triangle or as a system of guide members constructed as an equilateral triangle with a height M which may be variable.

An arm K_r which corresponds to the control member K_r of FIG. 1 and therefore is designated by the same reference numeral is pivotally mounted about a top A of the triangle and points on a scale I_r which is the equivalent of the indicator I_r of FIG. 1.

The interior ends of the rulers C_1 , W_1 and G_1 are adapted to engage or are connected with an abutment K_w which corresponds to the control member K_w of FIG. 1 and which is movable along the geometrical line which coincides with the longitudinal direction of the arm K_r . This abutment may either be reciprocally mounted on the arm K_r , or the arm may be reciprocally mounted with the abutment firmly secured on the arm.

The geometrical system of FIG. 3 is based on the discovery that the geometry of equilateral triangles and the electrical analogy thereof provide a computing aid for proportioning components of a mixture to fulfil requirements as hereinbefore described.

From the geometry of equilateral triangles it is known that the sum of the distance from any point inside the triangle perpendicular to all the three sides is equal to the height of the triangle. It will therefore be understood that the lengths of the rulers C_1 , W_1 and G_1 inside the triangle which are referred to by C, W and G will be the analogue values of the three components of the mixture, the entire amount of which is equal to the height M of the triangle.

By considering the case where the abutment K_w is moved down to the bottom c of the triangle corresponding to the analogue values W_m and C_m of the components W and C, the point Q where the arm K_r intersects the bottom line c of the triangle will divide the bottom line into two portions the lengths of which are $2 \cdot \sqrt{3} \cdot C_m$ and $2 \cdot \sqrt{3} \cdot W_m$.

Insofar as the factor $2 \cdot \sqrt{3}$ is the same this means that for any angular position of the arm K_r there will be a predetermined ratio $f=W:C$, and by letting the arm point on the scale I_r and calibrating the same the ratio can be made readable.

By designing the system in such a manner that the rulers are reciprocable in their longitudinal direction for permanent cooperation or engagement with the abutment K_w and simultaneously can be displaced in the direction perpendicular to their longitudinal directions, the geometrical system provides a calculation aid for proportioning a mixture which satisfies the conditions

$$W:C=Wf$$

and

$$(W+C):(W+C+G)=g$$

corresponding to a concrete mixture with water, cement and gravel as basic components.

The geometrical system is used in the simple manner that the arm K_f first is adjusted to read the desired ratio "f" on the indicator I_f . Thereby the ratio $W:C$ is adjusted and this ratio is kept constant during displacement of the abutment K_w along the arm K_f . By displacing the abutment K_w until the desired analogue value W can be read on the ruler W_1 a mixture is calculated with the desired water/cement ratio and the desired amount of water whereby the analogue values of gravel and cement can be read on the rulers C_1 and W_1 .

The corresponding electrical equivalent of the geometrical system is also included in FIG. 3 and comprises a voltage divider P_g in the form of a potentiometer with a movable tapping K_w . An input voltage corresponding to the height of the triangle $M=C+W+G$ is applied over the potentiometer P_g .

Between the top end of the potentiometer P_g and its movable tapping, a further potentiometer P_f is provided with a variable tapping K_f which is provided with an indicator (not shown) corresponding to the indicator I_f in FIG. 1, so that for example the control knob of the potentiometer points on a scale which is graduated corresponding to the scale I_f of FIG. 3.

The two variable tapings are connected with output terminals MS_1 and MS_2 and the ends of the potentiometer P_g is connected with output terminals OM and OMS .

An indicator I_w for the analogue value of water is provided between the two variable tapings of the potentiometers and further indicators I_c and I_g corresponding to those of FIG. 1 may be provided between the other output terminals.

As indicated in dash and dotted lines the tapping K_f of the potentiometer P_f corresponds to the arm K_f of the geometrical system and the tapping K_w of the potentiometer P_g corresponds to movement of the abutment K_w along the line of the arm K_f .

The electrical system of FIG. 3 is used for proportioning the concrete mixture in such manner that when a predetermined strength is specified, the water/cement ratio is first adjusted by means of the tapping K_f until the desired ratio can be read on the indicator. When, thereafter, the tapping K_w is adjusted until the indicator I_w shows a predetermined amount of water corresponding to the desired slump, the outputs C , W and G between the output terminals are electrical voltages corresponding to the analogue values of each of the three components.

A similar mechanical geometrical system with electrical analogy is shown in FIG. 4 adapted to adjust between the three sizes of stone in the skeleton as well as adjusting the ratio between skeleton and the total amount of the batch.

For the sake of simplification the three rulers are designed by the analogue values S_1 , S_2 and S_3 as readable inside the orbits of the triangle. The three rulers are connected at a point AN where two pivotable arms K_{s1} and K_{s2} intersect.

Provided the mixture is going to be calculated with the ratio

$$\frac{S_1}{a} = \frac{S_2}{b} = \frac{S_3}{c}$$

it will be usual to specify the ratio between the sizes of the stone in percent such as for example $a=50$ percent, $b=30$ percent and $c=20$ percent.

By adjusting the angular positions of the two pivotable arms K_{s1} and K_{s2} relatively to each other it is possible to adjust the ratio between S_1 , S_2 and S_3 as $a:b:c$.

By, prior to this adjustment, adjusting the height of the triangle according to a unit analogue value, for example 100, the ratio between S_1 , S_2 and S_3 will be expressed in percent and can be indicated on correspondingly calibrated scales on the rulers S_1 , S_2 and S_3 .

By thereafter decreasing the height of the triangle by displacing the horizontal top line until its adjustment member K_{s3} indicates the desired ratio between the total amount of skeleton and the total amount of the mixture on the scale I_w and keeping the arms K_{s1} and K_{s2} locked in the adjusted positions, the length of the rulers inside the triangle will be reduced while retaining the adjusted proportions in percent and when the control member K_{s3} has been adjusted to the desired ratio g according to the last one of the two formulas hereabove the actual analogue values of S_1 , S_2 and S_3 can, by correspondingly calibrated scales of the rulers, be read out of the device.

The electrical analogy of FIG. 4 comprises an input potentiometer D_3 which an input potential is applied. By initially adjusting the variable tapping K_{s3} of the potentiometer D_3 to the top of the potentiometer as indicated in dotted lines the input potential will be applied across the potentiometer A_1 which is provided between the variable tapping K_{s3} and the bottom of the potentiometer D_3 and by means of the variable tapping K_{s1} of the potentiometer A_1 and the variable tapping K_{s2} of the potentiometer B_1 which is provided between tapping K_{s1} and the bottom of the potentiometer A_1 , the input voltage can be divided in the proportions $a:b:c$ with the proportions readable on the indicators I_{s1} , I_{s2} and I_{s3} in percent.

When thereafter the variable tapping K_{s3} of the potentiometer D_3 is adjusted to the desired ratio between the entire amount of skeleton and the entire batch amount as readable in percent on the indicator I_w , the analogue output values between the output terminals OMS , OS_1 , OS_2 and OS_3 respectively will be proportionally reduced, while retaining the percentage adjustment between the three components.

As previously mentioned it will frequently be found that a mixture, such as is the case with concrete, is specified to contain a further component L which in concrete stands for entrained air in a certain proportion to the entire amount of the batch whereby the following conditions must be fulfilled

$$(S_1+S_2+S_3):(L+C+W+G+S_1+S_2+S_3)=d$$

in which d is the air in percent.

Such a single component can be symbolized by the height of an equilateral triangle.

As apparent from the foregoing the height of the triangle of FIG. 3 which is referred to by M corresponds to the entire amount of mortar which is water plus cement plus gravel and the height of the triangle of FIG. 4 when adjusted to the desired percent of skeleton in the entire mixture corresponds to the skeleton. The triangle of FIG. 3 can therefore be referred to as the M -triangle, and the triangle of FIG. 4 as the S -triangle.

By calculating the entire batch by using the mechanical geometrical systems it is therefore possible to combine the M -triangle and the S -triangle in the manner indicated in FIG. 5 and by spacing these two triangles a distance corresponding to the height of a small triangle L which symbolizes the amount of entrained air the total height of the sum of the three triangles between the points A and A_2 will represent the entire amount of the batch.

Normally the amount of entrained air will be approximately 2 percent when no special measures are taken.

In some cases it is desired, however, to provide more air in the final mixture by means of additives.

Since it is desired in analogue computer to have the analogue value corresponding to the entire batch by way of a unit analogue such as 1,000 corresponding to, for example 1 m^3 which is equal to 1,000 litres, it is in FIG. 5 supposed that in such cases where there will be more air than the natural 2 percent in the mixture, the compensation for different air contents is obtained by diminishing the amount of mortar by displacing the bottom line of the M -triangle to read in the percent of air on a correspondingly calibrated scale I_L corresponding to the indicator I_L of FIG. 1.

Obviously it will also be possible to keep the height of the M-triangle constant and reduce the height of the S-triangle in accordance with the amount of air.

While FIG. 5 schematically indicates a combination of the systems of FIGS. 3 and 4, a more specific combination of the geometrical mechanical systems of FIGS. 3 and 4 is illustrated in FIG. 6.

The apparatus comprises a system of rails with stationary rails M_a , M_b and M_{a1} , M_{b1} which form the sides in two oppositely directed equilateral triangles with tops A and A_2 , the distance between which can be indicated on a scale I_1 to be adjusted according to a unit analogue value of the entire amount such as for example 1 m.³ equal to 1,000 liter.

The bottom rail M_c of the M-triangle can be displaced by means of an adjustment member K_L to indicate the distance between the two triangles L corresponding to the contents of entrained air on a scale I_L which extends from the horizontal line M_{c1} of the S-triangle.

In its turn the horizontal line M_{c1} of the S-triangle can be displaced by means of the adjustment member K_{a3} to indicate the percentage contents of skeleton in the entire batch on the scale I_{a1} .

The remaining adjustment members of FIG. 6 are referred to by the same reference numerals as in the previously explained figures.

In the following it is supposed that a concrete mixture is desired proportioned according to the following specification:

1. Skeleton composition

$$S_1:S_2:S_3=a:b:c$$

2. Ratio Paste—Skeleton

$$(S_1+S_2+S_3):(L+C+W+G+S_1+S_2+S_3)=d$$

3. Entrained air in percent of total mix

$$L:(L+C+W+G+S_1+S_2+S_3)=e$$

4. Water—Cement ratio

$$W:C=f$$

5. Mortar composition, i.e. W+C in percent of mortar

$$(W+C):(W+C+G)=g \text{ and}$$

6. Total amount of a computing size batch by volume

$$L+C+W+G+S_1+S_2+S_3=1 \times 1,000 \text{ liter.}$$

In previous computations of concrete a typical procedure has been substantially as follows:

The water/cement ratio is calculated from a formula to give the desired strength. The volume of air is taken from a table. The approximate quantity of water needed to produce the desired slump is taken from a table whereafter the exact volume of water can be calculated. Thereafter, knowing the water/cement ratio, the exact volume of cement can be calculated. Thereafter the percent of coarse aggregate or skeleton can be taken from a table. The volume of sand can then be calculated. Eventually, by multiplying with the specific gravity, the batch quantities can be calculated. Such calculation based entirely on concrete theory requires an expert and will take him between 1 and 2 hours.

By means of the proportioning aid or computing device according to the invention it is only necessary to read the proportions as specified, i.e. a , b , c , d , e and f into the device, i.e. to put the data into the device, which is a simple manual procedure, and by eventually adjusting g until the analogue value of water "W" indicates the desired amount, all the other values readjust themselves and all the batch quantities can be read out of the device. The whole procedure takes less than 1 minute and the use of the device does not require an expert.

By means of the system of FIG. 6 it is only necessary to read in the proportional values a , b , c , d and e which is a simple manual procedure and thereafter adjusting the value g until the desired analogue value of water W is readable on the scale. Thereby all the other analogue values have readjusted themselves and all the correct analogue values can be read out of the system which thereby provides a calculation aid for quickly and exactly determining the correct analogue values of the individual components of the mixture according to individual specifications without the necessity of using an expert.

The mode of use and operation of the proportioning aid or computing device of FIG. 6 is compared with the calculation procedure hereabove explained as follows with respect to proportioning a batch as hereabove specified.

The adjustment member K_{a3} is initially set in a position corresponding to a unit amount of total skeleton so as thereby to enable the proportions between S_1 and S_2 and S_3 to be read out in percent.

Thereafter the arms K_{a1} and K_{a2} are swung relatively to the size of the S-triangle until the desired percent between the stones can be read out of the rulers S_1 , S_2 , and S_3 and the arms are locked in the adjusted positions relatively to the sides of the S-triangle.

By means of the member K_{a3} the line M_{c1} of the S-triangle is thereafter displaced until the percentage contents of skeleton relative to the entire amount is readable on the scale I_{a1} .

Thereafter the bottom line M_c of the M-triangle is displaced until indication of the percent of air which is expected—either about 2 percent naturally or more in the case of use of additives—is readable on the scale I_L .

Thereafter the pivotable arm K_f is adjusted to read the ratio f between water and cement on the scale I_f , and eventually the abutment K_w is displaced until the desired amount of water W is readable on the appertaining ruler on the M-triangle.

After these adjustments all the analogue values can be read out of the system.

The electrical analogy of the geometrical system of FIG. 6 is shown in FIG. 7 in which the electrical analogies of FIGS. 3 and 4 are combined.

The voltage from a stabilized voltage source VS is adjustable by means of a member OP in such a manner that a stabilized voltage which is supplied between input terminals IT_1 and IT_2 has an analogue value which represents the value $L+C+W+S_1+S_2+S_3=1,000$ for example corresponding to 1 m.³ or 1,000 litres.

This analogue value is readable on an indicator I_1 and corresponds to the geometrical distance between the tops A and A_2 of the triangles of FIG. 6.

As an equivalent to adjusting the distance between the triangles of FIGS. 5 and 6, the potentiometer D_1 of FIG. 5 is connected directly over the input terminals so as to enable the proportion $L:(L+C+W+G+S_1+S_2+S_3)$ to be directly adjusted on this potentiometer and the analogue value of the amount L of entrained air can be read between the output terminals OL and OM on the indicator I_L .

The potentiometer D_3 is also connected directly across the input terminals I_{f1} and I_{f2} . The variable tapping K_{a3} of the potentiometer D_3 is connected with the output terminal OMS. Hereby the voltage portion between the terminals OMS and OS₃ corresponds to the entire amount of skeleton and is referred to by S and the output voltage between the output terminals OM and OMS corresponds to the entire amount of mortar and is designated by M.

The skeleton voltage S is divided into three portions by means of the potentiometers A_s and B_s of FIG. 4 and in a similar manner the mortar voltage M is divided into three portions by means of the potentiometers P_w and P_f of FIG. 3.

The potentiometer arrangement P_{Kw} as indicated in dotted lines will be explained later.

The terminal IT_1 is connected with the variable tapping K_{a3} of the potentiometer D_3 through a connection in which a manually operable switch S_w is provided so as to enable the input voltage to be applied directly across the input potentiometer A_s of the skeleton voltage portion.

In the embodiment illustrated, the ratio indicator for W:C is a differential coil instrument, the two coils of which at one end are connected with the variable tapping K_f and the other ends of each of the coils are connected with the outputs OM and MS₂ respectively.

The previously described method is, by means of the arrangement of FIG. 7, carried out in the following manner.

A. ADJUSTMENT OF SKELETON COMPOSITION

- a. The switch S_w is closed. The adjustable tapping K_{s1} of the potentiometer A_s is adjusted until the indicator I_{s1} indicates the desired percent of stones of size S_1 , for example the smallest size.
- b. The variable tapping K_{s2} of the potentiometer B_s is adjusted until the desired percent ratio of stones of size S_2 is readable on the indicator I_{s2} . The latter adjustment also automatically adjusts the analogue output voltage S_3 to the desired percent of the amount of stones of size S_3 so that the three amounts $S_1 + S_2 + S_3 = 100$ percent.
- c. The switch S_w is opened.
- d. The variable tapping K_{s3} of the potentiometer D_3 is thereafter adjusted until the indicator I_{s3} indicates the desired percent of skeleton in the entire amount.

B. ADJUSTMENT OF AIR IN THE MIXTURE IN PERCENT

In ready mixed concrete there is always a natural content of air of between 1 and 2 percent and normally it will be sufficient to set the air adjustment K_L to 2 percent. By use of additives the amount of air can be increased and if it is specified that additives giving for example 5 percent air are going to be used in the specific mixture, the adjustment K_L should be set to 5 percent, whereby the output between the terminals OL and OM will correspond to the adjusted amount of entrained air in the mixture.

- e. The air is accordingly adjusted by setting the variable tapping K_L .

Hereby the total batch analogue voltage has been disposed of with respect to the skeleton and the air, and the remaining voltage which is now disposable is between the terminals OM and OMS.

C. ADJUSTMENT OF STRENGTH AND SLUMP.

The remaining adjustment is now to divide the remaining output voltage between the output terminals OM and OMS according to specified strength and slump which is done in the following manner.

- f. The tapping K_f is adjusted until the desired water/cement ratio is readable on the indicator I_f which may be calibrated directly according to the strength of the concrete.

Finally the tapping K_w is adjusted until the specified amount of water is readable on the indicator I_w . Hereby the amounts of gravel and cement are automatically readjusted and both amounts can be read out on the instruments I_c and I_g and the output voltages C and G correspond to the adjusted values.

After this procedure which can be completed in less than one minute by a trained person all the analogue output voltages are adjusted to respond to the desired amounts by volume of the components of the mixture of a predetermined total amount, for example 1,000 litres which is the value to which the indicator I_t is supposed to have been set initially.

In the foregoing no attention was paid to the potentiometer P_{kw} shown in dotted lines in FIG. 7 and provided between the variable tappings K_w and K_{s3} of the potentiometers P_g and D_3 . The variable tapping K_{kw} of this potentiometer is connected with the input of an operational amplifier DA, the other input of which is connected with the variable tapping K_w and which operates as a multiplier. When this arrangement is used the connection between the point x and the output terminal M_{s2} is disconnected and the output of the amplifier DA is connected directly with the output M_{s2} .

This arrangement serves the purpose of correcting the output voltages W and G for a contents of water in the gravel which will be found normally under practical conditions.

Obviously, if there is 5 percent water in the gravel and the water/cement ratio is adjusted according to a predetermined strength, the addition of gravel with 5 percent water will increase the water contents and disturb the adjusted balance of the ratio W:C with the result that the concrete strength will be reduced. In such an event it is therefore necessary to reduce the analogue value W between the terminal M_{s1} and M_{s2} with a corresponding amount of water which is present in the gravel.

The content of water in the gravel can be measured in different ways and if it is found that the content is for example 5 percent, the variable tapping K_{kw} of the potentiometer P_{kw} is set to 5 percent.

- 5 The output from the amplifier DA hereby divides the total analogue voltage $W+G$ in such a manner that the G-voltage is increased by 5 percent and the W-voltage is reduced corresponding to the volume of 5 percent gravel whereby the total volume is kept constant.

- 10 Instead of using a manually operable adjustment by means of the potentiometer P_{kw} it is possible to use an electronic network such as a servomultiplier which is controlled by means of the output voltage of an equipment which measures the contents of water in the gravel so that an automatic correction for the content of water in the gravel is obtained without the necessity of making any manual adjustments.

- 15 In smaller mixing stations where the administration of each component is effected under manual control, a remote control instrument panel may be provided with indicators which give precise instructions to the personnel about the amount of each individual component. In such event each instrument should be calibrated to show the exact amount of each component by volume or by weight according to standard practice. In order to avoid mistakes with the use of such a scheme, the instruments for the commands may be digital instruments giving the amounts by weight or volume in exact figures.

- 20 In most concrete mixing stations, however, automatic or semiautomatic administration devices are used with weighing stations for the components to be dispensed by weight and/or fluid meters for components to be dispensed by volume. In such event the proportioning or computing device according to the invention with output voltage fractions each of which is the analogue value of one component—which also may be derived from a triangle system to which electrical output devices are added—lends itself to a substantially complete automatic administration by combining the application of a analogue output voltages as amount control voltages to the corresponding respective administration stations with sequence control operable to select the stations in sequence one after the other in response to the programmed completion of the operation of each station.

- 25 In practice the use of the analogue output values from the computing device to control automatic dispensing of the components in a weighing station can be achieved by means of a device in the weighing station which produces an analogue value which increases as the dispensing proceeds, a differential which compares the analogue value produced in the weighing station and control means operable to interrupt the dispensing when the analogue values have become equal.

- 30 Preferably a stepwise interruption of the dispensing will be used in such a manner that the rate of dispensing will be decreased at a predetermined stage of the dispensing such as at a predetermined difference between the analogue value supplied by the computer and the corresponding voltage supplied by the weighing stations such as for example corresponding to dispensing of between 90 and 95 percent of the predetermined amount so as to thereby ensure against over-dispensing of any of the components.

- 35 Such a dispensing arrangement is shown schematically in FIG. 8 and illustrates the arrangement in connection with the dispensing of one of the components, for example the cement.

- 40 In FIG. 8, 50 is a silo with a closure member 52 the opening and closing of which can be controlled by a control member 54 and which can be partly closed from the open condition by means of a control member 56.

- 45 When the closure member is open the material is guided from the silo 50 along a chute 58 or in any other suitable manner to a weighing device 60 with a scale 62 which indicates the amount of material supplied to the weighing device.

- 50 An arrangement operable to produce a potential is connected with the weighing device and comprises a voltage source BW and a potentiometer P_{kw} with a variable tapping

K_{wp} which is moved by the movable parts of the weighing device as the dispensing proceeds so as to thereby produce an increasing voltage C_w between the top of the potentiometer P_{wp} and the variable tapping K_{wp} .

Obviously, when the analogue voltage C corresponding to the desired amount of the component in question is supplied across the input terminals I_{w1} and I_{w2} of the device, it is possible to use a differential which compares the analogue input voltage and the voltage produced by the weighing device and which interrupts the dispensing when the desired amount is supplied to the weighing device.

The voltage source BW is adjustable and is initially adjusted to a value which by the dispensing of an amount of cement by weight between the tapping K_{wp} and the top end of the potentiometer P_{wp} produces a voltage C_w which is equal to the analogue input voltage between the terminals I_{w1} and I_{w2} when the cement amount indicator I_c which is calibrated according to weight indicates the same amount of cement.

For practical purposes, however, it is necessary in the system to include a multiplication amplifier in the form of an operational amplifier OA with feedback over a potentiometer P_{oa} by means of which the multiplication factor of the amplifier can be adjusted.

The reason is as follows:

As previously mentioned the analogue computer is constructed to always give an analogue voltage portion corresponding to the values of the individual components corresponding to a total batch volume of for example 1 m^3 .

If a different total amount is specified by the customer it is obviously necessary to provide for a proportional correction of the amount of the individual components. Since the analogue input voltage for the amount C of cement always corresponds to the amount of cement in 1 m^3 , it is necessary if for example 3 m^3 is requested to reduce the voltage produced by the weighing device in the proportion 1:3 which can be obtained by adjusting the potentiometer P_{wp} of the amplifier OA to an amplification factor corresponding to multiplication in proportion 1:3.

The output of the amplifier OA is connected with the input terminal I_{w2} through a differential device indicated by way of a relay R_d with a normally closed contact K_{rd} which is connected with the control device 54 for closing the closure member 52. The differential member R_d is shunted by another differential member R_d which is provided with a bias in such a manner that it will be actuated when the output voltage from the amplifier OA has been increased to a value which is slightly less than the value at which the differential device R_d will respond. The relay R_d has a contact K_{rd} which is normally closed and which is opened to actuate the control device 56 to partly close the member 52 when the device R_d is actuated.

In the embodiment shown, the bias for the relay R_d is produced by supplying an alternating voltage across a potentiometer P_r between the variable tappings of which and the one end of the primary winding of a transformer T_r is connected with a secondary winding in which a rectifier E_r is connected.

The arrangement of FIG. 8 indicates schematically the arrangement used for one of the components, for example the cement and it will be appreciated that similar arrangements are used for the other components and are adjusted from a central location such as from the selector board 102 of FIG. 2 in which the control member K_x is operable to adjust the amplification factors of the potentiometers as well as the tapping of the potentiometer P_r to thereby regulate the bias of the relays R_d in accordance with the ratio between the total amount to be dispensed and the unit amount corresponding to the analogue values supplied from the computing device.

By means of the ratio of the transformer T_r and if necessary by using an unlinear potentiometer P_r , it is possible to control the part closing of the closure member 52 with substantial uniform difference between actual amounts dispensed and desired amounts without that difference being influenced by the total amount.

The mode of operation of the arrangement of FIG. 8 is substantially as follows:

When a dispensing switch such as indicated by SD of the selector board of FIG. 2 is actuated, the closure member 52 of the silo is opened and the dispensing starts.

As the dispensing proceeds, the tapering K_{wp} of the potentiometer P_{wp} is moved and depending on the amplification factor of the amplifier OA as adjusted by means of the proportion selector member K_x of the selector board of FIG. 2 the analogue voltage C_w produced by the weighing device is converted into an analogue voltage C'_w which is equal to the unit value of the computing device. As the voltage C'_w increases the differential device R_d will first be actuated when the voltage supplied from the amplifier OA is slightly less than the input analogue voltage or reference voltage C .

Hereby the contact K_{rd} is opened and actuates the control member 56 to partly close the member 52 so as to thereby decrease the rate of dispensing of the component. When thereafter the voltage C'_w supplied by the amplifier OA has been increased to be equal with the voltage C , the differential device R_d is actuated and actuates the control member 54 to close the member 52 and thereby interrupt the dispensing.

The other components are dispensed in a similar manner by means of similar control arrangements either simultaneously by means of individual weighing devices or in sequence controlled by a suitable sequence control.

In concrete production it is possible to control the dispensing of gravel and the skeleton components by using a single weighing device to which the components are supplied from different silos by connecting the differential devices R_d and R_d to be actuated in cascade.

In the case of compensation for difference in quality of one of the components such as difference in quality of cement, an arrangement in FIG. 12 can be included in the computing device or added to an existing computing device.

The arrangement of FIG. 12 provides for automatic adjustment of the analogue value of that component of a mixture which varies with respect to quality.

Obviously if a component of a mixture varies in quality from one supply to the next, it is not necessary to use so much of the component in a mixture when the quality is better as when the quality is worse.

The arrangement of FIG. 12 enables a simple method for correcting the dispensing in response to changes in the quality of one component by using in the beginning the calculated analogue value of the component in question as based on a known mixture and adjusting a multiplication device in the analogue computer to the ratio between two digital values which can be calculated from proportions between the physical properties of the known mixture as a master mixture or reference mixture and a test mixture produced with a part of the component from a new supply.

In the following the arrangement of FIG. 12 will be described with reference to concrete mixing.

In the production of ready mixed concrete it is necessary to dispense the cement with a sufficient supply to ensure that the nominal strength of the concrete is always obtained. The strength of the concrete is governed by the coefficient of variation which is the ratio between the crush strength of the concrete by standard deviations and the middle crush strength. Variations in the strength of the cement which can be quite substantial from supply to supply increase the coefficient of variations substantially but by uniform cement quality the coefficient of variation is reduced whereby the otherwise necessary strength margin can be reduced and result in savings of cement.

The proportion between the strength of a known mixture and a mixture to be produced subsequently can be expressed by the ratio between two digital values.

The crush strength of a concrete mixture after 28 days can be calculated by using Bolomey's formula

$$\delta = K \left(\frac{C}{W} - 0.5 \right)$$

in which σ is the crush strength for example in kg/cm.², K is a constant which primarily depends on the strength of the cement, C, is the cement by weight and W is the water by weight.

For each new mixture it is possible to determine the factor K by means of a test moulding and using an accelerated test method used by those skilled in the art and one of which is referred to as the Jespersen-method which will give the result in about 2 hours.

By making such a test with cement of one supply and inserting the values in Bolomey's formula it will be found that

$$\delta_m = K_m \left(\frac{C_m}{W} - 0.5 \right)$$

in which σ_m , K_m and C_m are strength, K-factor and amount of cement in this mixture which can be used as the reference mixture.

With the next supply of cement a corresponding test is made with the same amount of cement C_m as in the reference mixture whereby other values of strength and factor K are found, namely

$$\delta_{cn} = K_{cn} \left(\frac{C_m}{W} - 0.5 \right)$$

Since it is desired to obtain the same physical property, namely the strength, this means that the following conditions must be fulfilled:

$$\sigma_m = \sigma_{cn}$$

If the amount of cement of different quality which is necessary in order to obtain the same strength is called C_{na} and this value is inserted in Bolomey's formula for σ_{cn} the condition is

$$K_m \left(\frac{C_m}{W} - 0.5 \right) = K_{cn} \left(\frac{C_{na}}{W} - 0.5 \right)$$

By solving this equation it is possible to calculate the amount C_{na} of cement which must be used in the mixture with cement of quality according to the new supply as

$$C_{na} = \frac{K_m}{K_{cn}} (C_m - 0.5 W) + 0.5 W$$

As apparent from this formula the proportion between the necessary amount of cement of new quality and cement of old quality is basically determined by the proportion between the two factors K_m and K_{cn} .

It is therefore possible to proceed in such manner that after having calculated this proportion which can be referred as the ratio between physical properties of the reference mixture and the new mixture, the analogue value of the amount of cement in the reference mixture can be found by multiplying with this ratio after consideration of the other digital values of the formula in order to produce an analogue value of the amount of cement which is corrected to comply with the cement quality of the new mixture. Hereby the same physical properties will substantially be obtained by means of the new cement quality in the new mixture.

The computing device of FIG. 12 is especially constructed for this method in connection with concrete mixing.

In FIG. 12 AC is an analogue computing device with input terminals I_1 and I_2 for reading in the analogue values of the amount C_m of cement which is necessary in the reference mixture with the known factor K_m and with input terminals I_2 and I_3 for reading in the analogue amount of water W_m .

As indicated in FIG. 12 in dotted lines the ratio between water and cement can be adjusted on a potentiometer P_7 so that the calculation device of FIG. 12 can be directly connected with a computing device of FIG. 7. The analogue computing device of FIG. 12 may, however, also be used in connection with other kinds of devices which are able to produce analogue values corresponding to the desired amounts of cement and water in a reference mixture.

The arrangement of FIG. 12 is provided with an adjustable control member K_{RAT} which is also shown as an adjustment member in FIG. 2 for adjusting the ratio $K_m:K_{cn}$ and output terminals O'_c and O''_c for reading out analogue value C_{na} of the amount of cement which is to be used in the new mixture

with quality of the new supply. The arrangement also has output terminals O'_w and O''_w for reading out the amount of water W_m . Preferably the amount of water is kept constant in order to secure the same slump of the new mixture as of the reference mixture.

Between the input terminals I_1 and I_2 and the outputs O'_c and O''_c an analogue multiplier is provided which when the ratio $K_m:K_{cn}$ is adjusted by means of the member K_{RAT} automatically gives the correct analogue value of cement C_{na} .

If the specific gravity of cement which is 3.15 is inserted in the last of the formulas hereabove, the following expression for the amount of cement C_{na} by volume is found as

$$C_{na} = \frac{K_m}{K_{cn}} (C_m - 0.159 \cdot W) + 0.159 W$$

By means of the system of voltage dividers shown in FIG. 12 where the input voltage W_m is divided by means of two resistors R_1 and R_2 and the potential between the point a between these two resistors and the input terminal I_1 is divided by means of two resistors R'_3 and R''_3 , it is possible to obtain such voltage proportions that the potentiometer R_a can be calibrated in accordance with the ratio $K_m:K_{cn}$.

OA is an operational amplifier which is connected as a multiplier.

This can be understood in the following manner:

It is required that the potential between the terminals I_1 and I_2 should be proportional with the expression in parenthesis in the formula, i.e. proportional with $C_m - 0.159 \cdot W$ so as to obtain direct proportionality with adjustment of the potentiometer R_a between the input on the terminal I_2 and the output on the terminal O'_c . The potential which must be added to the expression in parenthesis is $0.159 \cdot W$ and this potential must be applied between the input terminal I_2 and the output terminal O'_c . This condition can be obtained by the following proportion between the resistors R_1 and R_2

$$R_1 = \frac{0.159}{1 - 0.159} R_2 = 0.189 R_2$$

By proportioning the resistors R_1 and R_2 in this manner a voltage across the resistor R_1 is obtained which is equal to $0.159 \cdot W$ and between the point a and the input terminal I_1 a voltage is obtained corresponding to $C_m + 0.159 \cdot W$.

By using equal values of the resistors R'_3 and R''_3 this voltage will be divided into two equal portions which means that across the resistor R''_3 a voltage is provided which is $\frac{1}{2}(C_m - 0.159 \cdot W)$ which multiplied by $2 \cdot K_m/K_{cn}$ gives the first part of the expression in the analogue value for C_{na} .

If the potentiometer R_a is adjusted to a ratio the voltage across the potentiometer R_a is

$$\frac{C_m - 0.159 W}{2\alpha}$$

By calibrating the potentiometer in such a manner that

$$\alpha = \frac{1}{2} \frac{K_{cn}}{K_m}$$

the total voltage between the output terminals O'_c and O''_c will be equal to the expression for C_{na} because the output voltage is composed by the voltage across the potentiometer R_a and the resistor R_1 of the voltage divider R_1, R_2 .

When $K_{cn} > K_m$, i.e. when the cement quality is improved, the analogue value C_{na} is decreased and a saving is obtained.

When $K_{cn} < K_m$, i.e. when the quality is decreased, the amount C_{na} is increased to obtain the same quality of the mixture.

As mentioned the analogue output values are calculated by volume. Since the volume of water the analogue of which is the same between the output terminals O'_w and O''_w as between the input terminals I_2 and I_3 and since it is always desired to deliver a volume unit, the system is also adapted to automatically recalculate the analogue value of such a third component of the mixture the amount of which can be allowed to be increased or decreased in response to decreasing or increasing of the amount of cement.

Such third component is the gravel in a concrete mixture and in the case of relatively minor changes in the amount of cement a corresponding increase or decrease of the amount of gravel does not cause any change of the slump beyond allowable limits. Otherwise, it is possible within the scope of the invention to use a special filler to replace the cement when required.

FIG. 13 illustrates an embodiment of the analogue computing device according to the invention in which an analogue value G corresponding to a predetermined amount of gravel to be used in the mixture is supplied to input terminals I_4 and I_5 , e.g. derived from a voltage divider in a system as disclosed.

The embodiment of FIG. 13 modifies the output of the analogue value G by adding thereto the numerical value of $C_m - C_{na}$.

In the arrangement of FIG. 13 a differential amplifier DA_1 is connected between the input terminal I_4 and an output terminal O'_p . The amplifier DA_1 has four inputs i_1 , i_2 , i_3 and i_4 of which i_1 and i_3 are connected with the input terminals I_1 and I_2 respectively whereby the voltage difference between the inputs i_1 and i_3 is equal to C_m . The inputs i_4 and i_2 are in a similar manner connected with the output terminals O'_c and O''_c respectively whereby the voltage across the inputs i_2 and i_4 is equal to C_{na} . According to the mode of operation of such differential amplifiers its output G_1 between the terminals O'_c and O''_c is

$$G_1 = i_1 + i_2 - i_3 - i_4 = (i_1 - i_3) - (i_4 - i_2) = C_m - C_{na}.$$

This means that the numerical value of $C_m - C_{na}$ is added to the analogue value G . In other words, if the cement quality is increased less cement is included in the mixture (C_{na} decreases) and more gravel is added to make up for the missing amount of cement. If the cement quality decreases compared with the master mixture, $C_m - C_{na}$ becomes negative, more cement is added to the mixture and the amount of gravel is decreased in order to keep the volume constant.

It will be understood that the invention is not limited to the embodiments shown and described hereinbefore.

A modification of a simple mechanical geometrical system with one triangle is illustrated in FIG. 9. The triangle is, as in FIG. 6, constructed with two relatively stationary rails M_a and M_b , the ratio determining lever K_f pivotable about the fixed point A and the parallel displaceable rail M_c . On each of the rails a guide member GU_1 , GU_2 and GU_3 respectively is slidably mounted. Each guide member has a guide channel which extends perpendicularly to the direction of the respective rail and in each of which a reciprocable member C , W and G is mounted, each of which represents one of the "rulers" hereinbefore mentioned. To each ruler is assigned a thermometer type indicator I_c , I_w and I_g on an indicator panel and between each of the reciprocable members and its associated indicator a transmission TR_c , TR_w and TR_g respectively is provided to operate each indicator to show a value which is equal to or proportional to that length of the appertaining ruler member which extends inside the triangle. The transmission may be mechanical, hydraulic or of any other convenient type and include suitable amplification means to provide for a longer movement of the "thermometer columns" than of the ruler members.

In FIG. 9 the indicator panel also includes an indicator I_t for the total amount represented by the height of the triangle adapted to be actuated through a transmission TR_t from a reciprocable member which is actuated by engagement with the rail M_c and is movable in a guide GU_t .

An abutment PT which may be a pin of equilateral triangular cross section is slidably mounted on the lever MR_f preferably against sufficient friction to keep it in any position to which it is adjusted. Alternatively the abutment PT may be fixed on the lever MR_f which in such event is reciprocable relatively to the fixed point A by means of a pin-and-slot connection.

Each "thermometer" may have two or more graduations, e.g. indicating volume as well as weight of a material with a predetermined specific gravity.

It is also possible within the scope of the invention to construct the calculation aid which has the character of a slide rule based on the geometry explained. A part of the slide rule embodying the invention is shown in FIGS. 10 and 11.

In order to facilitate the understanding of the structure of FIG. 10, also the triangle with its two sides M_a and M_b and with its displaceable side M_c is shown, although it will be obvious that in the practical embodiment only the members which are reciprocable perpendicular to the side of the triangle are necessary.

The device of FIG. 10 is mounted on a support SU which may be a board or a sheet of plastics material. The graduated scale S_f for the f -ratio is printed on the support and the pivotable lever K_f is reciprocable relatively to the point A as explained with reference to FIG. 9 with the abutment PT in the form of a pin firmly secured on the lever K_f . On the support a bracket BR_1 is secured with a middle portion which extends parallel with and slightly spaced from the top surface of the support, so as to form with the support a guide channel for an elongated rectangular sheet member S_w of a width which is not much less than the extension of the side of the triangle, perpendicular to which the sheet member can slide. A similar arrangement is made with respect to the other side M_b of the triangle with a second bracket BR_2 and another slideable sheet member S_c . As indicated in FIG. 10 the interior ends of the reciprocable sheet members S_w and S_c engage the abutment PT . Obviously, the sheet members represent the slideably rulers and by providing graduations GU_w and GU_c on the sheet members and making the graduations readable, the analogue values C and W can be read directly.

In a practical embodiment shown in FIG. 11, which illustrates a part of the device of FIG. 10, the guide member BR may be of transparent material such as Perspex with a line RL engraved thereon for the purpose of reading the graduation GU_w which may be graduated in analogue values of the amount. In addition a further plurality of graduations GU_2 , GU_3 and GU_4 may be engraved on the slideable sheet member with the further graduations enabling the amount of the volume of the graduation GU_w to be read out of the device in different terms, such as for example weight or other properties. By way of example one graduation may give the volume of water in litres and another the volume in gallons, and in order to select the graduations a slide S_H with a window may be moveable on the bracket BR transverse to the ruler S_w .

For using the device in calculating concrete a further graduation of the slideable sheet member may show the slump, so that the mixing operator can read the correct amount of water directly into the device by adjusting the water slide merely to the desired slump.

It will be appreciated that in the device a third slide may be moveable perpendicularly to the third side of the triangle and that for a composition with seven components a slide rule device constructed according to FIG. 10 will include six slides assigned to two triangles as well as displaceable members with lines engraved thereon.

I claim:

1. A method of proportioning a plurality of components of a batch mixture comprising at least a first, a second and a third component, and in which mixture a first physical property is determined by the ratio between the first and second component, and a second physical component, comprising the steps of using an analogue computing device, producing an analogue value with said computing device corresponding to the total amount of a batch, dividing said total analogue value into mutually adjustable portions corresponding to analogue values of each of the three components, adjusting a portion of said total analogue which represents the sum of said first and said second component first, to such predetermined ratio between the two analogue values which correspond to the desired first physical property with said ratio made readable, retaining said mutual adjustment and the ratio between the analog value which represents the third component, adjusting the sum of the analogue values which represent the first and

the second components until a reading indicates such analogue value of said second component which corresponds to said second physical property by means of an indicator, reading out the three analogue values and mixing the bath according to said readings.

2. A method as claimed in claim 1, in which a fraction of the second component is included in the third component, comprising the steps of measuring the amount of said second component which is included in said third component, using an analogue computing device with an adjustable correction device operatively connected with the means for dividing the total analogue value in portions corresponding to the analogue values of said second and said third components, and programming said correction device to decrease the analogue value of said second component to be read out with the amount of said second component which is contained in said third component.

3. A method as claimed in claim 1 for proportioning a batch which in addition to the three components comprises a further group of components which are desired to be mixed in the bath in mutual predetermined proportions as well as in a predetermined ratio relative to the entire amount of the mixture, comprising the steps of first proportioning the components of said second group in predetermined ratio by percent by dividing an analogue value which represents a unit measure into desired proportion between the components of said second group, thereafter adjusting said analogue value which represents said second group to such a ratio to the analogue value which determines the entire amount of the batch which corresponds to the desired proportion between the total amount of the components of said second group and the entire batch amount, and after adjustment of the analogue values of said first, second and third component in accordance with the desired physical properties, using all the analogue values for proportioning the batch.

4. A method as claimed in claim 3, in which the dispensing of the components is controlled by producing by means of a dispensing device, an analogue value which increases as the dispensing proceeds, comparing the analogue value produced by the dispensing device with the analogue value which is derived from the analogue computing device and is indicative of the amount of the component to be dispensed, and interrupting the dispensing when the analogue value produced by the dispensing device has been increased to the value of the other analogue.

5. A method as claimed in claim 4, in which a third analogue value is produced which is less than but smaller than the analogue value which is indicative of the amount of the component to be dispensed, and in which the analogue value produced by the dispensing device is first compared with said third analogue value and upon becoming equal therewith, the dispensing device is controlled to decrease the rate of dispensing.

6. A method of proportioning a concrete bath containing cement, water and gravel, the cement and water being present in a predetermined ratio which determines the strength, and the water being present in a predetermined amount which determines the slump, by using an analogue computing device which has means for producing an analogue value corresponding to the desired total amount of the batch and dividing said total analogue value in portions which represent each of the components, comprising the steps of first adjusting one analogue value which represent the sum of the amounts of water and cement in a desired ratio between cement and water corresponding to the desired strength of the concrete and indicating said ratio, thereafter adjusting the ratio between the analogue value which corresponds to the amount of gravel and the sum of the analogue values which represent water and cement without changing the first adjustment until a predetermined amount of water which corresponds to the slump can be read out of the computing device and thereafter using the analogue values of the three components adjusted in this manner for proportioning the batch.

7. A method as claimed in claim 6, in which the gravel contains an amount of water, comprising the steps of measuring the water contents in the gravel and using an analogue computing device which when operatively connected with the means for producing analogue values corresponding to water and gravel includes a correction device and adjusting said correction device to decrease the analogue value which corresponds to water with that amount of water which is included in the gravel.

8. A method as claimed in claim 6, for proportioning concrete which in addition to cement, water and gravel comprises a skeleton having a different modulus aggregates and with a desired ratio between the total aggregates and the total amount of the mixture, comprising the steps of dividing an analogue value which represents a unit amount into portions which represent each of the modulus aggregates by percent, adjusting said analogue value to a desired ratio relatively to the analogue value which represents the entire amount of the mixture to the desired ratio between the amount of skeleton and the total amount of the mixture and after having divided the remaining amount of the analogue value into portions which correspond to analogue values of cement, water and sand to give the desired physical properties using all the analogue values for proportioning the mixture.

9. A method as claimed in claim 6, in which the dispensing of the components is controlled by producing, by means of the dispensing device, an analogue value which increases as the dispensing proceeds, comparing the analogue value which is derived from the analogue computing device and is indicative of the amount of the component to be dispensed, and interrupting the dispensing when the analogue value produced by the dispensing device has been increased to the value of the other analogue.

10. A method as claimed in claim 9, in which a third analogue value is produced which is a fraction smaller than the analogue value which is indicative of the amount of the component to be dispensed, and in which the analogue value produced by the dispensing device is first compared with said second analogue value and upon becoming equal therewith, the dispensing device is controlled to decrease the rate of dispensing.

11. An analogue computing device for proportioning a plurality of components of a batch mixture, comprising at least a first, a second and a third component, and in which mixture a first physical property is determined by the ratio between the first and the second component and a second physical property determined by the amount of the second component, comprising means for producing an analogue value which corresponds to the entire amount of the batch, means for dividing said total analogue value into a first fraction which represents the analogue value of the sum of the two components, the ratio between which determines the first physical property and a second fraction which corresponds to the analogue value of the third component, means for dividing said first analogue fraction into two portions, each being indicative of the analogue values of the two components, means for indicating the proportion between said two analogue values, and means for indicating the one of the numerical values of the two components, the amount of which determines the second physical property of the mixture.

12. Apparatus as claimed in claim 11, having for each group of three components three reciprocal rulers movable perpendicular to the direction of each of three sides of a hypothetical or physical equilateral triangle, the height of which corresponds to the analogue value of the entire amount of that portion of a batch which is going to be mixed by the three components in question and about one corner of which an arm is pivotally mounted with an abutment which is displaceable in the longitudinal direction of the geometrical line of the arm for engagement with the interior ends of the rulers, and in which the rulers are calibrated to indicate the distance of each ruler from the end which engages the abutment to the side of the triangle.

13. Apparatus as claimed in claim 12, in which the rulers directly or indirectly are connected with control means for automatic control of the dispensing of the individual components in accordance with the reading of the rulers.

14. Apparatus as claimed in claim 13, in which the rulers are connected with electrical potential generators operable to control said generators to produce electrical potentials analogue with the readings on the rulers, and operable to control the dispensing of the components.

15. Apparatus as claimed in claim 12, in which an indicator device is provided in connection with the pivotable arm, and is operable to indicate the ratio between the readings of those two rulers which are movable perpendicular to the two sides of the triangle which intersect at the pivot of the arm.

16. Apparatus as claimed in claim 15, in which the bottom line of the triangle opposite the pivot point of the arm is displaceable in a direction perpendicular to the height of the triangle, and that the height of the triangle is readable on a scale.

17. Apparatus as claimed in claim 16, for proportioning of concrete, in which the scales of the two rulers which are movable perpendicular to the two sides of the triangle which intersect the pivot point of the arm are calibrated corresponding to the amounts of water and cement, and that the third ruler is calibrated corresponding to gravel.

18. Apparatus as claimed in claim 17, for proportioning a mixture having a plurality of further components which in a second group must be mixed in a desired ratio having a further group of three rulers for each group of components movable relative to the sides of a further triangle having one line parallel with the bottom line of the triangle of the first group of components opposite the point of intersection about which the pivotable arm is mounted.

19. Apparatus as claimed in claim 18, in which the distance between the two triangles is variable and readable on a scale.

20. Apparatus as claimed in claim 19, in which one triangle corresponds to the components water, cement and gravel in concrete and the rulers in the other triangle correspond to a different size of skeleton, and that the distance between the two triangles corresponds to entrained air.

21. Apparatus as claimed in claim 11, having an electrical voltage source, means for producing therefrom a voltage which is the analogue value of a predetermined amount of a batch, a first voltage divider operable to divide said analogue voltage into a first portion which is the analogue value of the sum of the two components, the ratio between which determines the first physical property of the mixture, and a second portion which is the analogue value of the third component of the mixture, a second voltage divider operable to divide said first portion into two mutually adjustable portions each corresponding to an analogue value of each of the two components, the ratio between which determines the said first physical property, means for indicating the ratio between said last-mentioned analogue values and means for indicating the amount of the analogue value of that one of said two components which determines the second physical property.

22. Apparatus as claimed in claim 21 for use with proportioning the components of concrete in which the first voltage divider is adapted to produce an analogue value which corresponds to the sum of water and cement and an analogue value which corresponds to gravel and the second voltage divider is adapted to divide the first analogue value into portions

which represent the analogue values of cement and water, respectively.

23. Apparatus as claimed in the claim 22 for proportioning concrete having cement, water and gravel, and skeleton comprising different sizes of stone as well as entrained air, having a first voltage divider operable to divide an analogue voltage, which corresponds to the analogue amount of a unisize batch, into a first portion which comprises the mortar and a second portion which comprises the skeleton, means operable to indicate the amount of skeleton in percent of the entire batch, means operable to divide the analogue portion which corresponds to skeleton into fractions, each of which corresponds to a different size of stone in the skeleton, means operable to indicate the analogue values of each of the sizes of stone in the skeleton in percent of the entire amount of skeleton, a further voltage divider operable to divide the entire batch analogue value into a first portion corresponding to the amount of entrained air and a second portion which corresponds to the remaining part of the batch, means operable to indicate the amount of entrained air in percent, means operable to divide the remaining portion of the entire batch which corresponds to mortar into a first portion which corresponds to the amount of gravel and a second portion which corresponds to the sum of water and cement, a voltage divider for dividing the last portion into two portions corresponding to water and cement respectively, means operable to indicate the ratio between water and cement and/or the strength of the concrete, and means operable to indicate the amount of water and/or the slump.

24. Apparatus as claimed in claim 23, in which switch means is provided operable to apply the voltage corresponding to the analogue value of the entire batch directly to the voltage divider system which represents the skeleton, thereby enabling the proportion between the skeleton components to be adjusted in percent.

25. Apparatus as claimed in claim 24 in combination with a dispensing device having means operable to produce an analogue value which increases as the dispensing proceeds, a differential operatively connected with the analogue output which is indicative of the amount of the components to be dispensed as well as with the analogue value produced by the dispensing device, said differential being operable to produce a signal when said analogue value produced by the dispensing device has been increased to the value of the other analogue, and control means operable by said signal for interrupting the dispensing.

26. Apparatus as claimed in claim 25 having means operable to produce an analogue value which is slightly less than the analogue value which indicates the amount of the components to be dispensed, an auxiliary differential device operable to compare said analogue value with the analogue value produced by the dispensing device and being able to produce a signal, and control means operable to reduce the rate of dispensing in response to said signal.

27. Apparatus as claimed in claim 26 comprising an amplification device operatively connected with the analogue value produced by the dispensing device to control the analogue value produced by the dispensing device in proportion to the ratio between the unit amount of batch as used in the computing device and the actual amount of batch to be dispensed.