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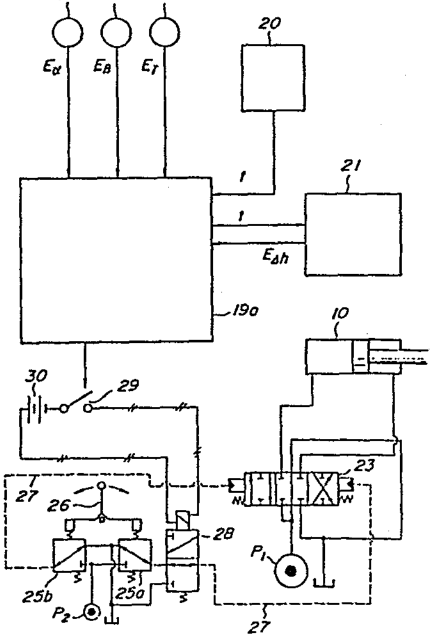
(54) **Dredging excavator.**

(57) A dredging excavator is equipped with computing means (19;19a;37) adapted to compute the depth from the water level to an excavation point on the bottom of the water, means (21; 36; 36a) to determine a tidal level at the excavation site on the basis of data which have in advance been obtained, correction means (62;82) for correcting a value, which as been obtained by the computing means, on the basis of a tidal level obtained by the tidal level determining means, and output means to output a value corrected by the correlation means. The dredging excavator can determine the excavated depth from a standard level to the present excavation-finished floor promptly and precisely without need for man power. The operator can proceed with the excavation readily to a target depth on the basis of the thus-determined value.

FIG. 4



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DREDGING EXCAVATOR

This invention relates to a dredging excavator, such as hydraulic backhoe ship or grab dredge ship, useful in excavating and dredging a sea or river floor to a prescribed depth.

Construction or expansion of a harbor, securement of a navigation route, cultivation of fish or sea weed or the like usually requires to excavate and dredge (hereinafter simply called "dredge") a sea floor or a river floor located near an estuary (hereinafter represented by "sea floor"). For this purpose, dredging excavators are used. A hydraulic backhoe ship, a sort of such dredging excavator, will next be described.

Figure 1 is a side view illustrating the approximate structure of a hydraulic backhoe ship. In the drawing, there are illustrated a hydraulic backhoe ship 1, a sea floor 2, spuds 3 driven in the sea floor 2, a sea level 4 and a pontoon 5 floating on the sea level 4. The pontoon 5 is held on the spuds 3 in such a way that the pontoon 5 is slidable up and down along the spuds 3 but is restrained from moving horizontally over the sea level 4. The pontoon 5 ascends along the spuds 3 as the tidal level arises, but it descends along the spuds 3 as the tidal level lowers. Namely, the height from the sea floor to the pontoon 5 changes continually in accordance with the tidal level. Numeral 6 indicates a swivel cab of the backhoe, which swivel cab is mounted on the pontoon 5. There are also shown a boom 7 hinged on the swivel cab 6, an arm 8 supported swingably on the boom 7, a bucket 9 supported turnably on the arm 8, a boom cylinder 10, an arm cylinder 11 and a bucket cylinder 12. An excavating mechanism is constructed of the boom 7, arm 8 and bucket 9. Numeral 13 designates the present excavation-finished floor to which the excavation has proceeded by the excavating mechanism.

By the way, the operator who is operating the excavating mechanism on the hydraulic backhoe ship 1 is unable to know the depth of the excavation-finished floor in the sea floor since he stays above the sea level 4. In order to proceed with the excavation to a prescribed depth, it is therefore necessary to use some means so that he would be able to know how deep he would have excavated.

As one of such means, it has conventionally been practiced to place some marks on a desired part of the boom 7 so as to estimate excavated depths in accordance with such marks. However, this prior art method merely permits extremely-rough estimation as to excavated depths because the boom 7 assumes various positions depending on the drawn state of the arm 8. In view of the fact that a tolerance of only 10 cm - 30 cm is generally permitted as to each target excavation depth, it is readily understood that the above-described method can hardly be employed. The above method cannot be relied upon for another reason, which will next be described. Each target excavation depth is not given as a depth from the sea level 4 at that particular time point but is determined in relation to a preselected standard level (for example, the lowest tidal level at low tide). Namely, let's now suppose that, in Figure 1, numerals 4, 14 and 15 indicate the present sea level, the lowest tidal level and the intended excavation-finished surface, respectively. The target excavation depth is therefore a depth h_0 as depicted in the drawing. Accordingly, it is always required to know ,as the present depth of excavation, the distance h between the lowest tidal level 14 and the present excavation-finished floor 13 and then to compare the depth h with the above-described target excavation depth h_0. However, the tidal level varies moment by moment. Such a change may reach as much as 1 m - 2 m where the tidal level undergoes a great variation. At such a place, it is readily understood that the height Δh of the sea level 4 from the lowest tidal level 14 changes continually in a range which is significantly wider than the tolerance range mentioned above as to the accuracy of excavation. The above method requires to observe the depth h_1 from this changing sea level 4 to the excavation-finished floor 13. The above prior method can thus not be adopted for the above-mentioned second reason too.

The following means is employed to determine the excavated depth h between the lowest tidal level 14 and the excavation-finished floor 13 while overcoming such drawbacks as mentioned above. Namely, a worker who is different from the backhoe operator measures the depth h_1 by providing a weight (lead) with a graded fishing line and lowering the fishing line until the weight reaches the excavation-finished floor 13. He then obtains a tidal level at that particular time point from a tide table so that the depth Δh is determined. Thereafter, he subtracts the depth Δh from the depth h_1 so as to determine whether the resulting value h has reached the target excavation depth h_0. However, this method requires not only a great deal of time but also an additional worker for the measurement. Besides, the above method is accompanied by another drawback that the accuracy of measurement is low due to slack of the fishing line and the like. Furthermore, it has also been proposed, as a method for knowing the tidal level at each specific time point without involving the above-mentioned cumbersome of referring to the tide table, to provide a float-type tide indicator on a quay, to convert each measurement result of the tide indicator into an electric signal, to transmit the signal by means of an FM transmitter, and then to receive the signal by a receiver installed on the pontoon 5 so that the operator can know the tidal level. This method is disclosed in "WORLD DREDGING & MARINE CONSTRUCTION", March, 34(1978). The facilities required in the above method are however very costly. Moreover, almost no contribution will be made to the solution of the above-mentioned drawbacks even if this method is employed.

Let's now explain certain problems which may be developed by the above-mentioned low measurement accuracy. It is obviously difficult to achieve an excavation satisfying the above-mentioned accuracy (10 cm - 30 cm), which is required as to the target excavation depth, when the excavation accuracy is low. Besides, the following problems will be raised. When excavating a sea floor or navigation route near a quay, it is, generally speaking, extremely dangerous to excavate the sea floor or the navigation route beyond a prescribed excavation depth because such a deep excavation may destroy the foundation of the quay or walls formed in the sea floor. If the excavation should proceed beyond the target excavation depth, it is therefore necessary to bury back such an over-excavated portion. However, such a reburying work requires tremendous man power and time, which are incomparably greater than those required in a reburying work on land, because the over-excavated portions has to be detected precisely, and the reburying gravel must be excavated on land, transported to the shore, reloaded on a ship or barge and then carried to the over-excavated site. Therefore, it is absolutely necessary to avoid the development of such a reburying-indispensable situation as feasible as possible. However, the possibility of developing such a reburying-indispensable situation becomes very high so long as the measurement accuracy remains low as mentioned above.

The present invention has been completed with the foregoing in consideration. An object of this invention is therefore to overcome the drawbacks of the above-described prior art techniques and to provide a dredging excavator which permits the prompt and accurate determination of the excavated depth from a standard level to a present excavation-finished floor and facilitates the excavation to a target depth on the basis of the thus-determined excavated depth.

In one aspect of this invention, there is thus provided a dredging excavator which comprises:

a pontoon;

an excavating mechanism mounted on the pontoon and adapted to excavate the bottom of the water;

computing means adapted to compute the depth from the water level to a digging point on the bottom of the water;

means to determine a tidal level at the excavation site on the basis of data which have in advance been obtained;

correction means for correcting a value, which has been obtained by the computing means, on the basis of a tidal level obtained by the tidal level determining means; and

output means to output a value corrected by the correction means.

The dredging excavator of this invention is equipped with the computing means adapted to compute an excavated depth and means to obtain a tidal level at the excavation site, whereby to correct the excavated depth in accordance with the tidal level and to output the thus-corrected value. Therefore, the dredging excavator permits the prompt and accurate determination of the excavated depth from the standard level to the present excavation-finished floor and facilitates the excavation to the intended depth on the basis of the thus-determined value.

The above and other objects, features and advantages of the present invention will become apparent from the following description and the appended claims, taken in conjunction with the accompanying drawings, in which:

Figure 1 is a side view showing the outline structure of a hydraulic backhoe ship;

Figure 2 is a block diagram for describing anexcavated-depth computing unit of a hydraulic backhoe ship according to one embodiment of this invention;

Figure 3 is a block diagram of an excavated-depth display and control unit of a hydraulic backhoe ship according to the first embodiment of this invention;

Figure 4 is a system diagram of a boom cylinder control unit of a hydraulic backhoe ship according to the second embodiment of this invention;

Figure 5 is a block diagram of an excavated-depth display and control unit of a hydraulic backhoe ship according to the third embodiment of this invention;

Figure 6 is a diagram of a cosine function stored in tidal-level computing means in the display and control unit depicted in Figure 5;

Figure 7 is a block diagram of the tidal-level computing means in the display and control unit depicted in Figure 5;

Figure 8 is a block diagram of excavated-depth computing means in the display and control unit depicted in Figure 5;

Figure 9 is a block diagram of an excavated-depth display and control unit of a hydraulic backhoe ship according to the fourth embodiment of this invention;

Figure 10 is a diagram illustrating an operation at tidal-level computing means in the display and control unit shown in Figure 9; and

Figure 11 is a block diagram of a specific example of tidal-level computing means in the display and control unit depicted in Figure 9.

The present invention will hereinafter be described on the basis of its embodiments depicted in the accompanying drawings.

Prior to describing each of the embodiments, an operation which is to be performed in each of these embodiments will be described with reference to Figure 2, in which the same reference numerals and characters identify the same elements of structure as those employed in Figure 1. In the drawing, there are shown the fulcrum A of the boom 7 supported on the swivel cab 6, the fulcrum B of the arm 8 supported on the boom 7, the fulcrum C of the bucket 9 supported on the arm 8 and the leading edge D of the bucket 9. There are also shown the length ℓ_1 of a line A-B, the length ℓ_2 of a line B-C, the length ℓ_3 of the line C-D, the angle α between a vertical line and the line A-B, the angle β between the line A-B and the line B-C and the angle γ between the line B-C and the line C-D. Furthermore, h_0, h, h_1 and Δh mean the depth between the lowest tidal level 14 and the target excavation-finished floor, the depth between the lowest tidal level 14 and the present excavation-finished floor 13, the depth between the sea level 4 and the present excavation-finished floor 13 and the height of the tide between the sea level 4 and the lowest tidal level 14, respectively. These depths are the same as their corresponding depths depicted in Figure 1. Designated at

h_2 is a distance between the sea level 4 and the fulcrum A.

Setting each of the dimensions in the above manner, the excavated depth h_1 from the sea level 4 is expressed by the following equation:

$$h_1 = \ell_1 \cos\alpha - \ell_2 \cos(\alpha + \beta) + \ell_3 \cos(\alpha + \beta + \gamma) - h_2 \quad \ldots (1)$$

Since the lengths ℓ_1, ℓ_2 and ℓ_3 and the distance h_2 have already been known, the excavated depth h_1 from the sea level 4 to the excavation-finished floor 13 can be determined when one detects the relative angles α, β and γ by suitable angle detector and performs an operation in accordance with Equation (1). Here, it is assumed that the draft of the pontoon 5, namely, the distance h_2 remains constant at any time point of measurement. By the way, the excavation depth which is to always to be compared with the target excavation depth h_0 is the depth h between the lowest tidal level 14 and the present excavation-finished floor 13. This depth h is a value obtained by subtracting the height Δh of the tidal level from the excavated depth h_1 which is a distance from the sea level 4 and has been obtained in accordance with Equation (1), namely, is given by the following equation:

$$h = h_1 - \Delta h \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Therefore, the depth of each excavation can be controlled by always precisely knowing the excavation depth h and governing the excavation so as to allow the excavation depth h to reach the target excavation depth h_0.

Reference is now made to Figure 3, in which there are illustrated angle detectors 16,17,18 provided at desired locations of the excavating mechanism and adapted to measure angles α, β and γ and output signals E_α,E_β,E_γ in accordance with the angles, a computing and controlling unit 19 composed of a microcomputer or the like and adapted to perform prescribed operations and controls, a clock counter 20 adapted to generate an output counted at each prescribed time point, a memory unit 21 adapted to store tidal levels, and a display unit 22 adapted to display a signal E_h corresponding to the excavated depth h computed at the computing and controlling unit 19. The clock counter 20 is equipped for example with a standard clock-pulse generator. It counts down clock pulses so as to count signals once every hour and outputs the count number (the elapsed time). In the memory unit 21, there is stored an hourly tide table for a harbor, where the hydraulic backhoe ship is operated, after a desired day.

In such a constitution as mentioned above, the clock counter 20 is actuated to start the counting when it has reached the desired day. A digital signal corresponding the initial count "0" is output from the clock counter 20 to the computing and controlling unit 19. At the computing and controlling unit 19, a value (for example, a numeral 0.1) which has been stored at an address corresponding to the count "0" is withdrawn from the memory unit 21. This value is the tidal level Δh to be corrected. One hour later, the clock counter 20 output a count "1" and a value (e.g., a tidal level 0.25) stored at an address corresponding to the count "1" is withdrawn from the memory unit 21. Upon an elapsed time of further one hour, the clock counter 20 outputs a count "2" and a value (for example, a tidal level 0.5) stored at an address corresponding to the count "2" is withdrawn from the memory unit 21. Thereafter, the same operation is repeated.

Here, the power supply of the computing and controlling unit 19 may be turned on to actuate the computing and controlling unit 19 when the excavation work by the hydraulic backhoe ship is started. On the other hand, the clock counter 20 continues its counting operation irrelevant to the computing and controlling unit 19 and outputs a count corresponding to the present day and time. In order to perform such an operation, a backup-type clock counter may be used as the clock counter 20.

When the power supply of the computing and controlling unit 19 is turned on upon initiation of the excavation work by the hydraulic backhoe ship, the computing and controlling unit 19 receives the signals E_α ,E_β,E_γ corresponding to the angles α,β,γ from the angle detectors 16,17,18 and then computes the depth h_1 in accordance with the above-described equation. Then, based on an output signal of the clock counter 20, the signal $E_{\Delta h}$ corresponding to the tidal level Δh at the present time point is obtained from the memory unit 21. The thus-obtained tidal level Δh is thereafter subtracted from the above-computed depth h_1 so as to obtain the corrected excavated depth h. The thus-determined depth h is output to the display unit 22, so that a value corresponding to the depth is displayed there. The operator of the hydraulic backhoe ship can proceed with the excavation work while watching values h to be displayed, whereby allowing him to control the depth of excavation without failure.

By the way, it is also possible to design the clock counter in such a way that its power supply is not turned off and to assemble it in the computing and controlling unit 19. Furthermore, the time interval of the tide table stored in the memory unit may be set at a time interval other than one hour. If one wants to improve the accuracy of the tidal level, which is used in an operation, by using a time interval shorter than that of an actually-available tide table, the following linear correction may be carried out. Namely, supposing that the tidal levels at a given time point t_1 and the next time point t_2 be respectively Δh_1 and Δh_2 in an obtained tide table, the tidal level

Δh at a time point between the time points is given by the following equation so as to perform a correction.

$$\Delta h = \Delta h_1 + \frac{t - t_1}{t_2 - t_1}(\Delta h_2 - \Delta h_1)$$

In addition, it should be borne in mind that each display at the displaying unit is not necessarily limited to a corrected excavated depth but may show a remaining depth to be excavated. In this case, the remaining depth to be excavated can be displayed if the target excavation depth is preset and the display unit is provided with means to subtract the corrected excavated depth from the preset value. Furthermore, it is also possible to provide an alarm device either in combination with the display unit or separately so that a warning sound may be produced when the remaining depth of excavation has reached 0 (zero).

In the above embodiment, hourly tidal levels at the working site of the hydraulic backhoe ship are stored in advance. The tidal level at the present time, which has been determined by the clock counter, is withdrawn so that the depth excavated from the sea level - which depth has been obtained as a result of an operation - may be corrected by the tidal level. The thus-corrected value, namely, the excavated depth form the lowest tidal level to the excavation-finished floor is always displayed. Accordingly, the hydraulic backhoe ship can determine, without need for any extra man power, the excavated depth from the lowest tidal level to the excavation-finished floor promptly and precisely. The operator of the hydraulic backhoe ship is thus allowed to complete readily the excavation to the target excavation depth while watching the display. The work efficiency has also been improved because the excavation work is not interrupted by measurement of each excavated depth.

Reference will next be made to Figure 4, in which the same numerals and characters designate the same elements of structure as those employed in Figure 3. Such elements of structure will not be described here for the sake of simplicity. Designated at numeral 19a is a computing and controlling unit which is composed of a micro-computer or the like and is adapted to perform prescribed operations and controls. The computing and controlling unit 19a is equipped with comparator means in which a target depth h_0 has been stored as a preset value. There are also illustrated a hydraulic pump P_1 adapted to drive the boom cylinder 10, a directional control valve 23 interposed between the boom cylinder 10 and hydraulic pump P_1 so as to control the actuation of the boom cylinder 10, an auxiliary hydraulic pump P_2, pilot valves 25a,25b, an operation level 26 adapted to switch over the pilot valves 25a,25b, and a pilot circuit 27 adapted to communicate the working oil from the auxiliary hydraulic pump P_2 to the directional control valve 23. Figure 4 also shows a pilot-operated directional control valve 28 incorporated in the pilot circuit 27 and connecting the pilot valve 25a with one (the right-hand one as seen in the drawing) of the pilot ports of the directional control valve 23, and a switch 29 incorporated in an electric circuit between an electromagnetic solenoid of the pilot-operated directional control valve 28 and the power supply 30. The switch 29 is ON-OFF controlled by signals output from the computing and controlling unit 19a.

Operation of the above embodiment will next be described. When the power supply of the computing and controlling unit 19a is turned on upon initiation of an excavation work by the hydraulic backhoe ship, the computing and controlling unit 19a receives the signals E_α ,E_β,E_γ corresponding to the angles α,β,γ respectively from the angle detectors 16,17,18 and then computes the depth h_1 in accordance with the above-described equation (1). Then, based on a signal output from the clock counter 20, the signal $E_{\Delta h}$ corresponding to the tidal level Δh at the present time point is taken out from the memory unit 21. Thereafter, the thus-obtained tidal level Δh is subtracted from the above-computed depth h_1 so as to determine a corrected excavated depth h. The thus-determined depth h is next compared with the preset target depth h_0 of excavation. When the comparison result indicates that the thus-corrected depth h is shallower than the target depth h_0 of excavation, in other words, when $h < h_0$, no signal will be output from the computing and controlling unit 19a so as to keep the switch 29 in an opened state. When the corrected depth h is equal to or deeper than the target depth h_0 of excavation on the other hand, in other words, when $h \geq h_0$, the computing and controlling unit 19a outputs a signal so as to close the switch 29.

When $h < h_0$, the switch 29 is kept open and the pilot-operated directional control valve 28 is thus kept unactuated and remains in the illustrated position. Therefore, the operator of the hydraulic backhoe ship can cause the boom cylinder 10 to expand and contract repeatedly by way of the directional control valve 23 by operating the operation lever 26 and switching over the pilot valves 25a,25b, whereby permitting free excavation.

When $h \geq h_0$ on the other hand, the switch 29 is closed and the pilot-operated directional control valve 28 is correspondingly switched over. Accordingly, the pilot valve 25a is disconnected from the pilot circuit 27 which is connected to the right-hand (as seen in Figure 4) pilot port of the directional control valve 23. The pilot circuit 27 is in turn connected to the reservoir. Even if the operator of the hydraulic backhoe ship operates the operation lever 26 to switch over the pilot valve 25a in the above state, the directional control valve 23 cannot be switched to the right-hand position as seen in the drawing. As readily envisaged from the drawing, the switching of the directional control valve 23 to the right-hand position connects the hydraulic pump P_1 to the rod-side compartment of the boom cylinder 10 and the bottom-side compartment of the same boom cylinder 10 to the reservoir, thereby actuating the boom cylinder 10 in the contracting direction and thus lowering the boom 7. The thus-lowered boom 7 enables to excavate a still deeper sea floor. By the way, it becomes absolutely impossible, as mentioned above, to switch the directional control valve 23 to the right-hand position once the pilot-operated directional control valve 28 has been actuated, thereby making it impossible to lower the boom 7 any further. In other words, the depthwise movement of the boom 7 is restrained and any further excavation is hence avoided when the present excavation-finished floor 13 has reached the target excavation-finished floor 15. If the operator wants to excavate a place closer to the hydraulic backhoe ship, he is required to withdraw the arm 8 toward the hydraulic backhoe ship and then to raise the leading edge of the bucket 9. This operation establishes the situation $h < h_0$ and cause the pilot-operated directional control valve 28 to regain its original position, thereby permitting a further lowering of the boom 7. Thus, the excavation can be carried out by the so-lowered boom 7 when such a closer place has not reached the depth h_0.

Similar to the preceding embodiment, it is also possible to build the clock counter in the computing and controlling unit by making its power supply free from turning-off, to suitably set the time interval of the tide table to be stored, and in this case to employ the linear correction method.

In the above embodiment, hourly tidal levels at the working site of the hydraulic backhoe ship are stored in advance. The tidal level at the present time point, which has been determined by the clock counter, is obtained, whereby correcting the excavated depth from the sea level which depth has been obtained by an operation. Then, the thus-corrected value, namely, the excavated depth from the lowest tidal level to the excavation-finished floor is always compared with the target depth of excavation. When the former depth has become equal to or greater than the latter depth, the boom is restrained from moving in the depthwise direction. Accordingly, the above hydraulic backhoe ship permits prompt and precise determination of the excavated depth from the lowest tidal level to the excavation-fished floor without need for any extra man power and at the same time, can avoid any excavation beyond the target depth of excavation and thus possible need for reburying work, thereby facilitating excavation work to a prescribed depth. In addition, the above hydraulic backhoe ship can improve the work efficiency because the excavation work is not interrupted by measurement of excavated depths. Furthermore, the operator of the hydraulic backhoe ship is not required to exercise any special attention as to the depth of excavation. His fatigue can thus be reduced to a significantly low level in this connection.

The third embodiment of this invention will hereinafter be described with reference to Figure 5. Numeral 36 indicates a tidal level computing unit adapted to compute a tidal level Δh at a given time point on the basis of a prescribed function (which will be described later). The tidal level computing unit 36 outputs a signal $E_{\Delta h}$ corresponding to the thus-computed tidal level Δh. Numeral 37 indicates an excavated-depth computing unit which receive the signals $E_\alpha, E_\beta, E_\gamma$ corresponding to the boom angle α, arm angle β and bucket angle γ depicted in Figure 2 and the signal $E_{\Delta h}$ and computes the excavated depth h in accordance with the equations (1) and (2). The excavated-depth computing unit 37 outputs a signal E_h corresponding to the thus-computed excavated depth h. By the way, the angles α, β, γ are detected respectively by the angle detectors 16,17,18. The angle detectors 16,17,18 output the signals $E_\alpha, E_\beta, E_\gamma$ which correspond respectively to the angels α, β, γ. Designated at numeral 38 is a display device, which receives the signal E_h from the excavated-depth computing unit 37 and then displays the excavated depth h.

In the above embodiment, the value Δh in the equation (2) is obtained by an operation at the tidal level computing unit 36 in accordance with a predetermined function without relying upon any tide table. A function useful in obtaining the value Δh will hereinafter be described with reference to Figure 6. In this embodiment, variations in tidal level are handled approximately as a cosine function. In Figure 6, the tidal level Δh is plotted along the vertical axis whereas the time t is plotted along the horizontal axis. The tidal level Δh is set at 0 when it is at low tide (i.e., at the lowest tidal level) and is set at H when it is at the highest tidal level. As the cosine function, a single period of from a lowest tidal level to the next lowest tidal level is stored as shown in the drawing. Let's now suppose that the time from the former lowest tidal level to the latter tidal level be t_0. Tidal level Δh is then given by the following equation:

$$\Delta h = \frac{H}{2} \cos\left(\frac{t}{t_0} \times 360^\circ - 180^\circ\right) + \frac{H}{2} \quad \ldots\ldots\ldots\ldots (3)$$

When variations in tidal level are expressed in terms of a cosine function in the above-described manner, it is necessary to use a certain time point T as a standard time point and then to express a given time point as an elapsed time from the certain time point T if one wants to determine a tidal level Δh at the given time point in accordance with the equation (3). Supposing now that the given time point, the time elapsed from the time point T to the given time point and the time elapsed from a lowest tidal level to the time point T (the time point at the lowest tidal level can be known from a tide table for the excavation site) be T', t_2 and t_1 respectively, the tidal level Δh at the time point T' can be expressed by the following equation:

$$\Delta h = \frac{H}{2} \cos\left(\frac{t_1 + t_2}{t_0} \times 360^\circ - 180^\circ\right) + \frac{H}{2} \quad \ldots\ldots\ldots\ldots (5)$$

Specific examples of the tidal level computing unit 36 and excavated-depth computing unit 37 will next be described with reference to Figure 7 and Figure 8. In Figure 7, numeral 40 indicates a starting-time signal setting unit. A time interval t_1 from a time point at which the tidal-level computing unit has been actuated (which corresponds to the time point T shown in Figure 6) to another time point at which the tidal level is lowest is set at the starting-time signal setting unit 40. The starting-time signal setting unit 40 generates a signal E_{t1} in response to the time point t_1. Numeral 41 indicates an amplitude signal setting unit which sets the value H/2 in the equation (4) and generates a signal $E_{H/2}$ corresponding to the value H/2. Designated at numeral 42 is an elapsed-time signal generator which outputs a signal E_{t2} corresponding to the time t_2 elapsed after the time point set by the starting-time signal setting unit 40.

The signals E_{t1} and E_{t2} are summed up at an adder 43 into a signal $E_{t1 + t2}$. The signal $E_{t1 + t2}$ is multiplied with a coefficient $360/t_0$ at a coefficient multiplier 46. A signal obtained for an angle 180° from a memory 45 is then subtracted from the thus-multiplied signal at a subtracter 46, thereby obtaining a signal $E_{\frac{t_1+t_2}{t_0}x360-180}$. This signal is then converted at a trigonometric function generator 47 to a signal $E_{\cos(\frac{t_1+t_2}{t_0}x360-180)}$ corresponding to the cosine of the angle $(\frac{t_1+t_2}{t_0}x360 - 180)^\circ$. Thereafter, an output $E_{H/2}$ from an amplitude signal generator 41 is multiplied at a multiplier 48, followed by an addition of a signal $E_{H/2}$ at an adder 49 to obtain a signal $E_{H/2\cos(\frac{t_1+t_2}{t_0}x360-180)} + \frac{H}{2}$, namely, a signal $E_{\Delta h}$ corresponding to the tidal level at that time point.

The specific example of the excavated-depth computing unit will next be described with reference of the block diagram of Figure 8. The boom angle signal E_α is converted to a signal $E_{\cos\alpha}$ corresponding to the cosine of the angle α at a trigonometric function generator 50, to which a coefficient $K_{\ell 1}$ corresponding to the length ℓ_1 between the fulcrum A and fulcrum B is multiplied at a coefficient multiplier 51 to obtain a signal $E_{\ell 1 \cos \alpha}$. The arm angle signal E is added with the signal E_α at an adder 32. The resulting signal is then converted at a trigonometric function generator 53 to a signal $E_{\cos(\alpha + \beta)}$ which corresponds to the cosine of the angle $(\alpha + \beta)$, to which a coefficient $K_{\ell 2}$ corresponding to the length ℓ_2 between the fulcrum B and fulcrum C is multiplied at a coefficient multiplier 54. From a subtracter 54, there is generated a signal $E_{\ell_1 \cos \alpha - \ell_2 \cos(\alpha + \beta)}$ as a result of subtraction of the output signal from the coefficient multiplier 54 from the output signal from the coefficient multiplier 51. The bucket angle signal E_γ is added with the output signal from the adder 52 at an adder 56, followed by its conversion at a trigonometric function generator 57 to a signal $E_{\cos(\alpha + \beta + \gamma)}$ corresponding to the cosine of the angle $(\alpha + \beta + \gamma)$. To the resulting signal, a coefficient $K_{\ell 3}$ corresponding to the length ℓ_3 between the fulcrum C and the leading edge D is multiplied at a coefficient multiplier 58. The output signal from the adder 55 and that obtained from the coefficient multiplier 58 are added together at an adder 59. Then, a signal corresponding to the depth h_2 from a memory

61 is subtracted at a subtracter 60. From the thus-obtained signal, the output signal $E_{\Delta h}$ from the tidal-level computing unit 36 is further subtracted at a subtracter 62 to obtain a signal:

$$E_{\ell_1\cos\alpha - \ell_2\cos(\alpha+\beta+\gamma) + \ell_3\cos(\alpha+\beta+\gamma) - h_2 - \Delta h}$$

namely, a signal E_h corresponding to the excavated depth h. This signal E_h is then input to the display device 38 as illustrated in Figure 5. The display device 38 then displays the excavated depth h.

By the way, the operator of the hydraulic backhoe ship inputs, at a suitable time point preceding the initiation of an excavation, the time point to the starting-time signal setting unit 40 of the tidal-level computing unit 36. Since the time point of the lowest tidal level at the work site has already been known from a tide table, the starting-time signal setting unit 40 outputs the time t_1 from the lowest tidal level to the preset time point. Thereafter, time t_2 elapsed from the preset time point is output from the elapsed-time signal generator 42. On the other hand, time $(t_1 + t_2)$ passed after the lowest tidal level is output from the adder 43. The operator of the hydraulic backhoe ship also adjusts the amplitude signal setting unit 41 so as to preset the amplitude H/2, thereby outputting the signal $E_{H/2}$. In this case, the difference H between the lowest tidal level and the highest tidal level has already been known for each working site. As has been described above, the operator can automatically compute and display excavated depths h, which have been corrected by their corresponding tidal levels, at the display device 38 only by adjusting the starting-time signal setting unit 40 and amplitude signal setting unit 41 prior to starting the excavation work. Since this display device 38 is provided at a location which is readily visible by the operator, the operator can proceed with the excavation work while watching excavated depths h displayed on the display device 38.

Since displayed excavated depths h have been computed in accordance with a predetermined operation and have been corrected in view of their corresponding tidal levels, the operator can obtain accurate values as to excavated depths. The operator is not required to do anything for obtaining excavated depths h so long as he sets only the time point and amplitude at the beginning. The work efficiency can be improved to a considerable extent. When a target depth of excavation is given as being equal to or deeper than the depth h_0, each excavated depth h can be displayed correctly. It is thus possible to minimize the volume to be over-excavated (i.e., the over-excavated volume), thereby making it possible to save the labor, time and cost.

The variation of tidal level changes slightly day by day. Thus, the time point of the lowest tidal level also changes slightly day after day. Accordingly, no error would be produced as to excavated depths h so long as the time point of the lowest tidal level is adjusted once every several days in the course of each excavation work. As the cosine function to be stored in the trigonometric function generator 47, it is possible to choose not only the single period of from a lowest tidal level to the next lowest tidal level but also many other functions such as the single period of from a highest tidal level to the next highest tidal level, the single period of from a lowest tidal level to the second next lowest tidal level and so on. When the hydraulic backhoe ship is used at a plurality of working sites and the amplitude change to a small extent from one working site to another, it is unnecessary to adjust the amplitude signal generator.

In the above description of each of the above embodiments, a cosine function was used approximately as variations in tidal level. It should however be borne in mind that suitable other functions may also be used without limiting to cosine functions.

When a river floor is excavated instead of sea floor, it is possible to display excavated depths, which have in advance been corrected in accordance with water levels changed by rainfalls, if one sets only the amplitude suitably in accordance with rainfalls at locations upstream the working site. Accordingly, the above-exemplified hydraulic backhoe ships may also be used to excavate river floors.

Furthermore, the tidal-level computing unit and excavated-depth computing unit may also be composed of a micro-computer instead of the analog-type computing unit employed in the above embodiments.

In addition, it is not necessary to limit the display of the display device to the display of excavated depths. The display device may show remaining depths to be excavated. In this case, such remaining depths to be excavated may be displayed provided that the display device is additionally provided with means adapted to store a target excavation depth and to subtract each corrected excavated depth from the target excavation depth. It is also possible to provide an alarm device either in combination with the display device or separately from the display device so that a warning sound can be produced when the remaining depth of excavation has reached 0.

In the above embodiment, an excavated depth corrected in view of its corresponding tidal level is computed by means of the tidal level computing unit and excavated -depth computing unit, and it is then displayed. Therefore, the above hydraulic backhoe ship can determine excavated depths promptly and precisely without need for any extra man power. The thus-determined excavated depths are then displayed to the operator, whereby facilitating the excavation work. Furthermore, the operator is not required to spend any time for measuring excavated depths. The work efficiency has hence been improved. Since excavated depths can be displayed accurately, it is possible to minimize over-excavated volumes. In addition, variations in tidal level are stored as a cosine function, it is possible to use the hydraulic backhoe ship according to this embodiment in almost all working sites without need for any large memory capacity.

Reference will next be made to Figure 9, in which the excavated-depth display and control unit of the hydraulic backhoe ship according to the fourth embodiment of this invention is illustrated in the form of a block diagram. In the drawing, the same numerals and characters designate the same elements of structure as those employed in Figure 5. Explanation of such elements is thus omitted. Numeral 36a indicates a tidal level computing unit adapted to compute a tidal level h at a given time point on the basis of a predetermined function (which will be described later). The tidal level computing unit 36a outputs a signal $E_{\Delta h}$ corresponding to the thus-computed tidal level Δh. The fourth embodiment is different from the third embodiment in that the fourth embodiment makes use of a different function as a basis for operations at the tidal level computing unit and the structure of its tidal level computing unit is hence different from that employed in the third embodiment.

As mentioned above, variations in tidal level change in accordance with place, time, etc. In many instances, it is possible to compute tidal levels by using such a cosine function as described in the third embodiment. Where still more accurate tidal levels are required or the variations in tidal level change from one period to another, such cosine functions as mentioned above may not be sufficient to compute tidal levels. This embodiment makes use of another cosine function which is capable to approximate tidal levels more precisely in such cases as mentioned above. Namely, the following approximation is used from a lowest tidal level to the next highest tidal level or from a highest tidal level to the next lowest tidal level.

$$h_x = \frac{1}{2}(h_1 + h_2) + \frac{1}{2}(h_1 - h_4)\cdot\cos(180^\circ \times \frac{T_x - T_1}{T_2 - T_1}) \quad \ldots(5)$$

The various parameters in the above approximation (5) will next be described with reference to the diagram shown in Figure 10. Namely, the curve F in Figure 10 is a curve representing variations in tidal level. Time t is plotted along the horizontal axis, whereas the depth from a standard plane in the sea floor to the sea level is plotted along the vertical axis. Any plane may be chosen as the standard plane. For example, an intended excavated floor may be chosen as the standard plane. h_0 indicates a tidal plane which serves as a standard for the target depth of excavation. The tidal level lowest in the year may be chosen as h_o. T_1 is the time at low tide immediately before the excavation. h_1 is the depth from the standard plane at that time. T_2 is the time at high tide immediately after the excavation. h_2 is the depth from the standard plane at that time. T_x means a time point at which one wants to determine the tidal level. h_x is the depth from the standard plane at that time. By the way, the times T_1,T_2 and depths h_1,h_2 can be obtained from the tide table.

Next, a specific example of the tidal level computing unit 36a of the above embodiment will be described with reference to Figure 11, which is a block diagram showing the specific example of the tidal level computing unit depicted in Figure 9. In Figure 11, there are illustrated setting units 65,66 adapted to set the depths h_1,h_2 respectively, setting units 67,68 for setting the times T_2,T_1 respectively, a setting unit 69 at which time points are set one after another with a predetermined interval, and a setting unit 70 adapted to set the depth h_0. Numeral 71 designates an adder for adding signals E_{h1},E_{h2} corresponding respectively to the depths h_1,h_2 set in the setting units 65,66, while numeral 72 indicates a coefficient multiplier adapted to multiply each output from the adder 71 by 1/2. Designated at numeral 73 is a subtracter adapted to subtract the signal E_{h2} from the signal E_{h1}. Numeral 74 is a coefficient multiplier for multiplying each output from the subtractor 73 by 1/2. Numeral 75 is a subtracter adapted to subtract a signal E_{T2} corresponding to the time T_1 set at the setting unit 67 from a signal E_{T1} corresponding to the time T_1 set at the setting unit 68. Designated at numeral 76 is a subtracter for subtracting the signal E_{T1} from a signal E_{Tx} corresponding to a time point T_x set at the setting unit 69. Numeral 77 indicates a divider for dividing a signal E_{Tx-T1} from the subtracter 76 by a signal E_{T2-T1} from the subtracter 75. Designated at numeral 78 is a coefficient multiplier adapted to multiply each output from the divider 77 by $\pi(180^{\circ})$. Numeral 79 is a function generator which receive a signal from the coefficient multiplier 78 and then outputs a signal corresponding to the cosine of the thus-received signal. Designated at numeral 80 is a multiplier for multiplying a signal output from the coefficient multiplier 74 by a signal output from the function generator 79. Numeral 81 indicates an adder for adding a signal from the coefficient multiplier 72 to a signal from the multiplier 80. Each output of the adder 81 becomes a signal E_{hx} corresponding to the depth h_x determined by the above equation (5). Designated at numeral 82 is a subtracter adapted to a signal E_{h0} corresponding to the depth h_0 set at the setting unit 70 from the signal E_{hx} output from the adder 81. The output signal of the subtracter 82 becomes a signal $E_{\Delta h}$ corresponding to the tidal level Δh, and the signal $E_{\Delta h}$ becomes a signal to be output from the tidal level computing unit 36a.

The operator of the hydraulic backhoe ship sets, at a suitable time point prior to starting an excavation, the time point at the setting device 69 of the tidal level computing unit 36a. Thereafter, times are set one after another with a predetermined time interval at the setting device 69. Signals E_{Tx} corresponding to the thus-set time points are to be output from the setting device 69. As apparent from the graph shown in Figure 10, the present embodiment represents the relationship between a low tide (or high tide) immediately before the time point and a high tide (or low tide) immediately after the time point by the equation (5). An operation is performed in accordance with the equation (5) at the tidal level computing unit 36a depicted in Figure 11. If the setting values of the setting units 65,66,67,68 are changed again in accordance with the tide table after passing through the high tide (or low tide) period, still more accurate tidal level signals $E_{\Delta h}$ will always be output from the tidal level computing unit 36a. Accordingly, an excavated depth h which has ben corrected by the corresponding tidal level is automatically computed and displayed at the display device 38.

It is possible to make the operator unnecessary to input prescribed values to the setting devices upon passage of each high tide (or low tide) so long as a separate memory is provided, the time points of low tides and high tides and their corresponding tidal levels are stored in the memory over a desired time period in accordance with a tide table, and these values are successively set at their corresponding setting devices. By the way, the tidal level computing unit and excavated-depth computing unit may be composed of a micro-computer instead of the above-described analog-type computing device. As already mentioned in the third embodiment, the display of the display device is not limited to the display of corrected excavated depths. It may be designed to show remaining depths to be excavated. Furthermore, the display device may produce an alarm sound.

In the above embodiment, excavated depths which have been corrected by their corresponding tidal levels are calculated by the tidal level computing unit and excavated-depth computing unit and are then displayed. The above embodiment can bring about the same effects as the aforementioned third embodiment. Moreover, the fourth embodiment is able to calculate still more correct excavated depths.

By the way, the detection of the relative angles may be effected in accordance with the strokes of their corresponding cylinders instead of relying upon the angle detectors. As mentioned in the beginning of this specification, the dredging excavator of this invention may be applied not only to sea floors but also river floors. Needless to say, the present invention may be applied not only to hydraulic backhoe ships but also to simple winch-equipped grab dredge ships and the like.

Having now fully described the invention, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made thereto without departing from the spirit or scope of the invention as set forth herein.

CLAIMS

1. A dredging excavator comprising:

a pontoon (5);

an excavating mechanism (7,8,9) mounted on the pontoon and adapted to excavate the bottom of the water;

computing means (19;19a;37) adapted to compute the depth from the water level to a digging point on the bottom of the water;

means (21;36;36a) to determine a tidal level at the excavation site on the basis of data which have in advance been obtained;

correction means (62;82) for correcting a value, which has been obtained by the computing means, on the basis of a tidal level obtained by the tidal level determining means; and

output means to output a value corrected by the correction means.

2. A dredging excavator according to Claim 1, further comprising display unit (22;38) for displaying the value output from the outputting means.

3. A dredging excavator according to Claim 1, further comprising difference-computing means to compute the difference between the value output from the outputting means and an intended excavation depth as well as a display unit (22;38) for displaying a value calculated by the difference-computing means.

4. A dredging excavator according to Claim 1, further comprising a display device and/or alarm device which are/is actuated when the value output from the outputting means has reached a preset value.

5. A dredging excavator according to Claim 1, further comprising comparator means adapted to compare the value output from the outputting means with an intended excavation depth as well as preventory means (28,29,30) adapted to prevent the excavating mechanism from moving in the depthwise direction when the value output from the outputting means has exceeded the intended excavation depth.

6. A dredging excavator according to Claim 5, wherein the preventory means is stopper means adapted to stop the downward movement of the leading end of the excavating mechanism.

7. A dredging excavator according to Claim 6, wherein the stopper means is a switch-over preventory mechanism which unables to switch a directional control valve (23) of a drive cylinder (10) of a boom making up the excavating mechanism (6,7,8,9) in a direction that the drive cylinder is contracted.

8. A dredging excavator according to Claim 7, wherein the switch-over preventory mechanism is a pilot-operated directional control valve (28) connecting a pilot line (27) of the directional control valve (23) to a reservoir so that the drive cylinder is actuated in the contracting direction.

9. A dredging excavator according to Claim 1, wherein the tidal level determining means is memory means (21) adapted to store tidal levels at the excavation work site in relation with various time points.

10. A dredging excavator according to Claim 1, wherein the tidal level determining means is computing means (36;36a) adapted to compute the variation of the water level at each time point in accordance with a predetermined function.

11. A dredging excavator according to Claim 10, wherein the predetermined function is a cosine function.

FIG. 1

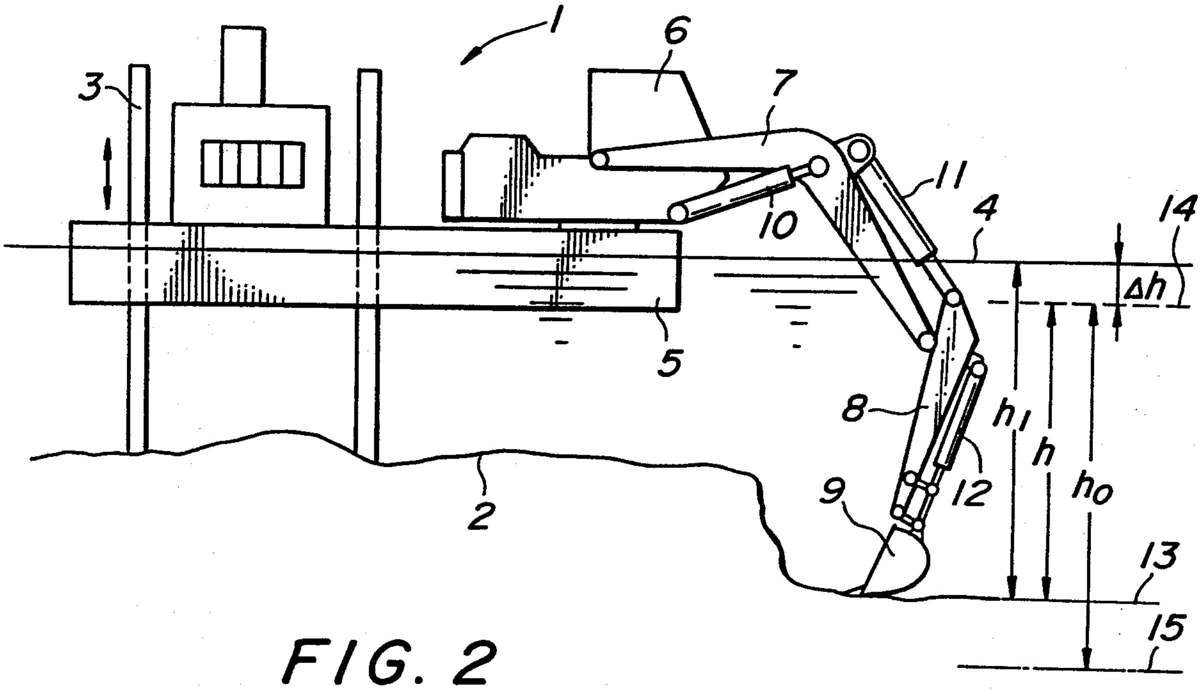

1
3
6
7
11
4
14
Δh
10
5
h1
h
h0
8
12
9
2
13
15

FIG. 2

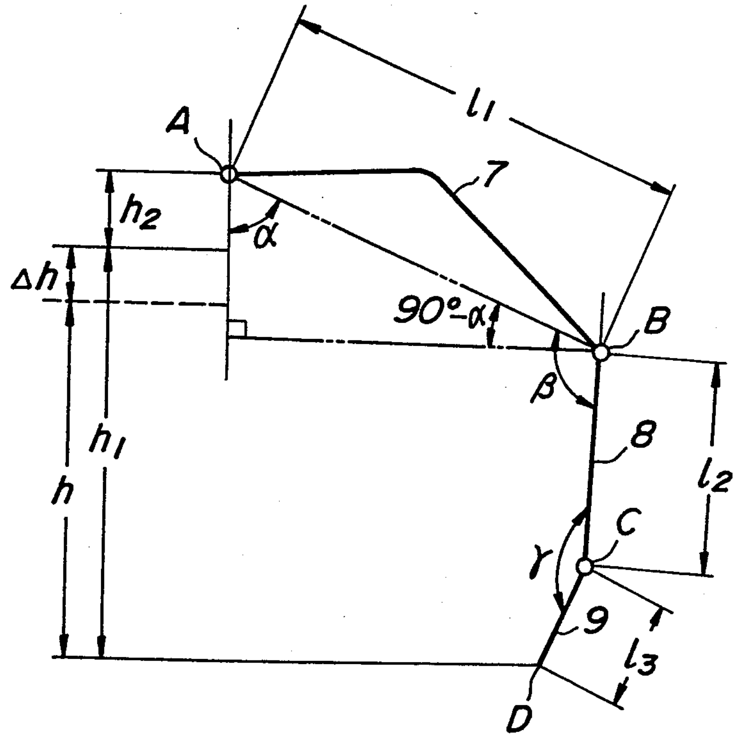

A
l1
7
h2
α
Δh
90°-α
B
β
8
h1
h
l2
C
γ
9
l3
D

FIG. 3

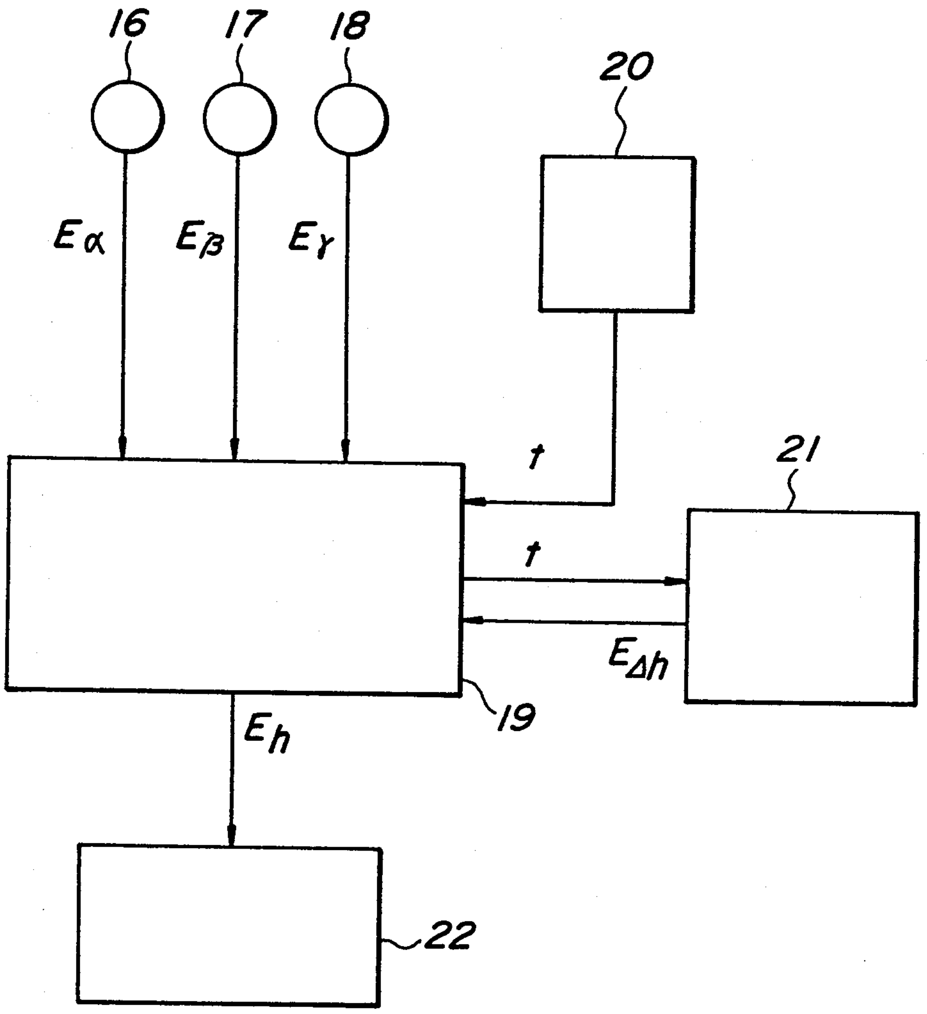


FIG. 4

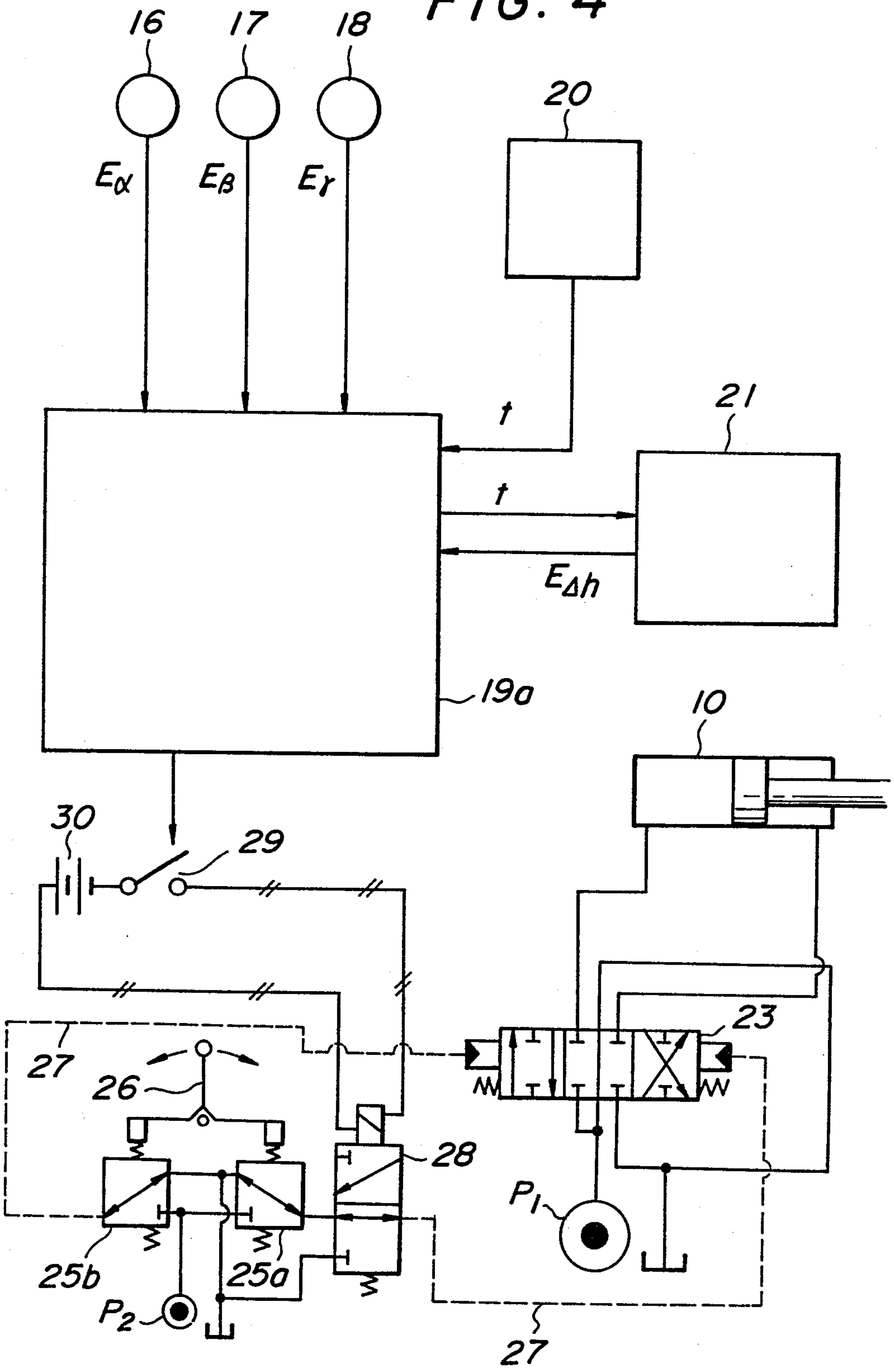

16
17
18
20
E_α
E_β
E_γ
t
21
t
$E_{\Delta h}$
19a
10
30
29
23
27
26
28
P_1
25b
25a
P_2
27

FIG. 5

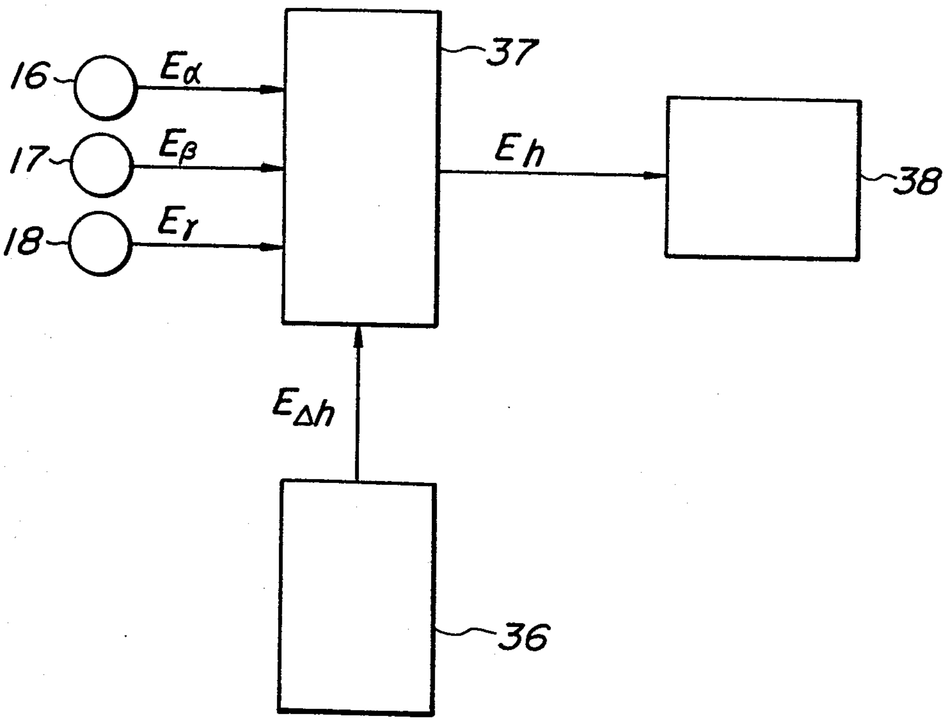

16
17
18
E_α
E_β
E_γ
37
E_h
38
$E_{\Delta h}$
36

FIG. 6

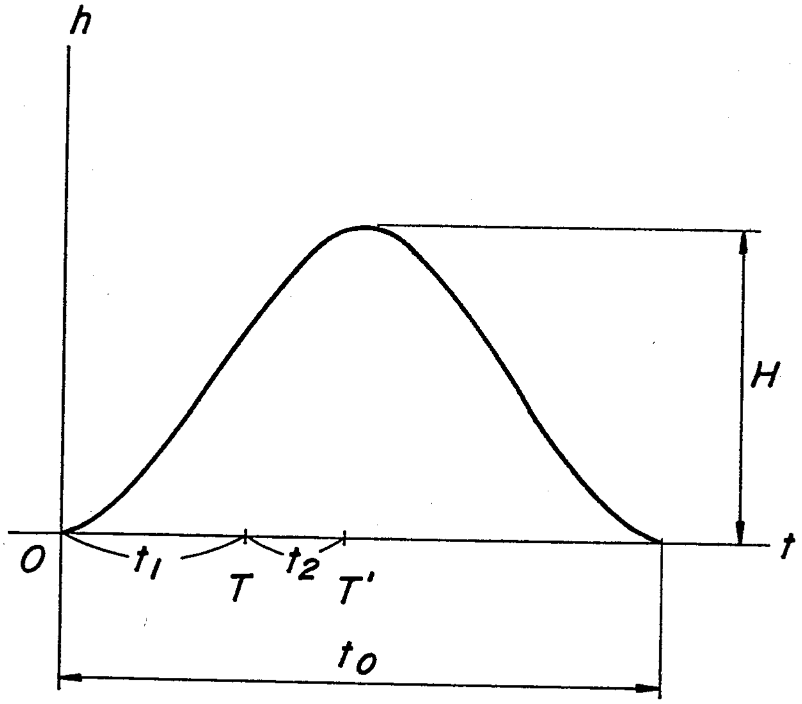

h
H
t
0
t_1
T
t_2
T'
t_0

FIG. 7

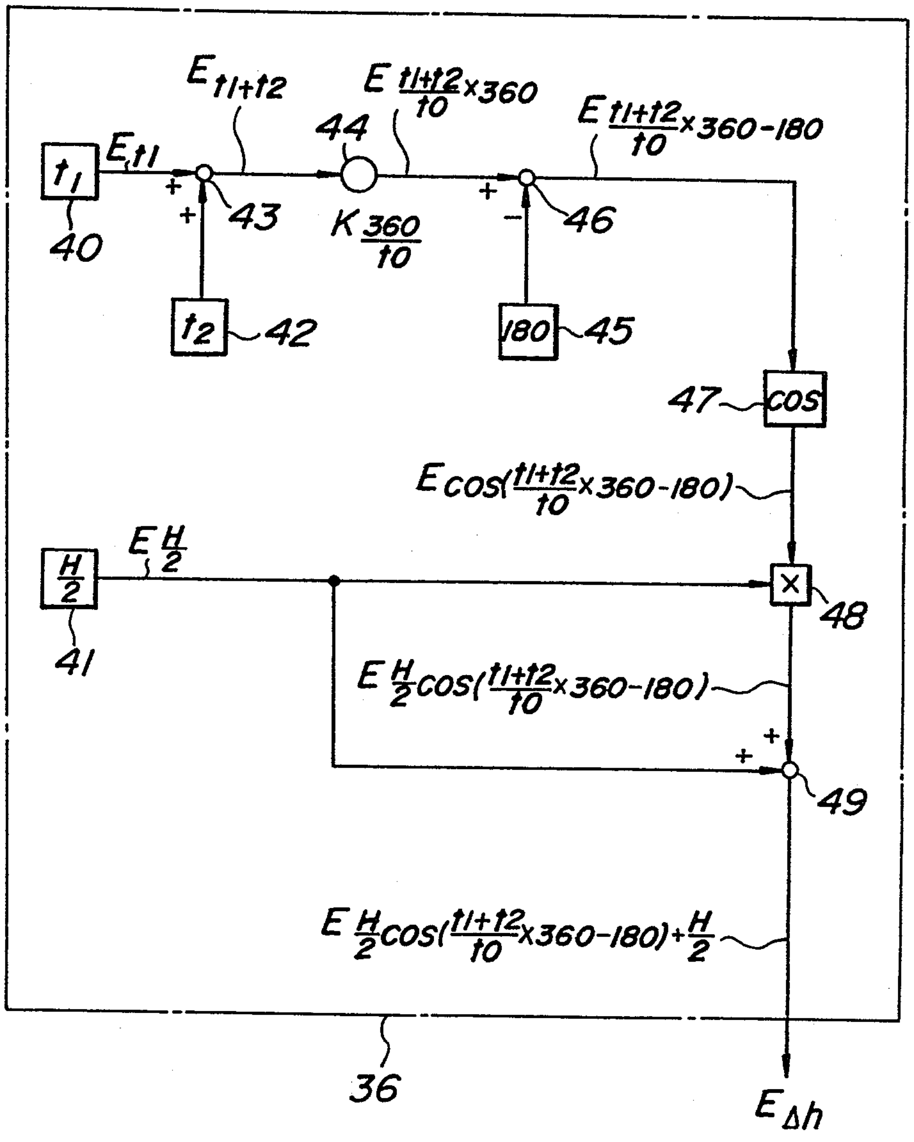

E_{t1+t2}
$E\frac{t1+t2}{t0}\times360$
$E\frac{t1+t2}{t0}\times360-180$
44
t_1
E_{t1}
+
+
43
$K\frac{360}{t0}$
+
-
46
40
t_2
42
180
45
47
cos
$E\cos(\frac{t1+t2}{t0}\times360-180)$
$E\frac{H}{2}$
$\frac{H}{2}$
×
48
41
$E\frac{H}{2}\cos(\frac{t1+t2}{t0}\times360-180)$
+
+
49
$E\frac{H}{2}\cos(\frac{t1+t2}{t0}\times360-180)+\frac{H}{2}$
36
$E_{\Delta h}$

FIG. 8

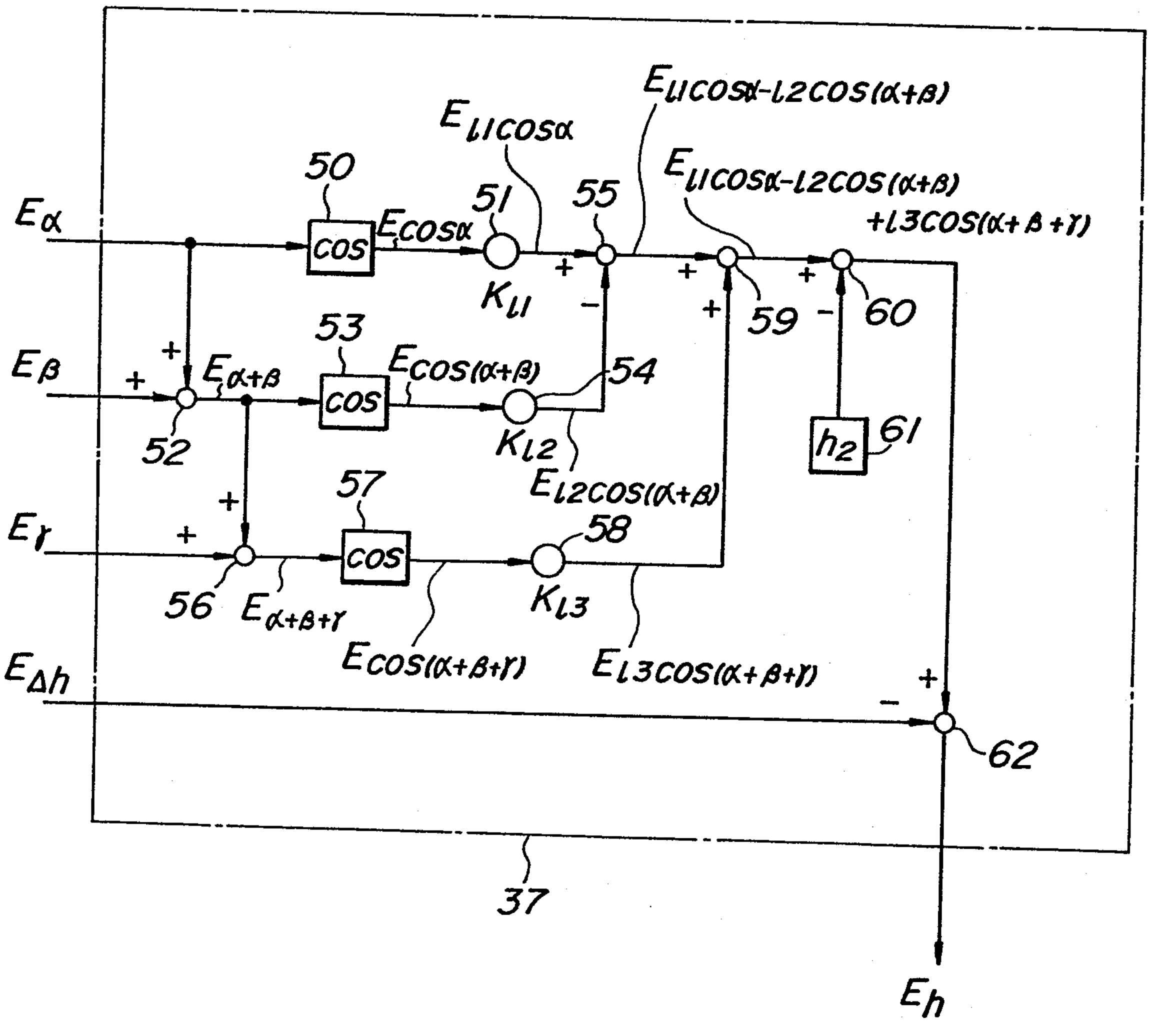

E_{α}
E_{β}
E_{γ}
$E_{\Delta h}$
50
cos
$E_{\cos\alpha}$
51
K_{l1}
$E_{l1\cos\alpha}$
55
$E_{l1\cos\alpha - l2\cos(\alpha+\beta)}$
$E_{l1\cos\alpha - l2\cos(\alpha+\beta) + l3\cos(\alpha+\beta+\gamma)}$
59
60
61
h_2
52
$E_{\alpha+\beta}$
53
cos
$E_{\cos(\alpha+\beta)}$
54
K_{l2}
$E_{l2\cos(\alpha+\beta)}$
57
cos
58
K_{l3}
56
$E_{\alpha+\beta+\gamma}$
$E_{\cos(\alpha+\beta+\gamma)}$
$E_{l3\cos(\alpha+\beta+\gamma)}$
62
37
E_h
+
−

FIG. 9

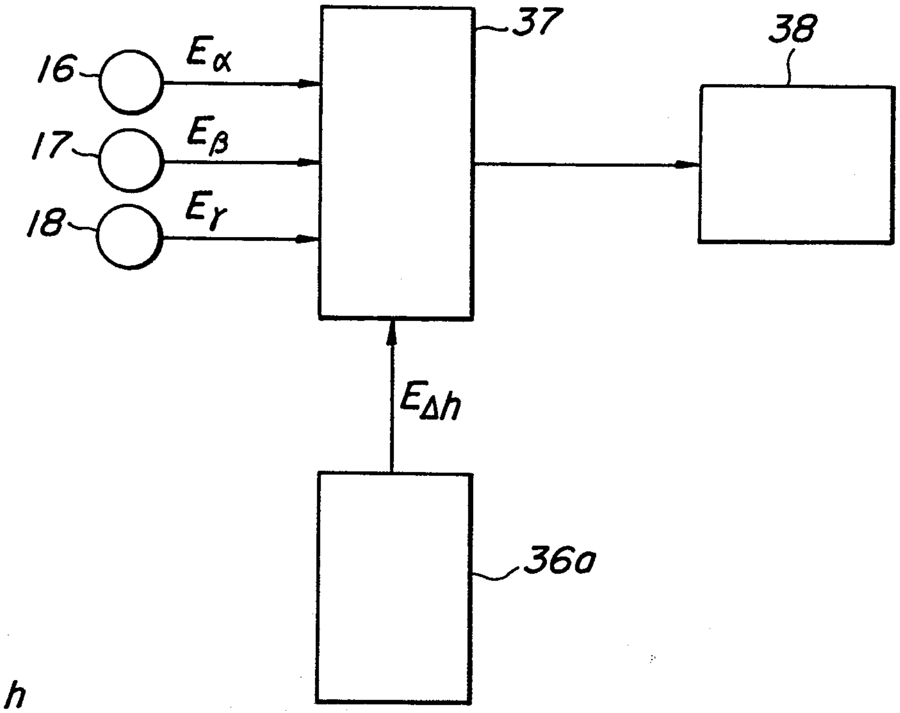

16
17
18
E_α
E_β
E_γ
37
38
$E_{\Delta h}$
36a

FIG. 10

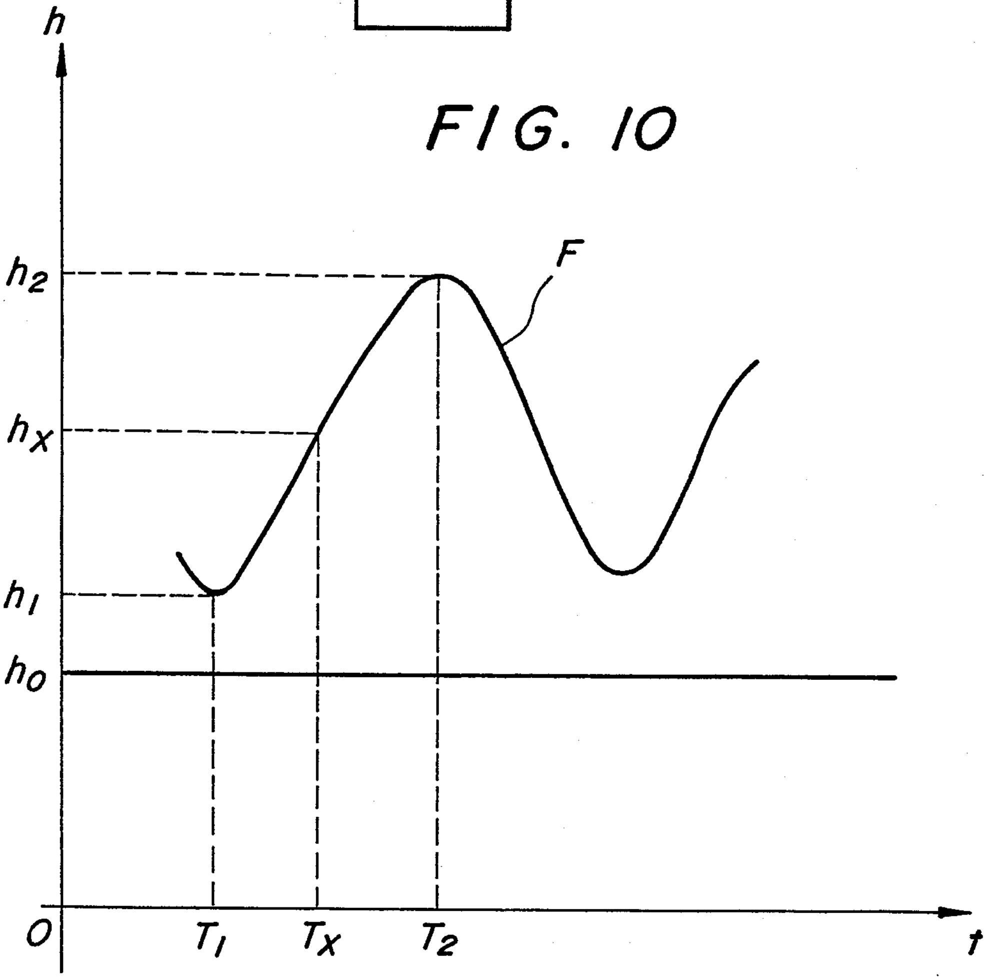
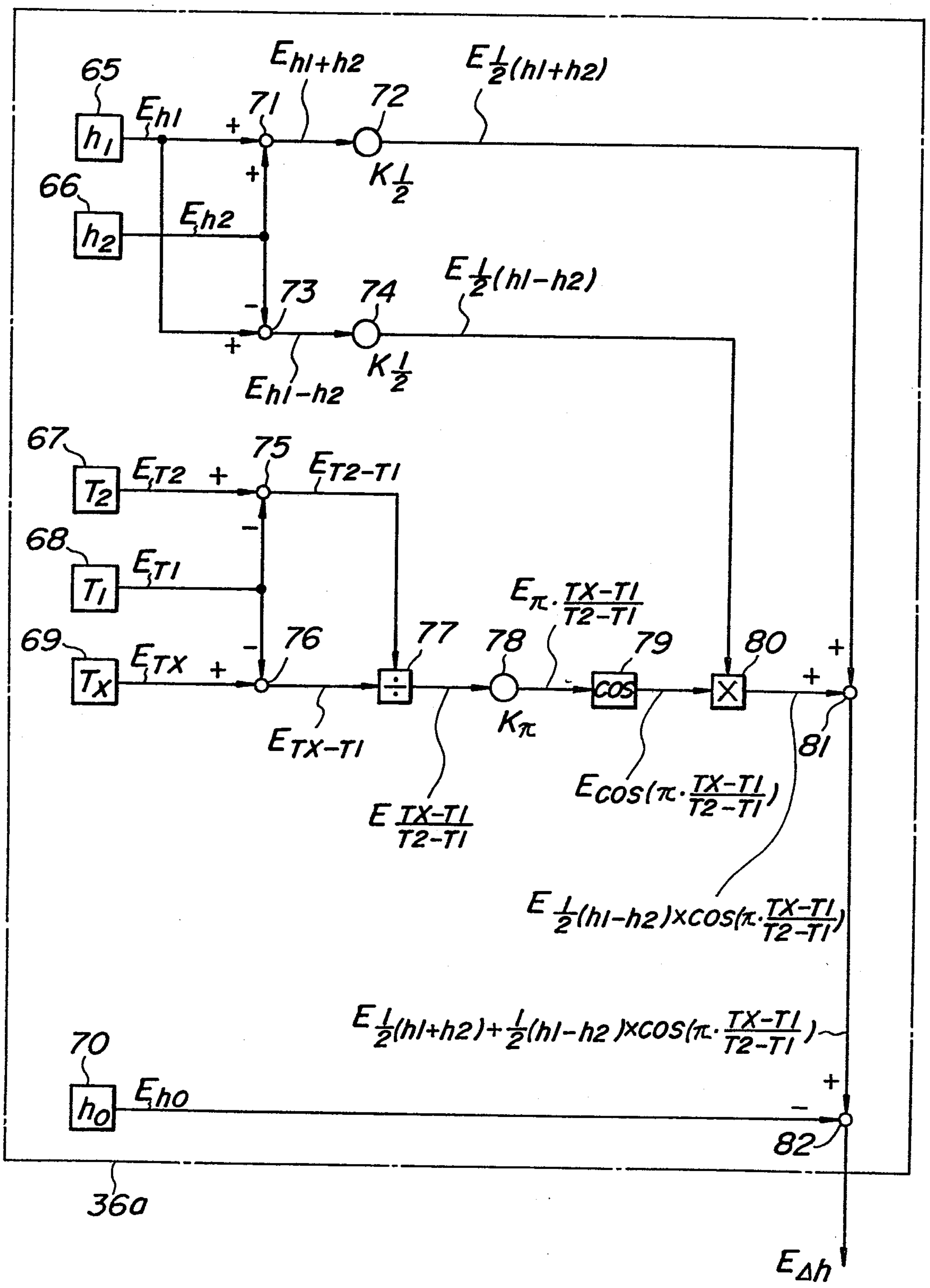

h
h_2
h_x
h_1
h_0
F
O
T_1
T_x
T_2
t

FIG. 11


65
h1
E_{h1}
+
71
E_{h1+h2}
72
$K\frac{1}{2}$
$E\frac{1}{2}(h1+h2)$
+
66
h2
E_{h2}
−
73
74
$E\frac{1}{2}(h1-h2)$
+
E_{h1-h2}
$K\frac{1}{2}$
67
T2
E_{T2}
+
75
E_{T2-T1}
−
68
T1
E_{T1}
−
69
Tx
E_{TX}
+
76
77
÷
78
K_π
$E_{\pi \cdot \frac{TX-T1}{T2-T1}}$
79
COS
80
×
+
+
81
E_{TX-T1}
$E\,\frac{TX-T1}{T2-T1}$
$E_{\cos(\pi \cdot \frac{TX-T1}{T2-T1})}$
$E\frac{1}{2}(h1-h2)\times\cos(\pi \cdot \frac{TX-T1}{T2-T1})$
$E\frac{1}{2}(h1+h2)+\frac{1}{2}(h1-h2)\times\cos(\pi \cdot \frac{TX-T1}{T2-T1})$
70
h0
E_{h0}
+
−
82
36a
$E_{\Delta h}$

European Patent
Office

EUROPEAN SEARCH REPORT

0125736
Application number

EP 84 20 0678

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
Y	DE-A-2 413 738 (BILLITON) * Page 3, paragraph 3; page 5, paragraph 2; claims 3,4 *	1,2,5, 6,9-11
Y	DE-A-2 620 809 (ORENSTEIN UND KOPPEL) * Page 9 - page 10, paragraph 1; page 13, last paragraph - page 14; figures 2-4 *	1,2,5, 6,9-11
A	WO-A-8 102 904 (BACHMANN) * Page 3, line 25 - page 7, line 4; figures 1,2,7 *	3,4
A	GB-A-2 000 326 (POCLAIN) * Page 2, lines 14-93; figure 1 *	7,8
A	EP-A-0 009 516 (AMSTERDAM BALLAST)	
A	DE-C- 893 630 (KÖSTER)	
A	DE INGENIEUR, vol. 87, no. 27, July 1975, pages 545-557, Den Haag, NL; W.H.A. VAN OOSTRUM: "Geprogrammeerd baggeren" -----	

CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
E 02 F 9/26 E 02 F 9/20

TECHNICAL FIELDS SEARCHED (Int. Cl. ³)
E 02 F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	08-08-1984	RAMPELMANN J.

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