METHOD AND APPARATUS FOR EARTH GRADING AND ALLE ARTS

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Application December 15, 1951, Serial No. 261,886

10 Claims. (Cl. 37—143)

The present invention relates to methods and apparatus for earth working including grading and allied operations.

One of the principal objects of the invention is the provision of a novel and improved method and apparatus for working earth to a desired surface, which utilizes as a basic information source a reference plane, such as a plane established by a radiated or otherwise propagated "plane" of energy, where the planet is established by an absolute reference elevation device, to control the elevation of an earth moving or cutting instrumentality during moving of the instrumentality in an appropriate manner relative to an earth surface, as for instance, in a direction generally parallel with the reference plane. Whenever the term or expression energy is employed herein it is meant to include not only radiated or propagated energy but also energy derived from barometric forces or gravitational forces.

Another of the principal objects of the invention is the provision of a novel and improved method and apparatus for elevation surveying which utilizes information sources of the character referred to above.

Another of the principal objects of the invention is the provision of a novel and improved method of and apparatus for elevation surveying which utilizes information sources of the character referred to above.

Further objects and advantages of the invention will be apparent to those skilled in the art to which it relates from the following description of the preferred embodiments of the invention described with reference to the accompanying drawings forming a part of this specification and in which similar reference characters designate corresponding parts throughout the several views:

For purposes of illustration, there is herein shown and described a preferred embodiment of the invention especially adapted for grading an earth area; for example, a field A, such as an air field or a field to be irrigated, to a desired plane surface by use of a radiated "plane" of electromagnetic energy. An omni-directional antenna B connected to a suitable transmitter C transmits electromagnetic energy equally in all directions in a confined, generally horizontal plane parallel to the plane to which the field A is to be graded. The transmitter C might comprise conventional short wave or infra-red transmission equipment and is provided with a suitable power source, not shown. The antenna B may be located in or to one side of the field A, as desired, and the reference plane of energy, designated generally as D, is established by mechanically positioning the transmitting antenna B to bear a known, fixed, dimensional relation to the plane to which the field A is to be graded by the earth grading apparatus. The antenna B is located remote from the earth grading apparatus which, as shown, comprises a vehicle E including an active earth moving instrumentality or element in the form of an elongated scraper or cutter blade F. A tractor G is shown for moving the vehicle E about the field A. The position of the lower active edge 10 of the blade F relative to the reference plane D is controlled by deviation of receiving antennas or sensing units H, H' from the energy reference plane D.

The vehicle E shown comprises an elongated, box-like body 11 supported for movement about the field A by a plurality of front and rear wheels 12, 13, respectively, and is adapted to move about the field A to be graded in a conventional manner by the tractor G which may be of conventional construction. Opposite ends of the scraper or cutting blade F are connected to and carried by the lower ends of a pair of connecting rods 16 of similarly constructed, vertically positioned, double-acting, reciprocating type fluid pressure operated motors J, the cylinders 17 of which are fixed to opposite sides of the vehicle body 11. Suitable bearing brackets also connected to opposite sides of the body 11 assist in guiding the connecting rods 16 which move in a generally vertical direction. From the foregoing, it will be apparent that opposite ends of the blade F can be independently moved with respect to the body 11 of the vehicle E by control of the flow of fluid pressure to and from opposite ends of the cylinders 17 of the motors J at opposite sides of the vehicle.

The detectors or sensing units H, H' are located above the vehicle proper and are mechanically connected to opposite ends of the earth moving blade F so that they always occupy the same relative position with respect to the lower active edge 10 of the blade F. As shown, the sensing units H, H' are connected to the lower ends of rods 20, 20', the lower ends of which are connected to the blade F. The rods 20, 20' are connected to opposite sides of the body 11 of the vehicle E by suitable guide brackets for movement parallel with the movement of the connecting rods 16. The connections between the sensing units H, H' and opposite ends of the blade 10 are preferably such that the relative distance therebetween can be adjusted, if desired.

The electromagnetic energy detectors or sensing units H, H' may be of any suitable type. Those shown are of the bolometer type; that is, their resistance changes with the amount of electromagnetic energy to which they are exposed. Each sensing unit comprises two vertically spaced, sensitive areas 21, 22 and 21', 22' essentially cylindrical in shape so as to be equally sensitive to incident radiation from all directions. The combined sensitive areas of each detector unit is greater in vertical di
The flow of pressurized fluid to and from the motor J is controlled by the sensing unit H. The flow of fluid to and from the motor J at the near side of the vehicle, as viewed in Fig. 2, is controlled by the sensing unit H and the flow of fluid to and from the motor J at the far side of the vehicle by the sensing unit H'. Since both the control for the motor J on the near side of the vehicle will be described in detail. Where corresponding parts of the control for the motor J on the other side of the vehicle appear in the drawings, they are designated by the same reference character with a prime mark prefixed thereto.

The two sensing areas 21, 22 of the detector unit H are arranged to form two active arms of a normally balanced Wheatstone bridge circuit, designated generally as M. When both sensing areas 21, 22 are equally "illuminated" by the radiation from the antenna E, the resistance of each area is the same and the bridge circuit remains in balance with no signal being transmitted to the amplifier 25. This condition corresponds to the desired dimensional relation between the reference datum plane D established by the omnidirectional radiated energy and the lower or cutting edge 10 of the active earth-moving element or blade F.

If the position of the cutting blade F is such that the midpoint of the detecting or sensing units H does not coincide with the plane D of radiated energy, then the two sensing surfaces 21, 22 thereof will be unequally illuminated and hence the bridge associated therewith will be unbalanced. The bridge is supplied with energy from a bridge supply circuit 23 which may be connected to the power supply 24 from a suitable generator on the tractor G. Any bridge unbalance signal is applied to an amplifier 25 and the output of the amplifier applied to one phase of a two-phase induction motor P. The second phase of the two-phase induction motor P may be connected to the bridge supply 23. The difference in the "illumination" of the two sensing areas 21, 22 will determine the amplitude and polarity of bridge unbalance and hence cause a signal to be generated which will be related to whether the particular end of the earth-moving device is too high or too low. The polarity of bridge unbalance determines the direction of rotation of the two-phase motor P. The magnitude of unbalance determines the angular rotation and contributes to the initial torque of the motor P in its blade positioning action.

The motor P is connected to a differential-type pressure valve R which controls the flow of pressurized fluid to opposite ends of the cylinder 17 of the motor J and maintains equal pressure on opposite sides of the piston of the motor. As the valve R is moved, the end of the blade F to which the motor J is connected is caused to be moved up or down, as the case may be. Pressurized fluid may be supplied to the valve R from a pump on the tractor G by supply and return lines 26, 27, respectively. The motion of the blade F tends to restore the mid-point of the sensing unit H to the reference datum plane established by the radiated energy. The construction is such that the deviation of the plane H from the reference datum plane supplies a signal which then acts to re-position the detector relative to the plane of the reference wave and, in turn, the blade F a predetermined distance therefrom.

The use of two detector or sensing units H, H' connected to opposite ends of the earth moving element in the manner shown constitutes one step towards automatic compensation for vehicle attitude; that is, any rotation or movement of the vehicle about its own axes, and maintains the active edge 10 of the blade F always parallel with the reference plane D or at a desired predetermined angle thereto. Alternatively a single detector or sensing unit may be employed to determine the position of the blade F with respect to the reference plane of the general plane of the vehicle and a suitable device employed to maintain the blade F level or in the desired angular position with respect to the reference plane.

The vehicle F shown comprises an elevator conveyor 28, the lower end of which is disposed adjacent to and connected to one end of the blade F. The upper end of the elevator conveyor 28 is connected to the body 11 by a link 29 which permits vertical movement of the conveyor and discharges the incinerated refuse into the rear end of the body 11 of the vehicle. The construction is such that excess earth accumulated in front of the blade F is transferred by the elevator 28 to the vehicle body. Provision is also made for supplying earth ahead of the blade F in the event there is a depression in the field being graded. For this purpose the front end of the body 11 is open as at 30 and the body 11 behind the opening 30 supplied with a conveyor 31 adapted to discharge earth deposited thereon as in the elevator conveyor 28 ahead of a scraper blade 32 located in front of and slightly above the level of the blade F. The conveyor 31 may be intermittently actuated, as required, to discharge earth from the body of the vehicle ahead of the blade 32 which spreads the same. A mechanical tamper or roller, designated generally as T, may be employed between the blades F and 32 if it is desired to tamp or compact the earth ahead of the blade F. The blade 32 includes manually operated means which may be provided for adjusting the blade vertically; however, it is preferably moved automatically in relation to the blade F. This can be accomplished, for example, by connecting the blade to a pair of pressure motors U similar to the motors J and connecting the motors U in parallel circuit with the motors J.

Obviously there is a maximum cut which the blade F is capable of taking, considering the character of the vehicle F, the power of the tractor G, the kind of earth encountered, and some suitable stop means is provided for limiting the maximum depth to which the blade F can be moved. If the control system is functioning properly, the blade F is maintained at all times in its desired position relative to the reference plane of electromagnetic energy and the bridge output is zero. If, however, the cut required at any particular instance is greater than the greatest cut which the blade F is capable of making, a continuous bridge output signal will exist.

This signal can be transmitted over a radio link by conventional transmission equipment, not shown, but includes the antenna V to a remote unit; for example, a self-tracking radar unit W which has as its function the recording of the position or location where further grading must be performed. The amount of fill required or excess dirt to be removed can also be recorded, if desired, as this will be a function of the strength and polarity of the bridge unbalance signal. The desired information can be recorded in graphic form, or the like, and constitutes a memory of performance which can form the basis for subsequent location, direction, etc., of the earth moving vehicle.

As an alternative construction, the sensing units H, H' could be replaced by absolute reference elevation devices; for example, gravity responsive or barometric pressure operated devices and the location of the blade F relative to the datum plane established thereby determined in a similar manner. In this event, the earth moving vehicle, as such, could remain the same as may the earth moving or cutter blade and its hydraulic positioning mechanism, the valve and valve operating motors, and the amplifiers for driving them. The radiation sensitive sensing units are absent in this embodiment, but will be different. The new bridge, however, may be supplied with energy and yield an output signal in the same manner as the bridge already described.

Two arms of the new bridge, constituting the ratio arms, can be conventional, variable resistors and the other two arms may consist of electrical wire resistance.
strain gauges. One of the strain gauges can be affixed to an absolute barometric pressure pick-up or device. The other of the strain gauges may serve as a dummy to account for ambient temperature changes, etc. The barometric element may consist of a evacuated chamber connected through a flexible bellows arrangement to a rigid member such that variations in atmospheric pressure would cause the rigid member to undergo a linear displacement. The electrical wire resistive strain gauge coupled to the active bridge arm would monitor the motion of this member. Movement of the wire would change the resistance of the strain gauge and hence unbalance the bridge. The barometric element would be operatively connected to the cutting blade and changes in height thereof would cause changes in pressure which, in turn, would vary the resistance of the strain gauge forming the active bridge arm and activate the hydraulic motors to re-establish the cutting blade at the predetermined desired height or elevation.

Two barometric sensitive devices, etc., can be employed, one connected to each end of the blade, and automatic compensation for relative attitude thus obtained in a manner similar to the manner in which it is obtained by the use of the two sensing units I, II, etc., of the preferred embodiment.

In operation, the bridge or bridges, as the case may be, can be balanced manually by means of the adjustable bridge radio arm resistances, with the cutting blade at the desired predetermined height or elevation and the vehicle thereafter moved about the field to be graded. Any deviation of the blade or either end thereof, as the case may be, up or down from the elevation established, will result in a change in pressure on the barometric element coupled thereto which, in turn, will change the resistance of the active bridge arm, thereby causing the bridge to produce an output signal which will, in turn, activate the automatic positioning mechanism to re-position the blade to its original predetermined elevation.

Variations in pressure, due to changing atmospheric conditions at any given time, may be compensated for by varying the resistance of one of the ratio arms of the bridge from a remote location via a radio link over which a control signal is transmitted to the vehicle, which signal is a function of the atmospheric pressure existing at a stationary point corresponding with the reference level or plane. This atmospheric pressure may be detected by a barometric pressure sensitive element similar to that referred to above. Variation of this stationary barometric pressure element can modulate a radio transmitter which would transmit a signal to the vehicle, which signal would act upon one of the bridge ratio arms so as to compensate for the variation in atmospheric pressure due to atmospheric phenomena.

Programmed type information can be incorporated into the system by sending a control signal to the vehicle via a radio link so as to vary the resistance of the ratio arm of the bridge in accordance with the prescribed predetermined program which may be correlated with positional information of the type yielded by the remote radar tracking unit previously referred to.

While a specific type of earth moving apparatus is illustrated, the earth moving mechanism may be employed; for example, a ditching mechanism, etc., is to have a desired inclination or slope, as would be the case in leveling a field to be irrigated or digging a ditch for a drainage system, the "plane" or the radiated energy can be inclined to the desired angle or provision can be made for manually or automatically changing, in a desired manner, the elevation of the reference plane by changing the physical position of the radiating antenna or the relative position between the earth moving instrumentality and the sensing units or the physical position of the absolute reference elevation devices, referring to the alternative arrangement described, with respect to the earth moving instrumentality, or the physical position of the so-called stationary, compensating, barometric pressure element if such is employed. For example, the range and angular position of the earth moving vehicle can be displayed at the remote radar tracking unit W on a cathode-ray tube in a manner known as a plan position indicator and photo-electric cells located above the plan position indicator so as to be illuminated by light from the spot appearing on the plan position indicator, said spot indicating the instantaneous position of the earth moving vehicle. As the various photo-electric cells are successively illuminated, electrical signals can be generated and employed to control hydraulic or other mechanism for changing the physical position of the radiating antenna, etc., in accordance with any desired predetermined "program."

As previously mentioned, the equipment referred to can be used to take levels. To do this, a sensing unit similar to one of the units referred to can be fixedly connected to a vehicle and the vehicle driven over the desired surface with a mechanism connected to the output of the bridge circuit for recording the amplitude and polarity of the signal received from the bridge. This signal will be a function of the deviation of the sensing unit from the reference plane and hence the record obtained will be an indication or record of the ground contour. The bridge signal may be recorded on the vehicle and/or transmitted to the self-tracking radar unit for recording.

From the foregoing, it will be apparent that the objects of the invention heretofore enumerated and others have been accomplished and that there has been provided a novel and improved method of and apparatus for grading, surveying, etc. While preferred embodiments of the invention have been shown, in considerable detail, the invention is not limited to the apparatus shown and described. Numerous changes may be made therein as will be apparent to those skilled in the art to which the invention relates; for example, the signals obtained from the bridge circuits disclosed and which are, in the preferred embodiment described, used to automatically control the position of the earth moving instrumentality with respect to the reference or datum plane, could be used to actuate a visible indicator, which visible indication could, in turn, be employed by an operator to manually control the position of the earth moving instrumentality.

While two embodiments including the two different sensing systems have been described in considerable detail, other embodiments are contemplated, such as systems employing, for example, infra-red radiation, phase-difference sensing and/or reflected energy and it is my intention to cover thereby all adaptations, modifications and uses of my invention.

Having thus described my invention, I claim:

1. The method of working earth which comprises establishing a reference plane of energy and utilizing said energy plane to control the position of an earth moving instrumentality relative thereto while moving said instrumentality in a direction generally parallel to said plane of energy.

2. The method of working earth which comprises radiating a plane of energy and utilizing said energy to control the position of an earth moving instrumentality relative thereto while moving said instrumentality in a direction generally parallel to said plane of energy.

3. In an earth working apparatus, a movable vehicle, an earth moving instrumentality carried by said vehicle for movement relative thereto, means for establishing a reference or datum plane of energy, and means responsive to deviation of the earth working apparatus from said reference plane for controlling the position of said instrumentality relative to said reference plane.

4. In an earth working apparatus, a movable vehicle having a frame, an earth moving instrumentality carried by said vehicle for movement relative to said frame,
power-actuated means for moving said earth moving instrumentality relative to said frame, means for establishing a reference or datum plane of energy, and means responsive to deviation of the earth working apparatus from said datum or reference plane for automatically controlling said power-actuated means to maintain said instrumentality in predetermined relative position to said reference plane.

5. In an earth working apparatus, a movable vehicle, an earth moving instrumentality carried by said vehicle for movement relative thereto, means remote from said vehicle for transmitting a plane of energy, and means on said vehicle for utilizing said energy to control the position of said earth moving instrumentality relative to said plane of energy.

6. In an earth working apparatus, a movable vehicle having a frame, an earth moving instrumentality carried by said vehicle for movement relative to said frame, power-actuated means for moving said earth moving instrumentality relative to said frame, means remote from said vehicle for transmitting a plane of energy, and means on said vehicle for utilizing said energy to automatically control said power-actuated means to maintain said earth moving instrumentality in predetermined position relative to said plane of energy.

7. In an earth grading apparatus, a movable vehicle, an earth moving instrumentality carried by said vehicle for movement relative thereto, means for establishing a reference or datum plane of energy, means for detecting deviation of the earth grading apparatus from said reference or datum plane, and means for utilizing said last-named means to control the position of said earth moving element relative to said reference or datum plane.

8. In an earth working apparatus, a movable vehicle including a frame, an earth moving instrumentality carried by said vehicle for movement relative to said frame, power-actuated means for moving said earth moving instrumentality relative to said frame, means remote from said vehicle for establishing a radiant energy reference or datum plane, and means including a radiant energy responsive device on said vehicle for automatically controlling said power-actuated means to maintain said earth moving instrumentality in predetermined relative position to said reference plane.

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