July 2, 1946. F. W. REYNOLDS 2,403,023

TELEVISION FOLLOWER APPARATUS

Filed Aug. 28, 1941 2 Sheets-Sheet 1

FIG. 1

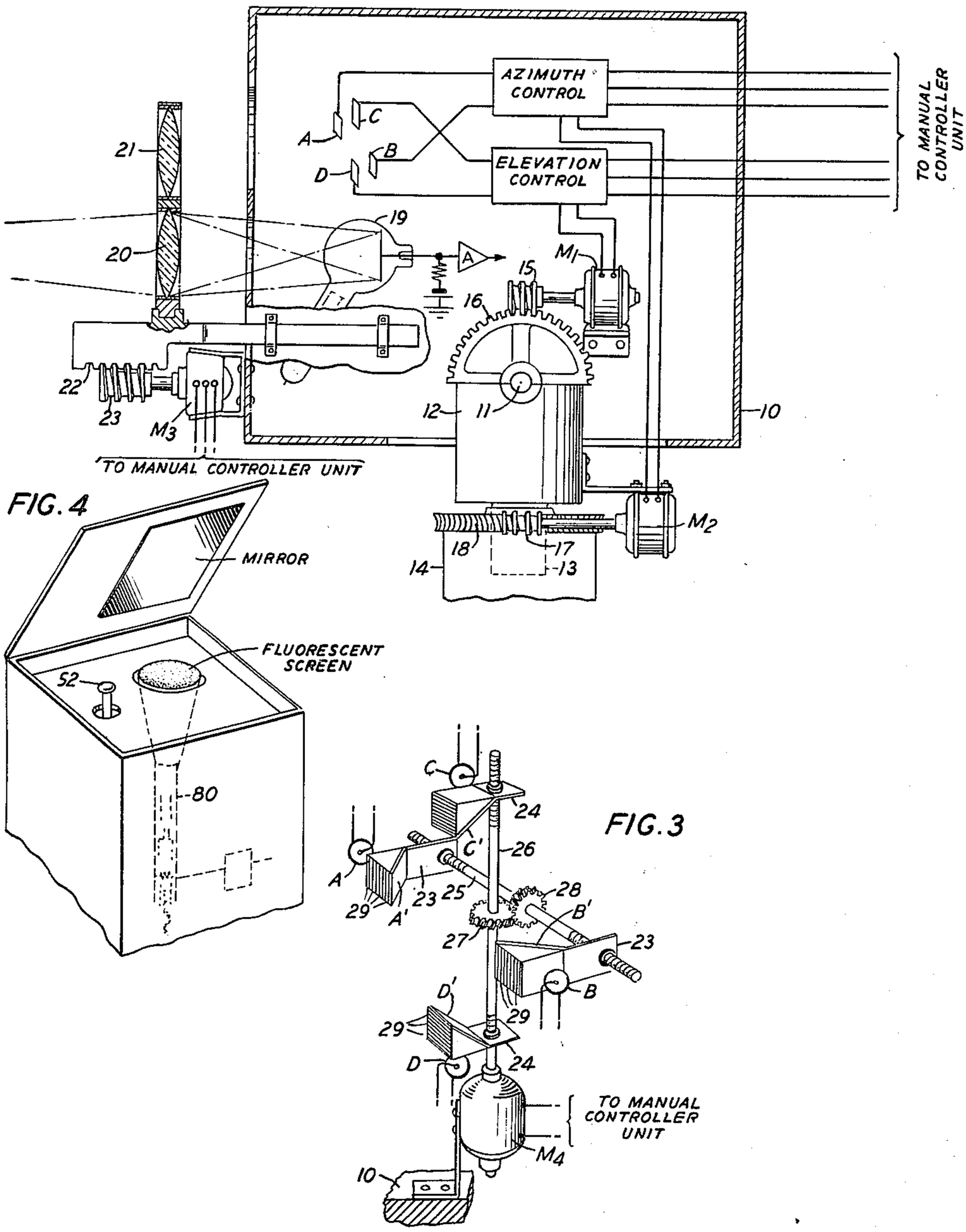

FIG. 4

FIG. 3

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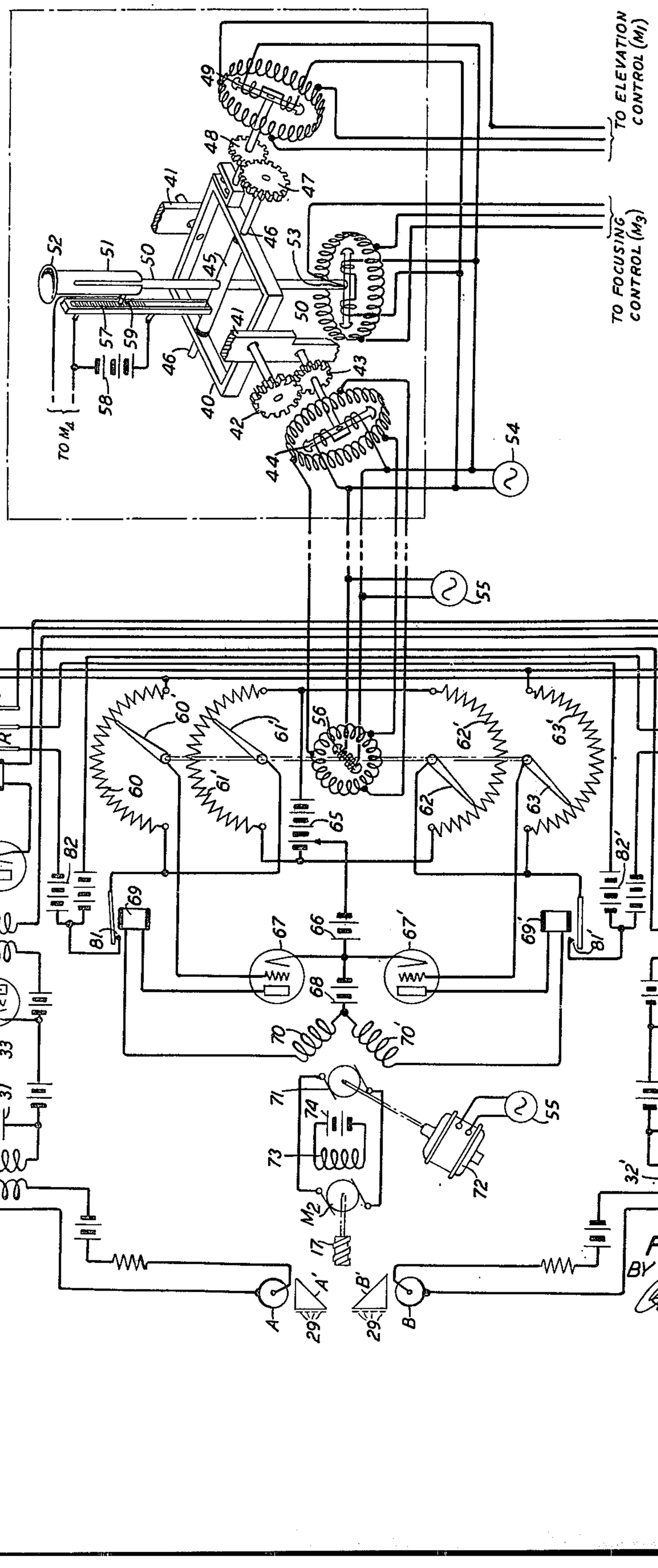

FIG. 2

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UNITED STATES PATENT OFFICE

2,403,023

TELEVISION FOLLOWER APPARATUS

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Application August 28, 1941, Serial No. 408,587

15 Claims. (Cl. 178—7.2)

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This invention relates to control systems and particularly to a system for controlling the direction of aim of a television pick-up device or camera in a manner to cause it to follow an object moving in an object field so as to hold the synthesized image substantially stationary on the receiver screen.

A principal object of the invention is to provide a simple and efficient combination of automatic control means with remote manual control means for orienting a television camera toward a moving object and causing it to follow the same.

Another object is to provide superposed controls, one of the automatic type and the other of the remote manual type, of such nature that large speed changes and changes in direction of movement which the camera executes in following a moving object are controlled manually by an observer of a synthesized image while small changes and minor departures from an average speed are controlled automatically. This permits the use of an automatic control apparatus of great sensitivity, since the demands made on it at high average object speeds are in general no greater than at low average object speeds.

In pursuance of these objects the television camera may be mounted in a manner to be rotatable from side to side and upwards and downwards so that it may be directed toward any desired part of an object field. These horizontal and vertical movements may be executed by suitable motors which, in accordance with the invention, are under the dual control of a local automatic apparatus and an observer who may be remotely located.

The manual speed control apparatus may comprise means such as a controller unit conveniently placed for manipulation by an operator who may be an observer of a synthesized television image at a remote point, and associated control apparatus, for example pairs of self-synchronous devices, which respond to the manually produced movements of the controller unit to cause the television camera to rotate in a desired direction and at a desired speed, both of which are under the manual control of the operator. Specifically, the controller unit movements may vary the control grid potential of an electronic tube whose output current flows in the field winding of a generator, the generator armature current in turn feeding the armature of an aim-altering motor.

The automatic control means may comprise paired optical means such as photoelectric cells or prisms associated with the cells between which an image is formed of the object to be followed and whose output signals are normally balanced but become unbalanced when, due to changes in the speed of the selected object, its image is displaced from its symmetrical position. These unbalanced currents are utilized to accelerate or decelerate the driving motors so as to restore the central position of the image and thus the balance. For example, they may cause an increase or a decrease in the potential of the electronic tube control grid whose mean potential is determined by the manual control.

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The photoelectric cells and associated circuits may conveniently be mounted in the same housing as the camera so as to be automatically aimed in the same direction. The two devices may be provided with objective lenses which are similar and similarly controlled so that parts of the object field which are in focus for the camera are also in focus for the automatic following device. Means may be provided for varying the spacing of the cells or prisms to accommodate images of different sizes.

It is a feature of the preferred embodiment that the speed changes caused by the automatic apparatus are proportional to the mean speed as produced by the manual control apparatus.

In accordance with a preferred embodiment, it is arranged that the movement of an image away from its centrally located position shall produce an alternating restoring signal instead of a direct one. This result may be secured by the disposition of a fine mesh screen immediately in front of each of the prisms, so that as the image advances further and further across a prism and away from its central position, successive spaces or apertures in the screen are occluded in succession so that the light impinging on the photoelectric cell increases by steps instead of continuously. This permits the use of an alternating current amplifier in place of a direct current amplifier which, as is well known, may be of high sensitivity to a desired signal and yet at the same time highly insensitive to spurious or casual signals and to variations in the electrode supply potentials and the like. Such direct current output as there may also be is preferably disposed of by by-passing or otherwise, the alternating component alone being utilized. Since the magnitude of this alternating component is a measure of the velocity of departure of the selected object from its proper relative position with respect to the photoelectric cell, this output current may serve as a restoring signal to operate the orienting motors in a sense to restore the central location of the image.

The invention will be more fully understood from the following detailed description of a preferred embodiment thereof taken in connection with the appended drawings in which:

Fig. 1 is a schematic view partly in perspective of a television camera housing containing a television camera and automatic following means

for causing the camera to follow the movements of a selected object in the object field;

Fig. 2 is a circuit diagram showing the connections of the automatic following apparatus and means for energizing the aim-altering motors under the dual control of the local automatic following means and the remote manual means;

Fig. 3 is a perspective view of means for adapting the automatic following means to objects of various sizes; and

Fig. 4 is a perspective schematic view of receiver apparatus including a manual controller unit which may be employed in the combination of the invention.

Referring now to Fig. 1, a housing **10** is mounted for rotation in a vertical plane about a pivot **11** on a pedestal **12**, which pedestal is in turn mounted for rotation in a horizontal plane about another pivot **13** on a base **14**. Rotation of the housing **10** in the vertical plane is effected by a motor M_1 fixed to the housing and driving a worm **15** which engages with a worm gear **16** fixed to the pedestal **12**. Similarly, rotation of the pedestal **12** about the base **14** may be effected by a motor M_2 fixed to the pedestal **12** and driving another worm **17** which engages with a worm gear **18** fixed to the base **14**. The housing **10** may contain a television camera **19** of any suitable type and also the automatic following apparatus to be described. Both the camera and the automatic following apparatus are preferably mounted behind individual apertures in the housing **10** and provided with adjustable focusing means such as objective lenses **20, 21**.

The objective lenses **20, 21** are preferably of the same focal length and may be fixedly attached to each other and mounted for axial movement together toward and away from the camera **19** and the automatic following apparatus respectively. For example, they may be mounted on a rack **22** slidably attached to the housing **10**, engaging with a worm **23** fixed to the shaft of a remotely controlled motor M_3. The principal optical axis of the automatic following apparatus is preferably parallel with the principal optical axis of the camera **19** and its lens **20**. By this arrangement, any object in the object field which is within the angle of view of the camera will likewise be within the angle of view of the automatic following apparatus, and likewise an object which is centrally located in the camera field will be centrally located in the automatic following apparatus field, i. e., it will be imaged centrally between the members of each pair of prisms of the automatic following apparatus.

As indicated in Fig. 1 and as more fully shown in greater detail in Figs. 2 and 3, the automatic following apparatus may conveniently comprise four photoelectric cells A, B, C, D disposed to receive light from the object field through four suitably disposed prisms A′, B′, C′, D′. These prisms may be symmetrically disposed at the sides of a square to receive light through the objective lens **21** from the same selected portion of the field of view toward which it is desired that the television pick-up device shall remain aimed. These prisms are preferably arranged in pairs, those marked A′ and B′ being responsive to horizontal movements of an object in the object field and those marked C′ and D′ being responsive to vertical movements. The two members of each pair are preferably spaced apart by a distance substantially equal to the width or height, as the case may be, of the image of the object which it is desired to follow. Thus the image is "framed"

between the edges of the four prisms. To adjust for objects of different sizes, each prism may be mounted on a base or bracket **23, 24** which is provided with threads which engage with corresponding threads on drive shafts **25, 26**. The threads on either end of the drive shaft **25** are cut in opposite directions, for example, the threads which move the azimuth control prism A′ may be right-hand threads and the threads which move the other azimuth control prism B′ may be left-hand threads. A similar arrangement may be provided with respect to the elevation control prisms C′ and D′, movement being imparted thereto through the drive shaft **26**. In order to avoid multiplicity of controls, it is preferred to couple the movements of the elevation control prisms with the movements of the azimuth control prisms in such a way that the remote observer retains control only for the "size" of his selected object as distinguished from its shape. To this end, two prism drive shafts **25, 26** may be geared together with gears **27, 28** of unity ratio, for example, gears whose teeth are cut at a bevel of 45 degrees, one of the shafts being directly driven by the remotely controlled prism-spacing motor M_4, mounted on the housing **10**.

At the same time it is contemplated that in certain fields of use it may be desirable to provide separate controls for the azimuth prisms A′, B′ and for the elevation prisms C′, D′ respectively, in which case it is only necessary to uncouple the two drive shafts one from the other and to provide separate drives, as by a duplication of the motor M_4, for each of the shafts **25, 26**.

In certain cases it may be sufficient to control the spacing of one pair of prisms only, in which case the spacing control of the other pair may be entirely eliminated.

Before entering any one of the prisms, the light of the object field may be arranged to pass through screens **29** composed of alternate transparent and opaque sections, which may be placed immediately in front of the prisms or indeed fixed to their forward faces. Such a screen has the effect of chopping a beam of light moving across the forward face of the prism so that the light impinging on the photoelectric cell has a pronounced alternating component.

Referring to Fig. 2, the output from each photoelectric cell, for example the A cell, is then fed into an amplifier designed to pass this alternating component but to block any direct component of the resulting signal. Such blocking may be effected, for example, by the use of an interstage transformer. This arrangement, furthermore, lends itself to the employment of tuning means, such as a condenser **31** tuning the secondary winding of a transformer **32** and a further tuned circuit **33** in series therewith, the frequencies to which these elements are tuned being preferably such as to emphasize the image-movement components and to exclude the noise frequency components in the output of the photocell A. Since these noise components are substantially higher in frequency than any frequencies to be expected due to movement of objects in the object field, they may be safely eliminated from the output of the apparatus, and this may conveniently be effected by means of a tuned alternating current amplifier stage comprising a triode **35** as shown. The resulting signal, which includes alternating components of frequencies below the noise frequency and excludes direct current or zero fre-

quency components, is then preferably rectified, as by feeding it through an interstage coupling to a rectifier such as a diode 36 whose output current passes through a relay winding 37.

The circuit of the other member of the first pair of photoelectric cells, that is the cell B, may be identical with that just described in connection with the cell A, the output of the final rectifier passing through a relay winding 37'. The operation and effect of these windings 37 and 37' will be described hereinafter.

For manually controlling the direction and speed of the camera, it is preferred to employ a modification of the apparatus described and claimed in U. S. Patent No. 2,306,862 granted to R. Bown Dec. 29, 1942 on an application filed July 8, 1941, comprising a controller unit having four degrees of freedom, namely, rocking from side to side, rocking forward and backward, axial twisting, and axial displacement. It is convenient to so arrange the controller unit of the aforementioned Patent No. 2,306,862 that the fore-and-aft rocking movement and the sideways rocking movement control the elevation control motor M_1 and the azimuth control M_2, respectively, the remaining movements of the manual controller unit being otherwise utilized as hereinafter described.

To this end a frame 40 may be mounted to rock in fixed journals 41 and may be provided with a gear 42 which engages with a pinion 43 fixed to the rotor shaft of a self-synchronous motor 44, so that rocking of this frame 40 rotates the rotor element within its field winding. Another member 45 may be mounted to rock about pivots 46 in the frame 40, the pivots 46 being disposed on a line perpendicular to the line joining the journals 41. This member 45 may in turn be provided with a gear 47 which engages with a pinion 48 fixed to the rotor shaft of another self-synchronous motor 49. A shaft 50 may extend upward through a hole drilled in the second member 45 and snugly engaging the shaft 50 to permit only rotational movements of the shaft 50 with respect to the member 45. Such rotational movement may be imparted to the shaft by twisting movements of a sleeve 51 which may be provided with a knob 52 shaped for convenient manipulation. This sleeve may be of square or channelled internal cross-section to fit snugly over the upper end of the shaft 50 which in turn, may be squared or splined to admit of axial movement between the sleeve 51 and the shaft 50 but constraining the shaft 50 to rotate with the sleeve 51. The lower end of the rotatable shaft 50 may be fixed or geared to the rotor element of a third self-synchronous motor 53.

The rotor windings of the three self-synchronous units 44, 49 and 53 may be excited as by an alternating current generator 54, which should be maintained in synchronism with a like generator 55 at the transmitter station in accordance with known practice for the remote control of angular movements. The polyphase windings of the units 44, 49, 53 may constitute control channels for the azimuth, elevation, and focusing control signals. To this end the polyphase winding of the unit 44 may be connected to corresponding terminals of the winding of a like unit 56, located at the transmitter station, whose operation and effect in controlling the horizontal movements of the television camera are described below. Likewise the polyphase winding of the self-synchronous unit 49 may be connected to the corresponding winding of a like unit not shown but which operates similarly to the unit 56 to control the vertical camera movements. Lastly the polyphase winding of the unit 53 may be connected to a corresponding winding of the motor M_3 fixed to the camera housing 10 and arranged to operate the rack 22 for advancing or withdrawing the objective lenses 20, 21 to bring distant or close objects into sharp focus both on the camera screen and in the space between the automatic followed prisms A', B', C', D'.

The inclinable member 45 of the controller unit may be provided with a resistor 57 to whose terminals are connected a current source such as a battery 58, and the sleeve 51 may be provided with a contacting element 59 which makes contact with this resistor 57 at one point or another depending upon whether the knob 52 is elevated or depressed. One terminal of this resistor 57 and the movable contacting element 59 may be connected, with or without the interposition of a pair of self-synchronous motors as hereinabove described in connection with the other controls, to the motor M_4 mounted on the transmitter housing 10 for remotely controlling the spacing between the prisms A', B', C', D'.

Turning now to the transmitter apparatus which responds to the remote manual speed control, the rotor element of the self-synchronous unit 56 may be directly coupled to a shaft which operates the moving contacts 60', 61', 62', 63' of four potentiometers 60, 61, 62, 63. The potentiometer resistors 61 and 62 are connected in parallel across the terminals of a potential source such as a battery 65 whose center tap is connected by way of a bias battery 66 to the cathode elements of two push-pull connected discharge devices 67, 67', the moving contacts 61', 62' being connected by way of portions of the potentiometer resistances 60, 63, to the control grids of these discharge devices 67, 67'. The anodes of these discharge devices are returned to the cathodes by way of a common potential supply source 68 and through relay windings 69, 69' and center tapped field windings 70, 70' of a direct current generator 71 which may be rotated at constant speed by a motor 72 driven by a constant frequency source of alternating current, for example the source 55 earlier referred to. The output voltage of the generator 71 may be fed to the armature of the direct current motor M_2, whose field winding 73 may be separately excited as by a direct current source 74.

If the knob 52 is held vertical or in a central position the rotor elements of the self-synchronous motors 44, 56 will adopt such positions that the potentials on the control grids of the discharge devices 67, 67' are alike. Thus, the anode currents will also be alike and, the circuits being balanced, the net magnetic field of the generator 71 will be zero. But if the knob 52 is displaced to one side or to the other from its central position, the rotors of the self-synchronous units 44, 56 will be turned and the moving contacts 60', 61', 62', 63' will likewise be displaced from their central positions. This will increase the control grid potential of one of the discharge devices, for example the device 67, by a certain amount and decrease the control grid potential of the other device 67' by a like amount, thus increasing one anode current and decreasing the other to produce a net field in the generator 71 depending in magnitude and sense on the direction and extent of the displacement of the knob 52 from its central position. Since the direction and speed of rotation of the motor M_2 depend on the direction and magnitude of the voltage generated by

the generator 71, which in turn depends on the magnitude and sign of its magnetic field, it will be understood that the person who manipulates the knob 52 may control the direction and speed of the horizontal movements of the housing 10 and with it the movements of the television camera 19. In case this operator be in position to observe a synthesized television image, as, for example, on the screen of a receiver device 80 (Fig. 4), to which vision signals derived from the camera 19 may be delivered for synthesis as an image in well-known manner, he may adjust and control the camera speed to correspond with the speed of a selected object moving horizontally in the object field in a manner to hold its image stationary on the receiver screen.

The vertical control apparatus may be a complete duplicate of the horizontal control apparatus described above, control signals being derived from rotation of the rotor element of the self-synchronous unit 49 due to fore-and-aft movements of the knob 52 and these control signals, after transmutation as above described, may control the direction and speed of the camera elevation control motor M_1.

For some purposes the manual control described above may be entirely sufficient, but under certain conditions it may be inadequate. For example, the nervous reactions of the observer may be too sluggish to hold the camera aimed squarely at a selected moving object despite sudden and varied changes in its speed. Thus it may be of advantage to provide precise control apparatus. It is to this end that the automatic follower apparatus is included in the system, which apparatus has been described in part hereinabove.

To complete the description of this part of the apparatus, the relay coils 37, 37′ through which flow the rectified signal currents derived from the photocells A, B are provided with three switch contacts R, R′, *b* and L, L′, *b*; and of the contacts of each group the first two are normally open and the third is normally closed. The third contact *b* is connected in series with the relay coil 37′ and the third contact *b*′ is similarly connected in series with the relay coil 37. They thus constitute "back contacts" and serve to ensure that when either one of the relays 37, 37′ is operative the other shall be inoperative.

The relay 69 through which flows the anode current of the discharge device 67 is provided with a switch contact 81, one side of which is connected to the mid-point of a potential source such as a battery 82, and the other side is connected to one end of the potentiometer 60. The relay 69′ is similarly provided with contacts 81′ which are similarly connected to a battery 82′ and one side of the potentiometer 63.

The negative terminal of the battery 82 is connected to the armature of the switch contact R and its positive terminal is connected to the armature of the switch contact L. Likewise, the negative terminal of the battery 82′ is connected to the armature of the switch contact L′ and its positive terminal is connected to the armature of the switch contact R′. The stationary members of the contacts R and L are both connected to the terminal of the potentiometer 60 which is remote from that connected to the switch 81 of the stationary members of the contacts R′ and L′ are both connected to the terminal of the potentiometer 63 which is remote from that connected to the switch 81′.

The operation of the apparatus above described

is as follows: Assume that the camera is being steadily moved in a right-hand direction and that this is accomplished by a flow of substantial current in the anode circuit of the tube 67 which is sufficient to hold the relay contacts 81 closed, the tube 67′ being either below its anode current cutoff or at least passing insufficient current to actuate the relay 69′. The potentiometer contacts 61′ and 62′ are shown in positions which produce this result, since they are positioned to place a large negative bias on the grid of tube 67′ and a small negative, or even a positive bias on the grid of tube 67.

Assume now that the object being followed should decrease its speed or that for some other reason the camera speed is too great. The image of the selected object will move to the right and its edge will occlude the narrow transparent strips of the screen 29 of the prism A′ to produce an alternating current signal in the circuit of the cell A and so current in the relay winding 37. This will close both of the contacts R and R′. R′, however, is ineffective since it is in series with the open contact 81′. Likewise, since this movement of the image produces no change in the anode current of the tube 67′, both of the contacts L and L′ remain open and the back contact *b*′ remains closed. Closure of the contact R connects the negative terminal of the battery 82 to one end of the potentiometer 60, while its center tap is connected to the other end. This places a portion of the battery voltage of negative sign on the control grid of the discharge device 67 which serves to reduce its anode current and therefore reduce the speed of the camera motor M_2 so as to bring the camera speed into correspondence with the object speed.

If, on the other hand, the camera is moving too slowly, the image will pass over the screen 29 of the prism B′ and the contacts L′ and L of the relay 37′ will be closed, the back contacts *b*′ being opened and so preventing accidental operation of the relay 37. Therefore, the contacts R and R′ remain open and the back contact *b* remains closed. Since the contact 81′ is still open, closure of L′ is ineffective, but closure of L connects the positive terminal of the battery 82 to the terminal of the potentiometer 60 which is remote from the terminal connected to the closed contacts 81, thus adding a positive increment of potential to the grid of the discharge device 67 which serves to accelerate the motor M_2 and cause the camera to overtake the object.

From the above description of the operations of the apparatus for increases and decreases in camera speed, respectively, in a right-hand direction, it will be understood that it operates in like manner for increases and decreases, respectively, in a left-ward speed initially obtained by rocking the knob 52 to the left, thus raising the control grid potential of the tube 67′ and reducing that of the tube 67.

The back contacts *b* and *b*′ serve to ensure against simultaneous operation of both relays 37 and 37′ which might otherwise occur when the prisms A′ and B′ are simultaneously covered by opposite sides of the image.

Apparatus for altering the vertical camera speeds by varying the energy supplied to the motor M_1 about a mean upward or downward speed obtained in response to forward or backward movements of the knob 52, which variations are controlled by signals derived from the photocells C and D, may be identical with that described above.

It will be observed that with this apparatus, in view of the manner in which the potentiometers, relays and switches are connected and poled, the magnitudes of the auxiliary correcting voltages introduced in the grid circuits of the devices 67 and 67' by the photocell currents are in each case proportional to the settings of the moving contacts 60' and 63' which, since these are ganged with the contacts 61' and 62', are dependent on the speed at which the camera rotates. This in itself is a highly advantageous result, since thus the camera speed changes bear the same relation to camera speeds as are most likely to be encountered with the moving objects being followed.

Though the invention has been described with reference to a television system only, it is not to be taken as limited thereto. For example, it may be employed as secondary apparatus when it is desired to hold the aim of other apparatus such as a search light or a gun on a moving object such as an airplane. Furthermore, variations may be made from the particular dual control arrangements described above without departing from the spirit of the invention. For example, either the automatic follower apparatus or the manual follower apparatus or both may take other forms without departing from the invention in its primary dual control aspect.

What is claimed is:

1. Television apparatus comprising a television pick-up device for generating image currents, means for transmitting said currents to a distant point, an image synthesizing device at said distant point for utilizing the transmitted currents to form an image, means associated with said pick-up device for orienting it, means at said receiving point in a position to be operated by an observer of the field of said image for controlling said orienting means whereby said observer may at will aim said pick-up device toward any selected portion of an extended object field, means associated with said pick-up device for automatically maintaining said device oriented toward any selected moving object located by said observer in any part of said field, said automatic means being under control of light received from said field in the vicinity of said object, and means at said receiving point in a position to be actuated by the observer while observing said image field for setting into operation said automatic control means at will, whereby a substantially stationary image of said moving object so selected by said observer is formed in said image field.

2. The combination with an aimable television device for generating image currents for transmission to a distant point and synthesis there to form an image, of apparatus for automatically holding said device aimed at a selected moving part of a field of view which comprises means for orienting said device under control of control signals, a pair of photosensitive elements disposed to be actuated by movements of a part of the object field in one direction and arranged to deliver control signals to said orienting means in response to said movement, another pair of photosensitive elements disposed to be actuated by movements of a part of said field in a perpendicular direction and arranged to deliver control signals to said orienting means in response to said movement, and means controllable from said distant point for changing at the will of an observer of said image the disposition of said photosensitive elements.

3. The combination with an aimable television device for generating image currents for transmission to a distant point and synthesis there to form an image, of apparatus for automatically holding said device aimed at a selected moving part of a field of view which comprises means for orienting said device under control of control signals, a pair of photosensitive elements disposed to be actuated by movements of a part of the object field in one direction and arranged to deliver control signals to said orienting means in response to said movement, and means controllable from said distant point for changing at the will of an observer of said image the disposition of said photosensitive elements.

4. The combination with a television pick-up device for generating image currents for transmission to a distant point for synthesis there as an image, of apparatus for automatically holding said device aimed at a selected moving part of a field of view which comprises means for orienting said device under control of control signals, a photosensitive element disposed to be actuated by movements of a selected part of an object field away from a preassigned location in one sense and to deliver control signals to said orienting means in response to said movements, another photosensitive element disposed to be actuated by movements of a neighboring part of said object field away from a preassigned position in an opposite sense and to deliver control signals to said orienting means in response to said movements, and means controllable from said distant point for changing at the will of an observer the disposition of said photosensitive elements.

5. The combination with a television pick-up device for generating image currents for transmission to a distant point for synthesis there as an image, of apparatus for automatically holding said device aimed at a selected moving part of a field of view which comprises a photosensitive element disposed to receive light from a selected part of an object field, a screen composed of alternate transparent and opaque sections interposed in the path of said light, an electric network adapted to transmit alternating components of the output of said element as restoring signals to said orienting means, and means under control of said restoring signals for reorienting said pick-up device in a sense to reduce relative movement between said moving field part and said photosensitive device.

6. The combination with a television pick-up device for generating image currents for transmission to a distant point for synthesis there as an image, of apparatus for automatically holding said device aimed at a selected object moving in a field of view, which comprises a photosensitive element disposed to receive light from that part of a field of view which is adjacent to an edge of a selected object in said field, a like photosensitive element disposed to receive light from that part of said field which is adjacent to an opposite edge of said object, a screen composed of alternate transparent and opaque sections interposed in the light path of each of said elements, an electric network adapted to transmit alternating components of the outputs of each of said elements as correcting signals, and means under control of said correcting signals for reorienting said pick-up device in a sense to reduce relative movement between said moving object and said photosensitive devices.

7. The combination with a television pick-up device for generating image currents for transmission to a distant point for synthesis there as an image, of apparatus for automatically holding

said device aimed at a selected object moving in a field of view, which comprises means at said remote point arranged to be manipulated by an observer viewing said image for causing said pick-up device to move at an average speed determined by said manipulation in a sense to hold said pick-up device aimed approximately at said object, and means associated with said pick-up device responsive to relative movements between said object and said pick-up device for automatically varying said average speed in a sense to hold said device aimed precisely at said object.

8. The combination with a television pick-up device for generating image currents for transmission to a distant point for synthesis as an image, of apparatus for automatically holding said device aimed at a selected object moving in a field of view, which comprises means at said remote point arranged to be manipulated by an observer viewing said image for causing said pick-up device to move at an average speed determined by said manipulation in a sense to hold said pick-up device approximately aimed at said object, means associated with said pick-up device responsive to relative movements between said object and said pick-up device for automatically varying said average speed in a sense to hold said device aimed precisely at said object, and means for causing said speed variations to be in substantially direct proportion to said average speed.

9. Apparatus for holding a dirigible element directed toward a moving object which comprises a television pick-up device attached to said element with its line of sight lying at a prescribed angle to the line of aim of said dirigible element, which comprises means for orienting said dirigible element and said pick-up device together, means arranged to be manipulated by an operator for delivering control energy to said orienting means for causing said device and element to move with an average speed in a manner approximately to follow a selected moving object, and means associated with said pick-up device responsive to relative movements of said object and said device for automatically varying said pick-up device speed in a manner to hold said device aimed precisely at said object despite variations in the speed of said object.

10. Apparatus for causing a dirigible element to follow a moving object, which comprises means arranged to be manipulated by an operator for causing said element to rotate about axes fixed with respect to said object in a manner corresponding to movements of said object at an average speed, and automatic means responsive to departures of said object speed from said average for causing related departures in the speed of rotation of said dirigible element.

11. Apparatus for causing a dirigible element to follow a moving object, which comprises means arranged to be manipulated by an operator for causing said element to move in a manner corresponding to movements of said object at an average speed, and automatic means responsive to departures of said object speed from said average for causing related departures in the speed of said dirigible element, said automatic means comprising a light-responsive device, means for forming an image of said object adjacent said light-responsive device, and means for deriving speed-varying signals in response to relative movements of said image and said light-responsive device.

12. Apparatus for causing a dirigible element to follow a moving object, which comprises a circuit arranged to deliver speed-varying energy to said dirigible element in response to variations in a voltage in said circuit, manual means for adjusting the magnitude and polarity of said voltage as desired to cause said dirigible element to move at an average speed, and automatic means for inserting an auxiliary voltage in said circuit in response to relative movements of said object and said element to cause variations in the speed of said element.

13. Apparatus for causing a dirigible element to follow a moving object, which comprises a circuit arranged to deliver speed-varying energy to said dirigible element in response to variations of a voltage in said circuit, manual means for adjusting the magnitude and polarity of said voltage as desired to cause said dirigible element to move at an average speed in a desired direction, means coupled to said voltage-adjusting means for presetting an auxiliary voltage in a manner dependent on the manually controlled average speed, and automatic means responsive to relative movements between said object and said element for inserting said auxiliary voltage into said circuit to modify said average speed in accordance with variations in said object speed.

14. Apparatus for causing a dirigible element to follow a moving object, which comprises two circuit control elements each having two fixed terminals and a movable terminal, said movable terminals being mechanically coupled to move in unison, a circuit including said circuit control elements for delivering speed-varying energy to said dirigible element in response to the setting of the movable terminal of one of said circuit control elements, the setting of the movable terminal of the other of said circuit control elements being so connected as to determine the magnitude of an auxiliary energy source, and automatic means responsive to departures of said dirigible element speed from said moving object speed for including said auxiliary energy source in said circuit to modify said dirigible element speed in a sense to reduce said departures.

15. The combination with an aimable television camera for generating image currents for transmission to a distant point and synthesis there to form an image, of apparatus for automatically holding said camera aimed at a selected object moving in the field of view of said camera, which comprises a control element located at said distant point and arranged to be angularly displaced by an observer viewing said image for delivering control energy to said camera in proportion to said angular displacements, means coupled to said camera for causing rotation thereof in response to said control energy at a speed and in a direction dependent on the magnitude and direction of the angular displacement of said control element whereby said observer may at will impart a constant average rotational speed to said camera of a sort to cause said camera to follow movements of said object at an average speed, means responsive to angular deviations of the line of aim of said camera from a line joining said camera to said object for producing variations in said average rotational speed in a sense to reduce said deviations, said speed-variation-producing means being coupled with said average speed producing means in a manner to cause the sensitivity of said speed-variation-producing means to increase with increases in said average speed.

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