Oct. 18, 1949. K. A. KAIL 2,485,292

AVIATION TRAINER

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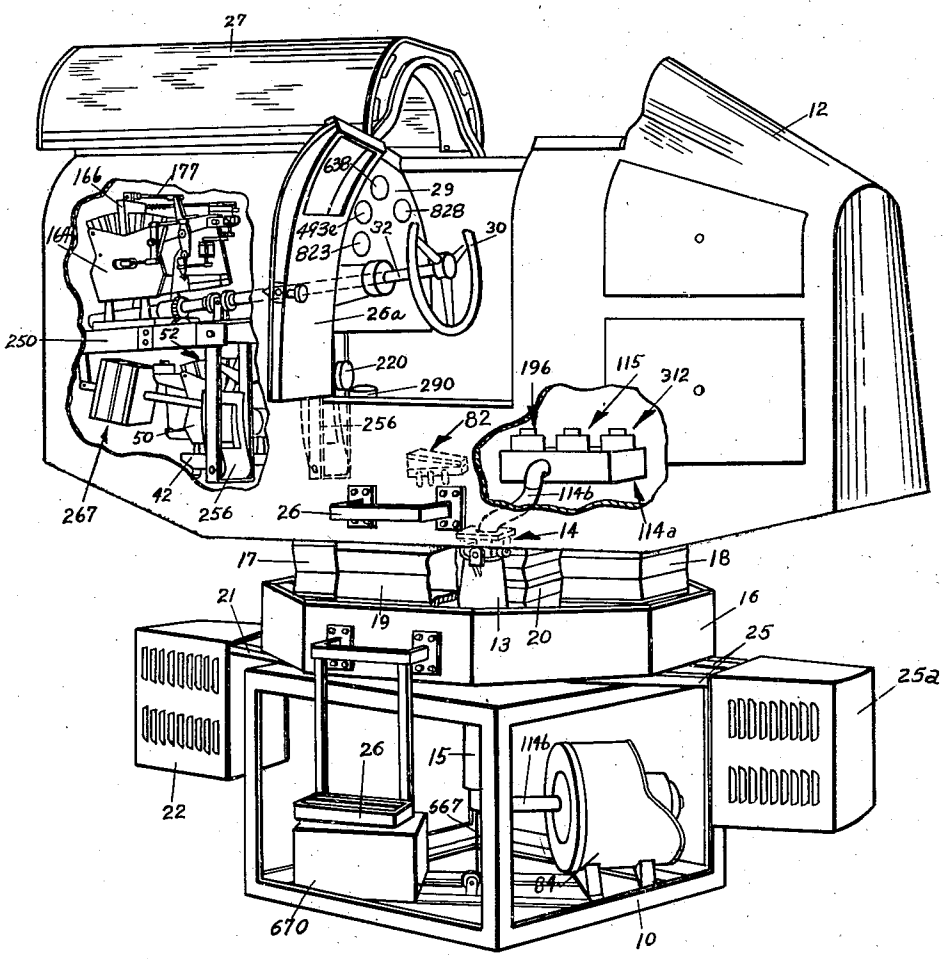


FIG. 1

KARL A. KAIL
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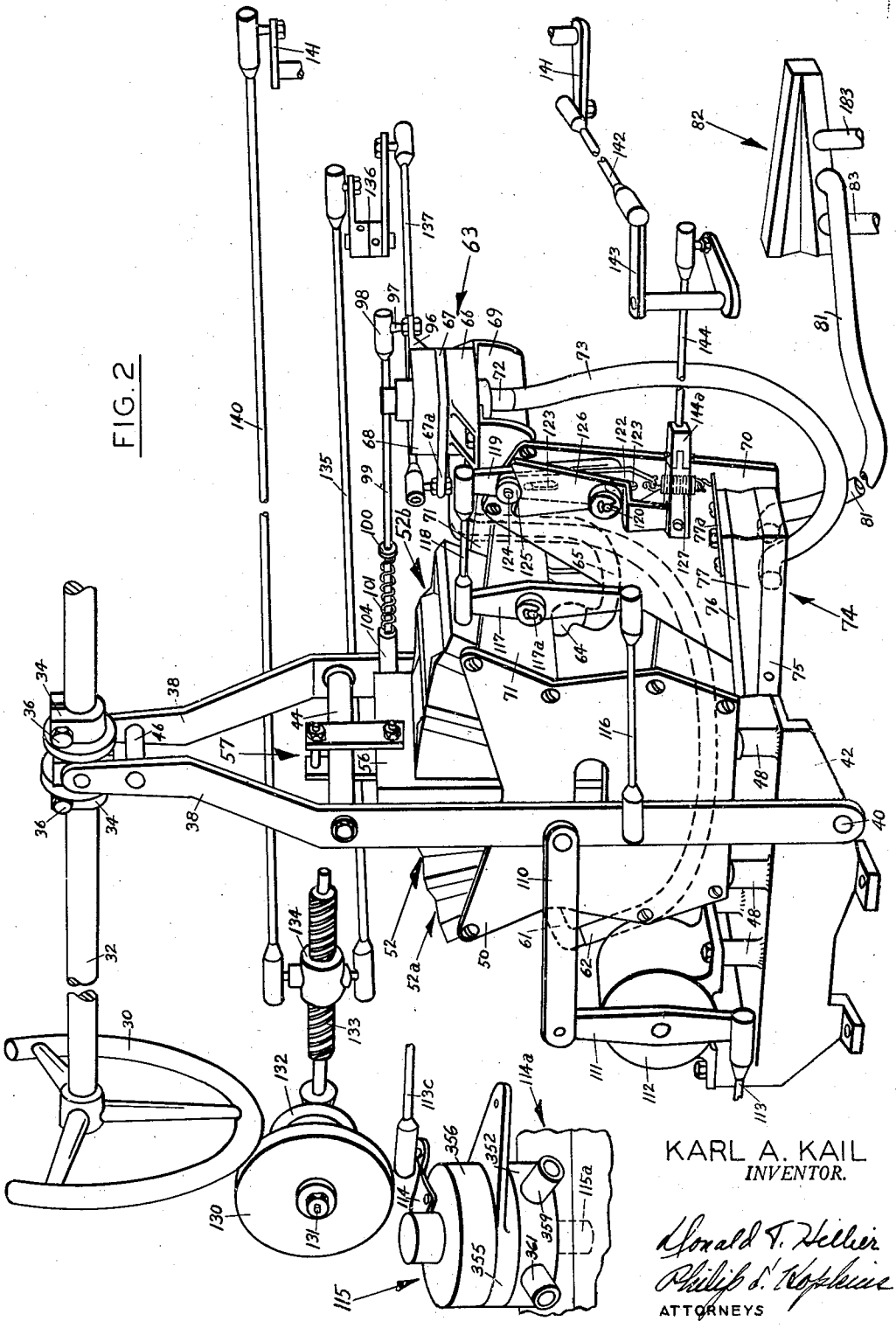
BY Donald T. Kellier
Philip S. Hopkins.
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Oct. 18, 1949. K. A. KAIL 2,485,292

AVIATION TRAINER

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FIG. 2



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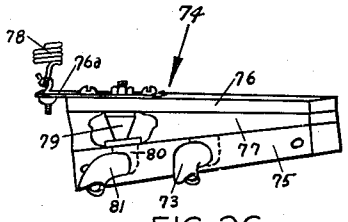


FIG. 2C

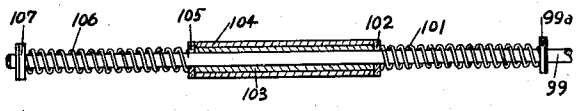


FIG. 2D

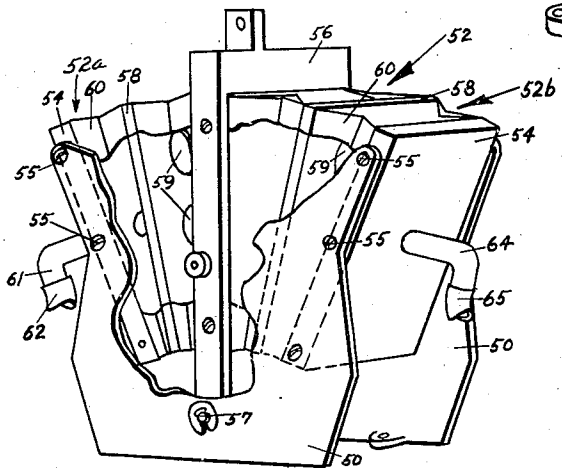


FIG. 2A

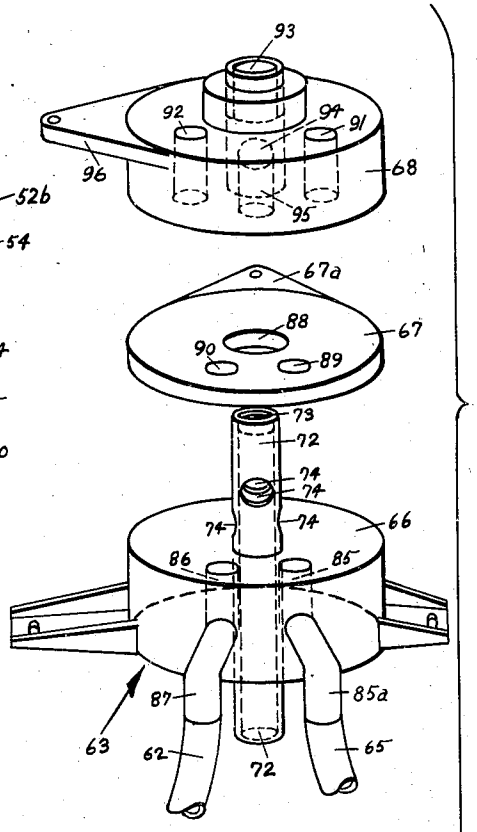


FIG. 2B

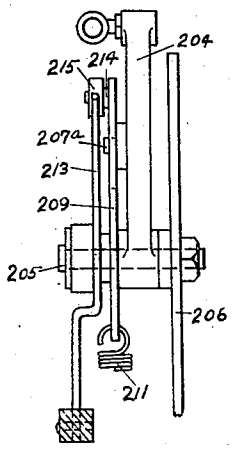


FIG. 3A

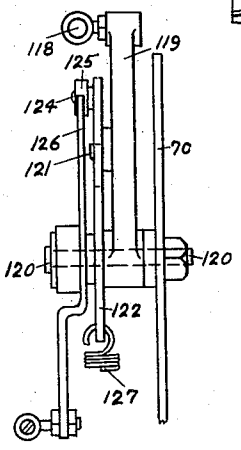


FIG. 2E

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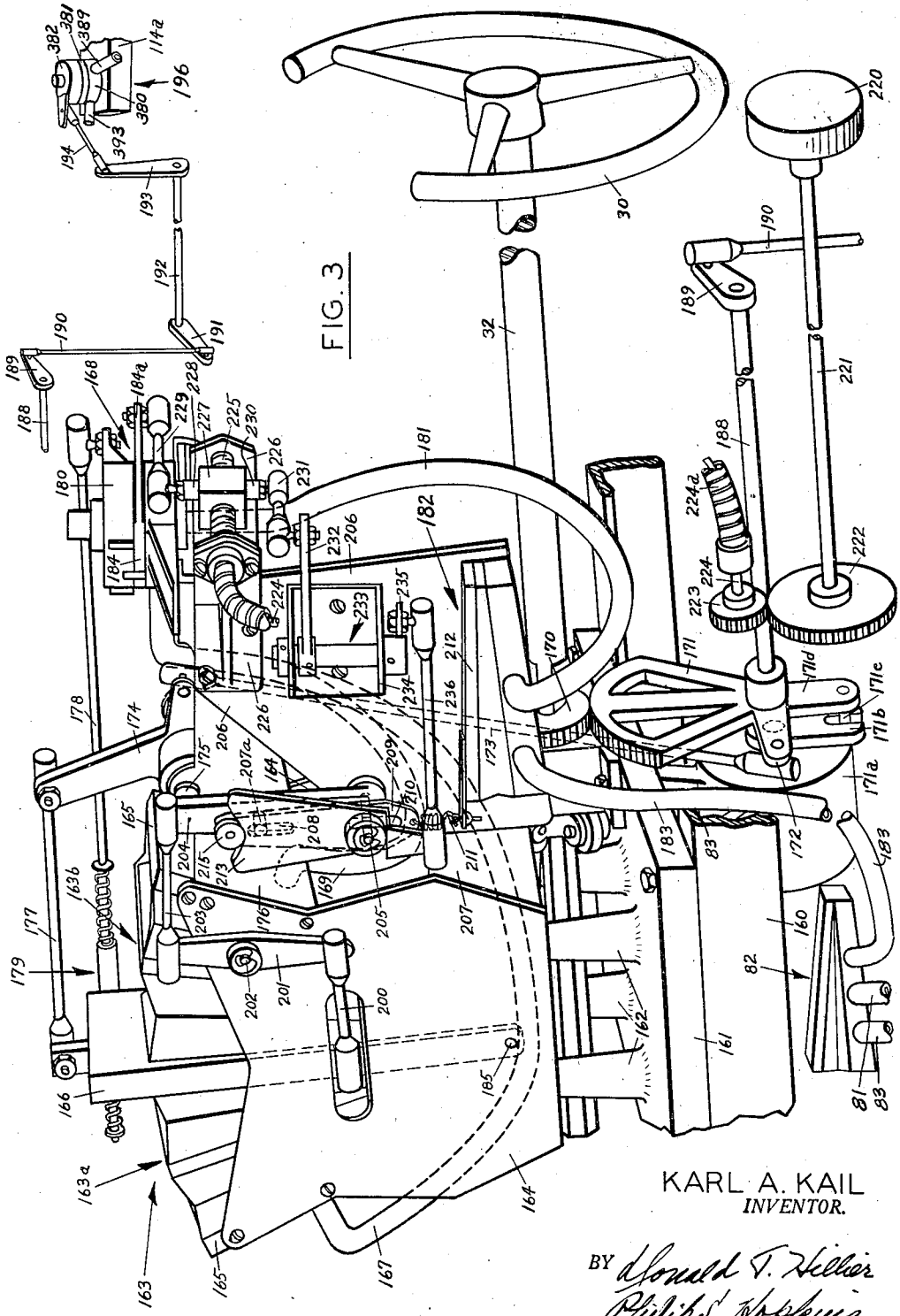


FIG. 3

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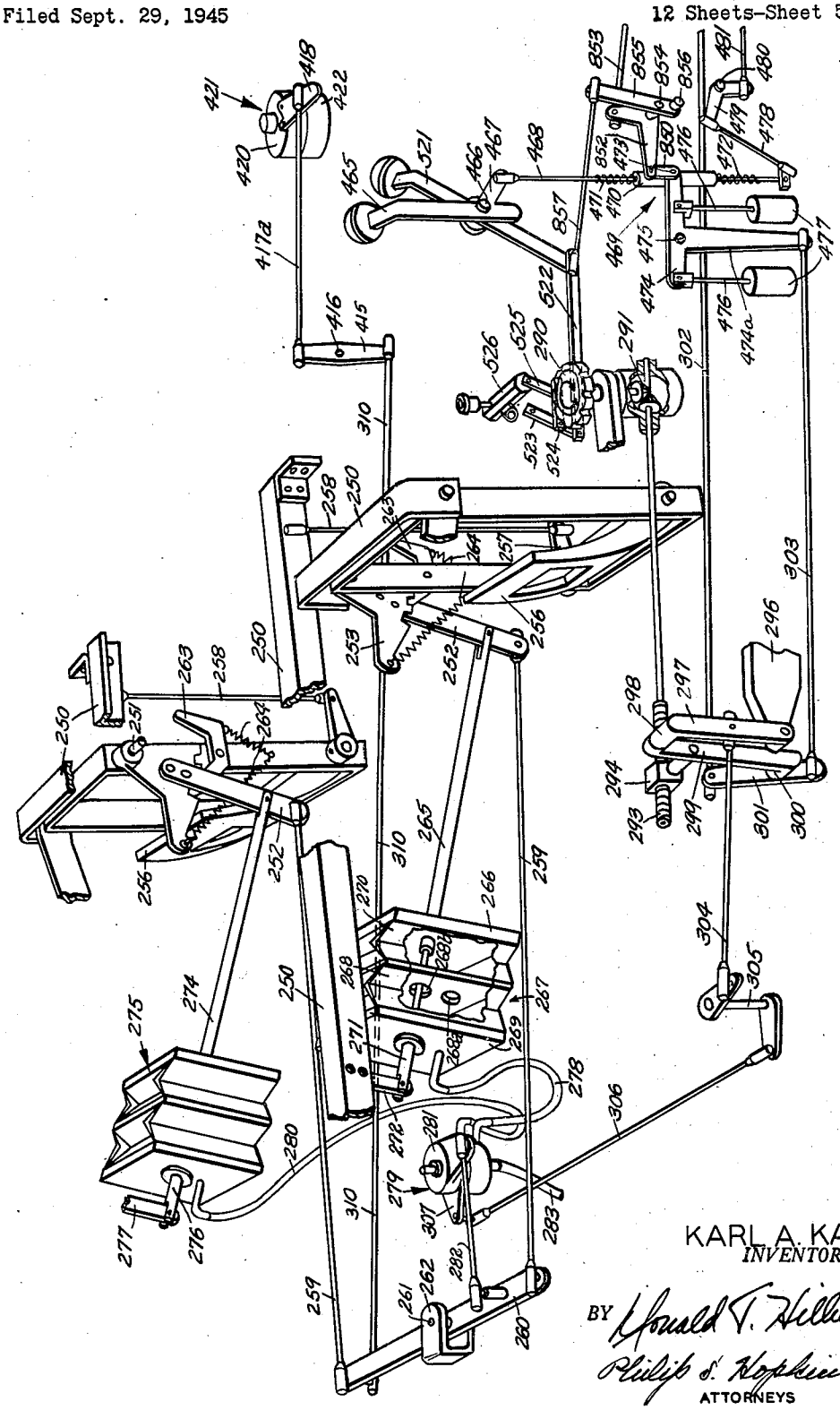


FIG. 4

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AVIATION TRAINER

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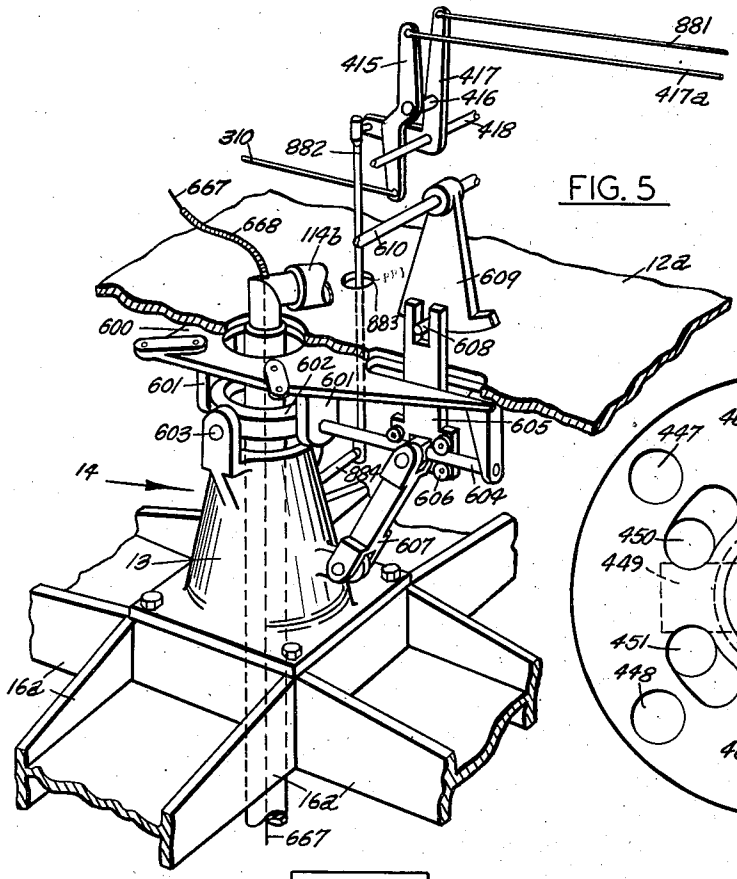


FIG. 5

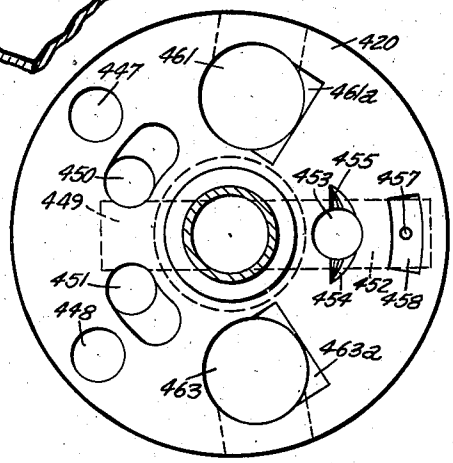


FIG. 7A

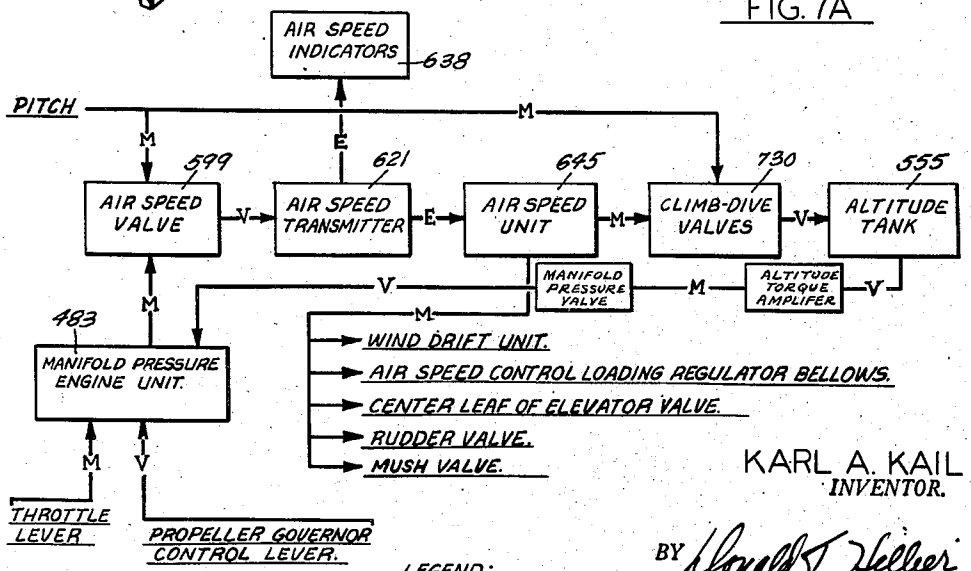


FIG. 8

LEGEND:
M - MECHANICAL.
E - ELECTRICAL.
V - VACUUM.

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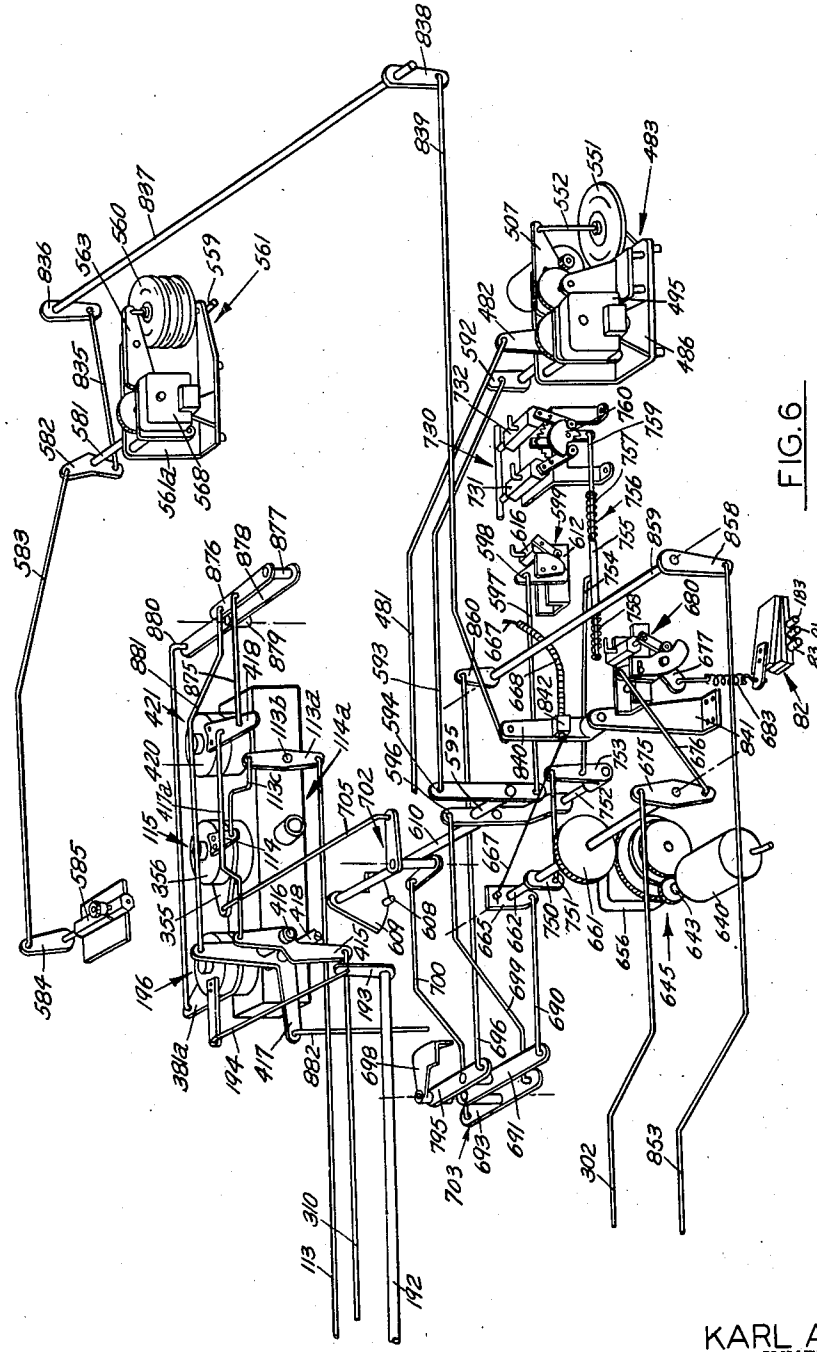


FIG. 6

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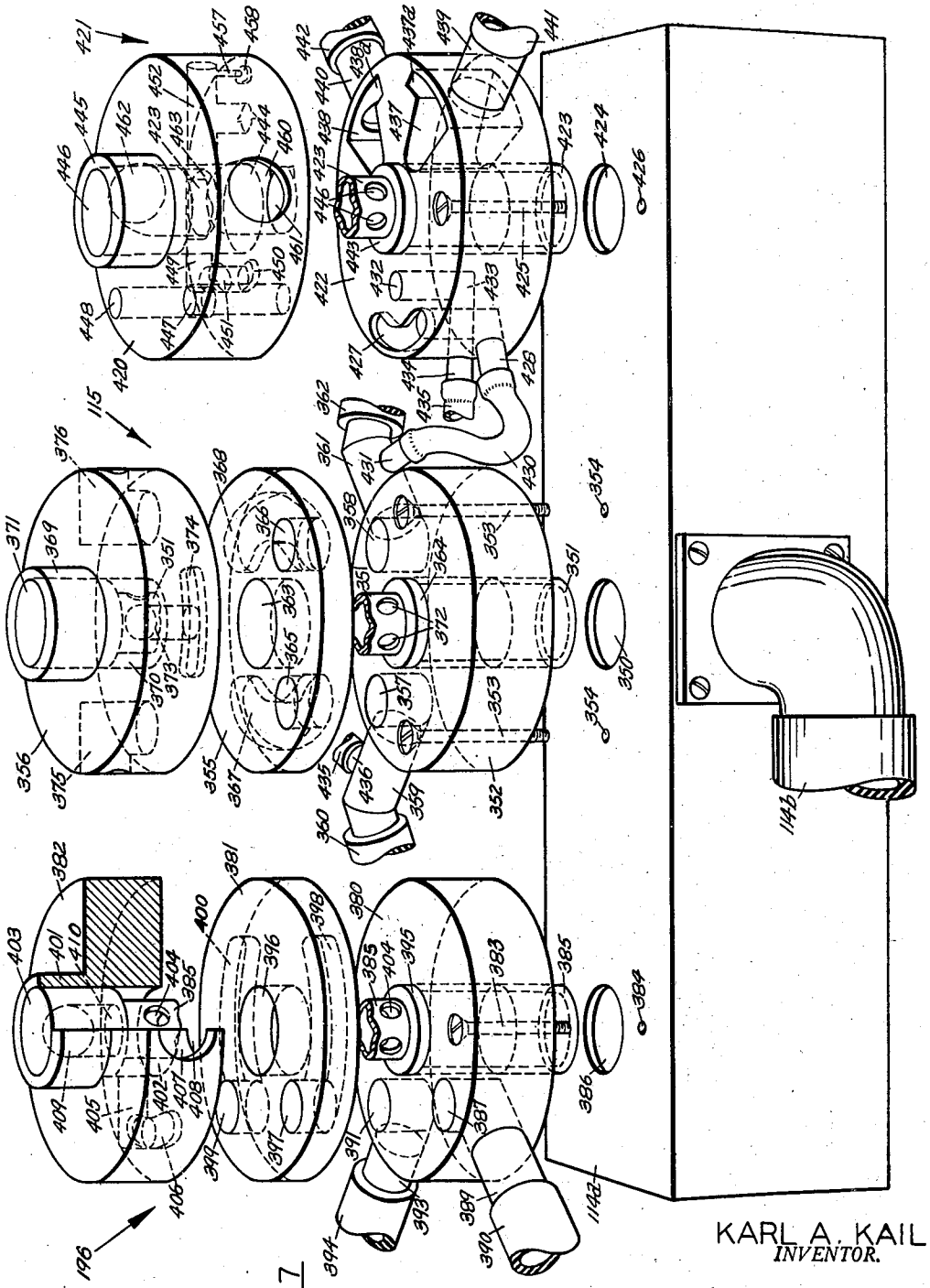


FIG. 7

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AVIATION TRAINER

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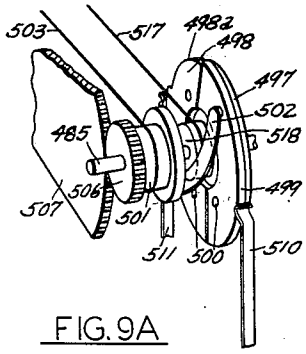


FIG. 9A

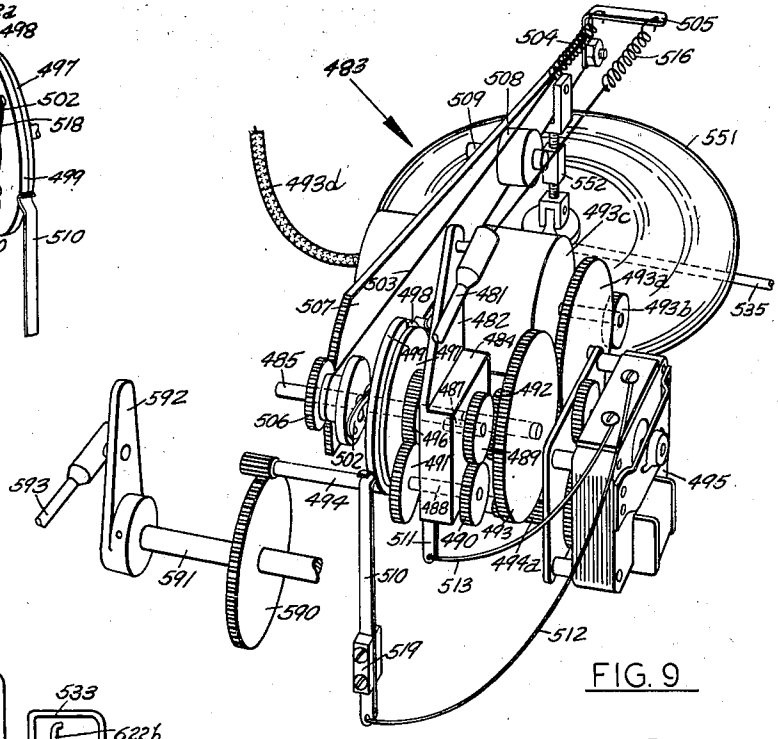


FIG. 9

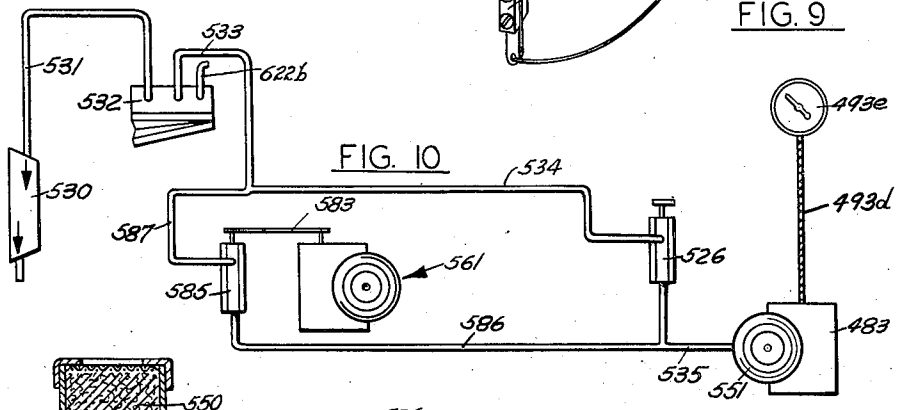


FIG. 10

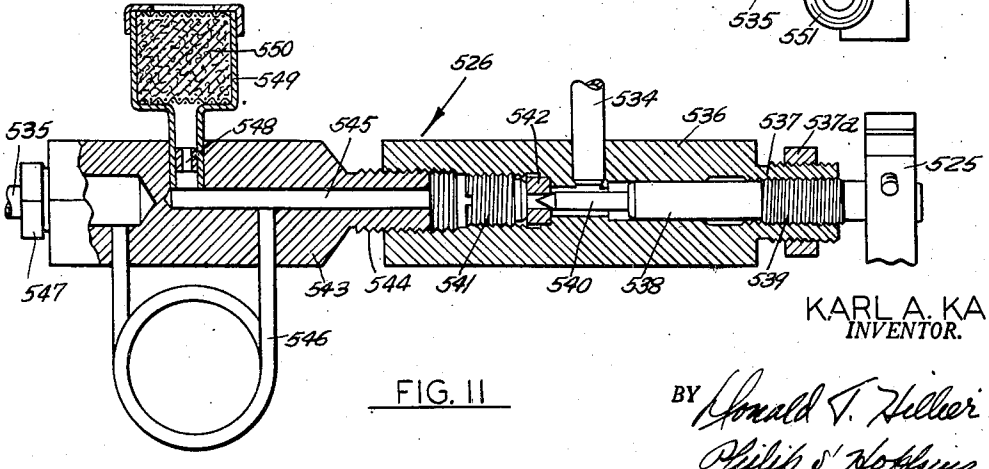


FIG. 11

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Oct. 18, 1949. K. A. KAIL 2,485,292

AVIATION TRAINER

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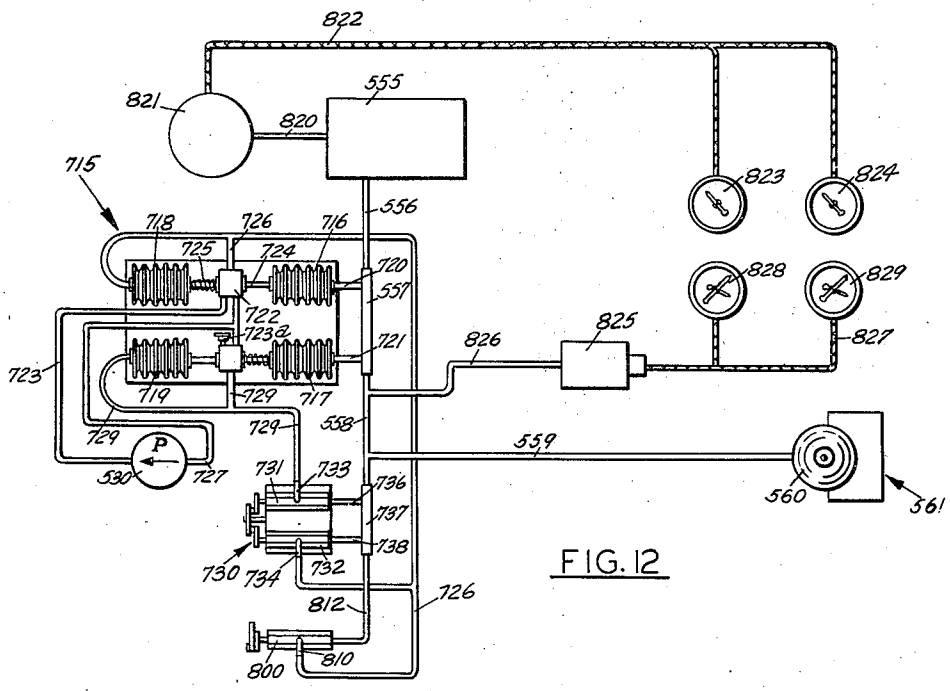


FIG. 12

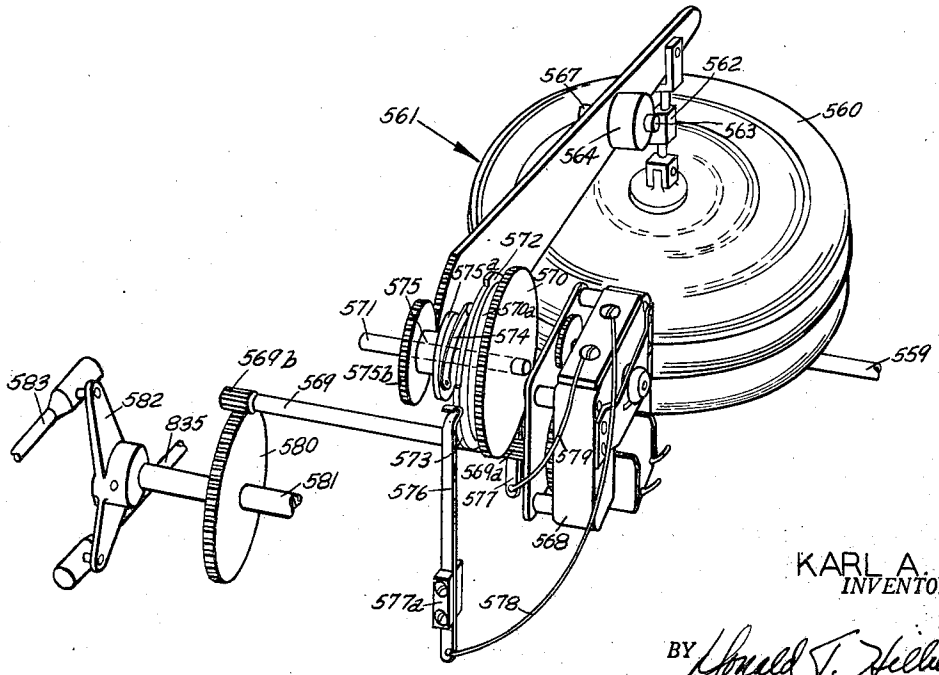


FIG. 13

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AVIATION TRAINER

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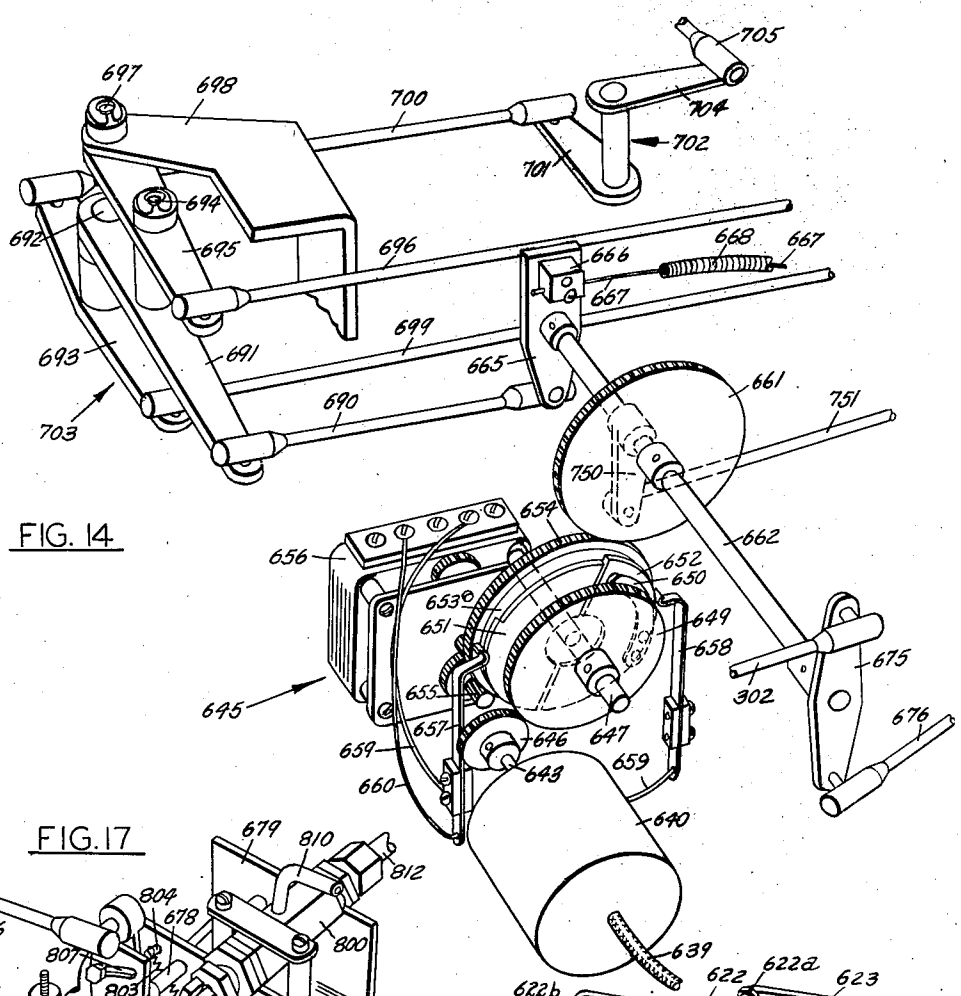


FIG. 14

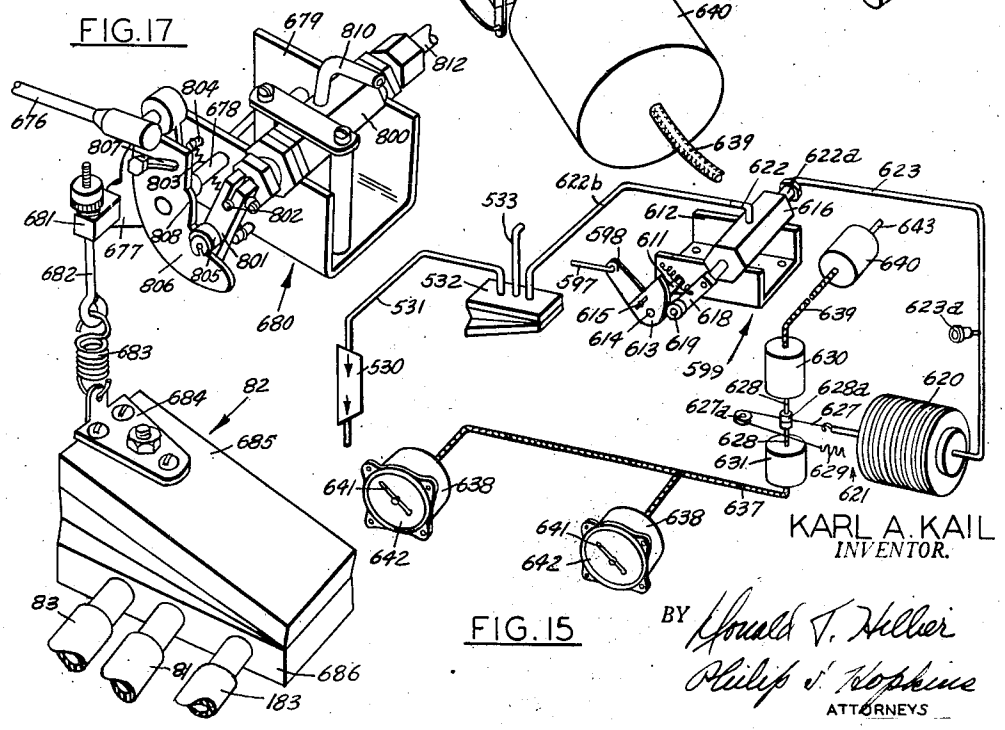


FIG. 15

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AVIATION TRAINER

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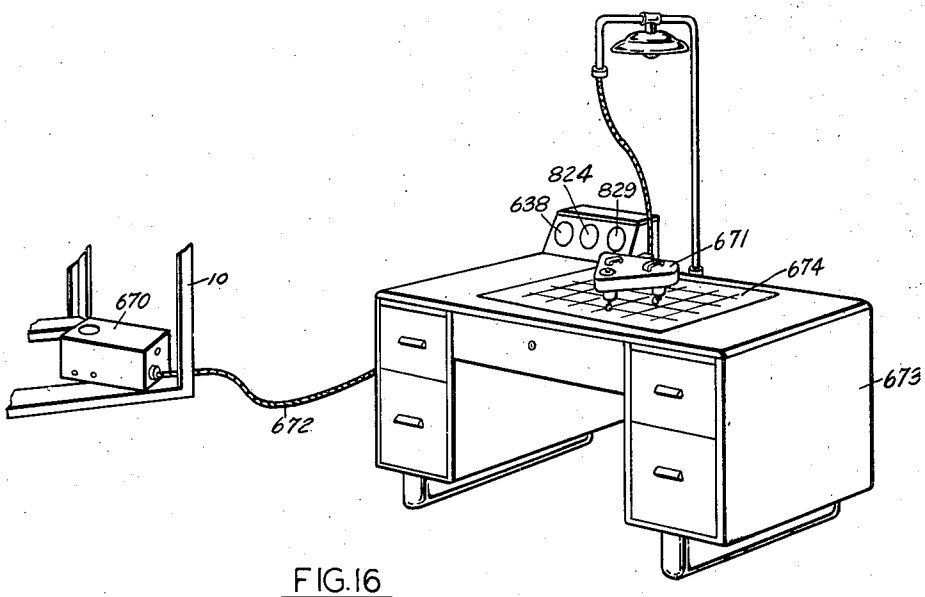


FIG. 16

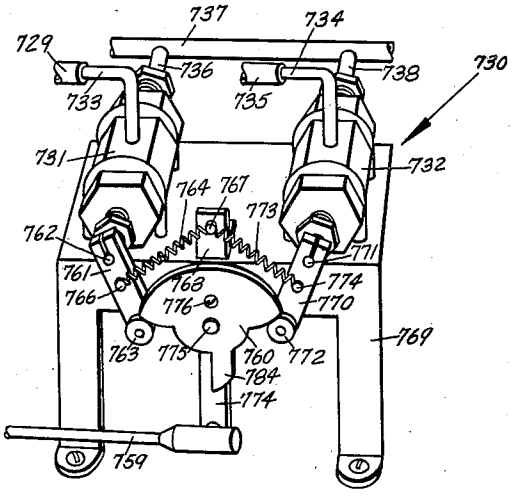


FIG. 18

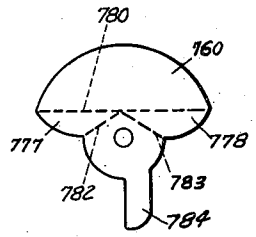


FIG. 18A

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Patented Oct. 18, 1949

2,485,292

UNITED STATES PATENT OFFICE

2,485,292

AVIATION TRAINER

Karl A. Kail, Montrose, Pa., assignor to Link Aviation, Inc., a corporation of New York

Application September 29, 1945, Serial No. 619,361

23 Claims. (Cl. 35—12)

1

This application, which is a continuation in part of my application Serial Number 601,776, filed June 27, 1945 for Simulated flight control loading and centering means for grounded aviation trainer relates to improvements in grounded aviation trainers which are widely used to instruct students in the art of flying aircraft, and will be illustrated in connection with trainers of the type disclosed in U. S. Patents 1,825,462 and 2,099,857. However, it will be appreciated that many of the improvements disclosed herein are applicable to other types of trainers, and the incorporation of my improvements in such trainers is intended to be covered hereby.

While trainers of the type disclosed in the above mentioned patents have been widely used with great success by the Army, Navy and civilian agencies, as well as by private organizations, the trainers known to the prior art were frequently criticised as not having the "feel" of an airplane. It is true that the prior art trainers could be turned by the simulated rudder pedals, banked by the simulated aileron control and pitched by the simulated elevator control, and also, the prior art trainers incorporated such features as turn with bank, bank with turn, nose down with turn, and turn tightening. However, many of the characteristics of an aircraft in flight were not present in such trainers. For example, in the flight of aircraft the engine power output produces a torque which tends, conventionally, to increasingly turn the plane to the left as the engine power and resultant torque increase. Also, an increase in air speed produces a tendency of the plane to turn to the right, while a decrease in air speed lessens this tendency.

At the same time, an increase or decrease in engine power output causes the plane to "hunt," and when the hunting has tapered out, the nose of the plane will be higher or lower, depending upon whether the power output was increased or decreased.

The above described torque and change in attitude as a result of a change in power output may, in most planes, be counteracted by the use of the trim tab controls provided in airplanes of the type which the trainers being considered simulate.

Also, a plane in actual flight will hunt about its transverse axis if the plane is placed in a climbing or diving position and the elevator control is then released.

In the case of a plane in actual flight, the plane will automatically turn in the direction of bank, but if sufficient opposite rudder is applied to prevent the plane from turning when it is banked, the inherent stability of the plane will cause the plane to assume level transverse flight.

2

It is an object of this application to disclose means in a grounded aviation trainer for simulating the previously outlined responses of planes in actual flight, in addition to retaining the listed prior art features of such trainers.

The prior art trainers also included a simulated air speed indicator responsive to the throttle lever setting and pitch attitude of the trainer fuselage. This application discloses means whereby the simulated air speed indicator indicates in accordance with the combined factors of pitch attitude and assumed manifold pressure or simulated engine output. In turn, the assumed manifold pressure is made a function of the combined factors of throttle lever setting, propeller governor control lever setting and assumed altitude. Assumed altitude is made to depend upon the factors of fuselage attitude and assumed air speed. Thus, assumed air speed affects assumed altitude which in turn affects assumed air speed through its influence on manifold pressure. These changes in the air speed and altitude systems are deemed to be important contributions to the art.

This application also discloses many other improvements such as cam operated instrument control valves, improvements to the conventional rudder valve, a mush valve for venting the altitude system to simulate a loss of altitude as a result of a loss of air speed, and means for simulating the difference between true and indicated air speeds. Also, a new method of centering the conventional climb-dive valves is disclosed.

In order that the exact nature of the improvements herein disclosed may be better understood, reference is made to the accompanying drawings, wherein

Fig. 1 is a general view of a grounded aviation trainer of the type being considered showing the general location of many of the major parts of this invention.

Fig. 2 is a detailed perspective view of the elevator control loading system, together with the elevator trim system.

Fig. 2A is a detail view showing the construction of the elevator and aileron control loading bellows.

Fig. 2B is a detailed exploded view of a typical control loading centering valve which may form a part of my invention.

Fig. 2C is a detailed showing of a typical control loading regulator bellows.

Fig. 2D is a detailed showing of a compensating spring arrangement which may be used in the practice of my invention.

Fig. 2E is a detail view of the cam arrangement shown generally in Fig. 2.

Fig. 3 is a detailed showing of the aileron control loading and trimming means.

Fig. 3A is a detailed view of the cam arrangement shown generally in Fig. 3.

Fig. 4 is a detailed showing of the rudder pedal loading and trim system.

Fig. 5 is a detailed perspective view of the universal joint and associated parts.

Fig. 6 is a perspective view showing the general relationship of many of the control systems of this invention.

Fig. 7 is a detailed exploded view of the construction of the main fuselage control valves.

Fig. 7A is a bottom view of the top leaf of the rudder valve.

Fig. 8 is a schematic view of the air speed system.

Fig. 9 is a detailed drawing of the manifold pressure unit.

Fig. 9A is a detailed showing of the switching arrangement of the apparatus shown in Fig. 9.

Fig. 10 is a schematic view of a portion of the manifold pressure system.

Fig. 11 is a cross-sectional view of a typical instrument control valve.

Fig. 12 is a schematic view of the altitude system.

Fig. 13 is a detailed drawing of the altitude torque amplifier.

Fig. 14 is a detailed drawing of the air speed unit and trim compound differential.

Fig. 15 is a drawing of a portion of the air speed system.

Fig. 16 is a showing of a portion of the trainer base, wind-drift unit, desk and recorder.

Fig. 17 is a detailed perspective view of the mush valve and air speed control loading regulator bellows.

Fig. 18 is an exterior drawing of the climb-dive valve assembly.

Fig. 18A is a detailed drawing of the cam associated with the climb-dive valves.

General description of trainer

Reference is now made to Fig. 1 which is a general disclosure of grounded aviation trainers of the type covered by U. S. Patents 1,825,462 and 2,099,857. Such trainers comprise a stationary base 10 above which is mounted a fuselage 12 simulating the fuselage of an actual aircraft. Within this fuselage there is a seat for a student positioned to the rear of the control wheel 30. The fuselage 12 rests upon a universal joint 14, shown in detail in Fig. 5, and this joint is supported by the pedestal 13 which is held by the main central vertical spindle 15 which is rotatably held by the stationary base 10. The conventional octagon is designated by 16 and as is well known to the prior art, octagon 16 is affixed to the main spindle 15 below the universal joint 14 and pedestal 13 by means of suitable horizontal arms 16*a* seen in Fig. 5 so that the octagon 16 rotates with the pedestal 13, spindle 15, universal joint 14 and fuselage 12 relative to the stationary base 10.

A forward pitching bellows 17 and a rearward pitching bellows 18 are provided, the bottom portions of each of these bellows being affixed to the arms 16*a* which hold the octagon 16 relative to the pedestal 13 and vertical spindle 15, and the upper ends of these bellows are affixed to the bottom 12*a* of the fuselage 12. These two bellows lie in a vertical plane through the longitudinal center of the fuselage 12. Upon the admission of vacuum to the forward bellows 17 and atmosphere to the rear bellows 18, the former bellows collapses and the latter expands causing the fuselage 12 to assume a diving attitude. On the other hand the admission of vacuum to the rear bellows 18 and of atmosphere to the fore bellows 17 causes the fuselage 12 to assume a climbing attitude. As will be more fully explained later, the admission of vacuum and atmosphere into the bellows 17 and 18 may be controlled by the student in the trainer by moving the control wheel 30 fore and aft of the fuselage 12, so that the student may control the diving and climbing position of the fuselage 12. The diving and climbing position of the fuselage are sometimes referred to hereinafter as "pitching."

At the same time, trainers of this type have a left banking bellows 19 as well as a right banking bellows 20 upon the opposite side of the universal joint 14 from the bellows 19. The admission of vacuum and air into these bellows may be controlled by the student through a rotation of the control wheel 30 so that he may place the fuselage 12 in any desired banking position within the limits of the apparatus.

Trainers of the type being considered are often equipped with a stick instead of a control wheel, and it will be readily apparent to those skilled in the art, after reading this specification, that they can substitute a stick for the wheel 30 and still obtain all of the advantages of my invention.

Fixedly carried by the octagon 16 are the horizontal arms 21 which support the turning motor 22. By means of a well known pulley arrangement connecting the turning motor 22 with the stationary base 10, the student in the fuselage 12 may, by pressing either of the rudder pedals 256, energize the turning motor 22 in such a direction that the turning motor 22, supporting arms 21, octagon 16, supporting arms 16*a*, bellows 17, 18, 19 and 20, spindle 15, pedestal 13, universal joint 14 and fuselage 12 will rotate either to the left or right, as desired, relative to the stationary base 10. Thus the student may control the simulated heading of the fuselage 12 in the same manner that he would control the heading of a plane in actual flight. The arms 25 are attached to the octagon and support the housing 25*a* in which may be placed a vacuum pump for operating the instruments in the trainer, as will be later more fully explained.

The steps 26 and door 26*a* allow access to the interior of the fuselage 12 and a slidable canopy 27 may be used to completely encompass the cockpit of the fuselage 12 in order to simulate blind flying conditions. The canopy 27 may be made of a suitable translucent material in order to permit enough light to enter the cockpit of the fuselage to enable the student to manipulate the trainer without the assistance of artificial lights placed in the interior of the fuselage. Such conditions closely simulate day-time blind flight conditions. On the other hand when it is desired to simulate night-time blind flying conditions, a suitable opaque material such as a cover may be placed over the canopy 27 in order that no light enters the cockpit through this canopy.

The student must then rely upon the conventional artificial lights which are placed inside the cockpit. Such an arrangement closely simulates night-time blind flying conditions.

An instrument panel 29 is inside the fuselage and upon this panel are instruments which simulate the instruments carried by actual aircraft. As is well known to the prior art, and as will be later explained more in detail, these instruments operate in response to simulated conditions just as the corresponding instruments in a real plane react to real flight conditions.

Simulated elevator control loading and trimming means

Referring now to Fig. 2, it will be seen that the control wheel in the fuselage is designated 30 and that this wheel is fixedly mounted upon the rear end of the forwardly extending shaft 32. As will become clear later in the description, the fore end of the shaft 32 is mounted in a bracket carried by the fuselage so that the shaft 32 may move axially. A pair of collars 34 are affixed upon shaft 32 as shown so that axial movement of the shaft 32, caused by the student's pushing or pulling the wheel 30, results in a pivoting of the upstanding members 38 which are pivotally mounted at their lower ends upon the horizontal transverse shaft 40 which is fixedly held by the bracket 42 mounted upon the floor of the fuselage as seen in Fig. 1. The upstanding members 38 are positioned with respect to one another by the crosspieces 44 and 46.

In Fig. 2 it will be seen that integral with the fixed bracket 40 are a plurality of upstanding members 48 which support a base plate (not shown) to which are attached the fixed, vertical, bellows supporting plates 50, these two plates being parallel and placed upon opposite sides of the elevator control loading bellows designated generally by 52.

Reference is now made to Fig. 2A which is a detailed disclosure of the construction of the bellows 52. In Fig. 2A it will be seen that the bellows 52 comprises a pair of end members 54 which are fixedly held by the plates 50 by means of screws 55. In the center of the bellows 52 is the main, generally upstanding, common bellows-forming member 56 pivoted at its bottom end by means of the rod 57 held by the plates 50. It will be seen that between the member 56 and each of the end members 54 is a rigid wooden member 58 each having a plurality of holes 59 therethrough. Two substantially airproof, flexible coverings 60 are provided, one on either side of the member 56 and attached thereto. In view of the described arrangement it will be appreciated that the bellows 52 in reality comprises two separate bellows, each having one fixed end in the form of its associated member 54 and each having a common movable central member in the form of the member 56. The left bellows seen in Fig. 2A is designated 52*a* and is connected through the port 61 and air-vacuum line with the three leaf elevator centering valve designated generally by 63. The right bellows in Fig. 2A is designated 52*b* and is connected through port 64 and vacuum-air line 65 with the elevator centering valve 63.

Reference is now made to Fig. 2B which shows the detailed construction of the elevator centering valve 63. As seen, this valve comprises a lower fixed leaf 66, a center movable leaf 67 and an upper movable leaf 68. Referring to Fig. 2 it will be seen that the lower fixed leaf 66 is affixed to the bracket 69 which in turn is affixed to the plates 70 and 71 which are affixed to the stationary side plates 50. Consequently the lower leaf 66 is fixed in relation to the interior of the fuselage 12.

Referring to Fig. 2B, it will be seen that fixedly mounted in the center of the lower leaf 66 is the vertical hollow stem 72 having a plug 73 in its upper end and a plurality of ports 74 in its side walls. Referring now to Fig. 2 it will be seen that the lower end of the hollow stem 72 is connected by means of the vacuum line 73 with the interior of the elevator control loading regulator bellows designated generally 74. The bellows 74 shown in detail in Fig. 2C comprises a lower fixed member 75 and an upper member 76 pivotally attached thereto. A suitable flexible, airtight covering 77 is provided. Attached to the upper pivoted member 76 is the plate 76*a* to which the lower end of the spring 127 is connected. Fixedly attached to the upper bellows member 76 is the needle 79 and a seat 80 is affixed to the lower member 75. Seat 80 is connected through the vacuum line 81 to the airspeed regulator bellows shown in Fig. 2 and designated generally 82. The air speed regulator bellows is connected by vacuum line 83 to the well known turbine 84 shown in Fig. 1.

As will be later more fully explained, the air speed control loading regulator bellows 82, located as shown in Fig. 1, is responsive to the climbing and diving movements of the fuselage 12 as well as to the simulated engine power output, so that the pressure within the air speed regulator bellows 82 is at all times inversely related to the assumed air speed of the fuselage. For convenience it may be stated that the higher the assumed air speed, the greater is the vacuum within the bellows 82.

Still referring to Fig. 2, the vacuum within bellows 82 manifests itself at all times in the central stem 72 of the lower fixed leaf 66 through the vacuum line 81, elevator control loading regulator bellows 74 and vacuum line 73, but as will later appear the bellows 74 controls the amount of vacuum in stem 72.

Referring to Fig. 2B it will be seen that a pair of vertical ducts 85 and 86 extend from the upper face of leaf 66 downwardly and partly through the leaf 66. Connecting with the duct 85 is the exterior port 85*a* which connects with the line 65 which, as seen in Fig. 2, connects with the right bellows 52*b* of the bellows assembly 52. Similarly, connecting with the duct 86 is the port 87 which connects with the line 62 which connects with the interior of the bellows 52*a* of the bellows assembly 52.

Referring again to Fig. 2B, it will be seen that the movable center leaf 67 has a central bore 88 adapted to receive the vertical stem 72 and that two ports 89 and 90 extend completely through the leaf 67. When the leaf 67 is assembled relative to the lower fixed leaf 66, leaf 67 being in the central or neutral position, the port 89 coincides exactly with the port 85 and the port 90 coincides exactly with the port 86.

In the upper movable leaf 68 are a pair of vertical ducts 91 and 92 which extend completely through the leaf 68. It will be appreciated that the upper ends of both of the ducts 91 and 92 are at all times connected with the atmosphere. Centrally located within the leaf 68 is the vertical bore 93 extending completely through leaf 68 and adapted to receive the stem 72 of the lower leaf. Communicating with the vertical bore 93 of leaf 68 is the transverse duct 94 which communicates

with the vertical duct 95 drilled in the lower face of the leaf 68.

When the three leaves of the valve shown in Fig. 2B are in the neutral assembled position, it will be appreciated that the vacuum in the stem 72 passes through the ports 74 in the stem into the ducts 94 and 95. In the neutral position, between the port 95 in leaf 68 and the ports 89 and 90 in leaf 67 there is no overlap, but the port 95 is tangent to the ports 89 and 90 so that a slight amount of vacuum leaks through the two latter ports. At the same time, in the central position, the atmosphere which is always present in the ports 91 and 92 cannot pass into either of the ports 89 or 90 because there is no overlap between the ports 91 and 89 on the one hand and ports 92 and 90 on the other. Consequently, when the leaves of the valve 63 are all in their neutral position, a slight amount of vacuum passes through the lines 62 and 65 into the bellows 52*a* and 52*b*, and the bellows are neutralized.

However, assuming that the upper leaf 68 is rotated counterclockwise from its neutral position, it will be appreciated that the vacuum port 95 will engage the port 89 which in the neutral position engages the port 85 of the lower leaf 66. At the same time the atmosphere port 92 will engage the port 90 which in the neutral position engages the port 86. Consequently, an increased amount of vacuum will be applied to the line 65 which connects with the interior of the bellows 52*b* and simultaneously atmosphere will be applied through the line 62 to the bellows 52*a*. The bellows 52*b* will therefore be contracted and the bellows 52*a* will expand. The common central member 56 will have a force applied thereto tending to move it to the right in Fig. 2 and by means of the clamping arrangement 57 and rod 44 the upper ends of the members 38 will tend to move toward the head of the fuselage. The shaft 32 and wheel 30 will have a force applied in the same direction.

On the other hand, it should be understood without a detailed explanation that when the three leaves of the valve 63 are in the neutral position, a clockwise movement of the upper leaf 68 will apply increased vacuum to the bellows 52*a* and atmosphere to the bellows 52*b*. The common central member 56 will have a force applied thereto tending to move it to the rear of the fuselage, and the shaft 32 and wheel 30 will have a tendency to move in the same direction.

Further, assuming that the leaves are in the neutral position and that the upper leaf 68 is moved counterclockwise to admit increased vacuum to the bellows 52*b* and atmosphere to the bellows 52*a*, it will be appreciated that a corresponding counterclockwise rotation of the center leaf 67 will shut off the passage of increased vacuum to the bellows 52*b* and will, at the same time, shut off the passage of air to the bellows 52*a*. The vacuum leak through the leaves when they are neutrally positioned will quickly neutralize the bellows 52*a* and 52*b*. On the other hand, with the leaves in their central position, should the upper leaf 68 be rotated clockwise to apply increased vacuum to the bellows 52*a* and air to the bellows 52*b*, a corresponding clockwise rotation of the center leaf 67 will shut off the passage of excess vacuum to the bellows 52*a* and air to the bellows 52*b*, and the two bellows will quickly become neutralized.

Referring again to Fig. 2, it will be seen that integral with the upper leaf 68 is the horizontal extension 96 which is pivotally connected by means of the stud 97 to the ball joint 98 affixed upon the forward end of the link 99. Affixed upon the link 99 is the stop 100 against which the forward end of the spring 101 compresses. Referring now to Fig. 2D, it will be seen that the rear end of spring 101 presses against the washer 102 encircling link 99. Integral with the link 99 is the enlarged portion 103 and encircling this enlarged portion is the sliding sleeve 104. A second washer 105 encircles link 99 and the fore end of a second spring 106 bears against washer 105. Stop 107 affixed upon link 99 positions the rear end of spring 106. Referring now to Fig. 2, it will be seen that the common bellows member 56 is attached to the sliding sleeve 104 so that the sleeve moves with member 56.

Assuming that the elevator centering valve is in the neutral position, in view of the preceding discussion it will be appreciated that the common bellows member 56 will also be in its neutral position. Consequently the bellows 52*a* and 52*b* will be neutralized. Now assuming that the student in the trainer desires to place the fuselage in a diving position, he will push the wheel 30 toward the head of the fuselage. The vertical members 38 will pivot about the rod 40, the upper ends of these members moving in the same direction as the wheel, and the upper end of the common bellows member 56 will also move toward the head of the fuselage. Sleeve 104 moves in the same direction compressing spring 101 and the compression of this spring acting upon the stop 100 moves the link 99 in the same direction. The upper valve leaf 68 will be rotated clockwise as seen from above and according to the previously explained operation of this valve, excess vacuum will be admitted to the bellows 52*a* and atmosphere will be simultaneously admitted to the bellows 52*b*. This admission of excess vacuum and air to these two bellows occurs as soon as the wheel 30 is pushed ahead of its neutral position. It will be appreciated that the admission of vacuum into the bellows 52*a* will tend to collapse the bellows 52*a* and the air admitted to bellows 52*b* will tend to expand the bellows 52*b*. Consequently a force resisting the forward movement of the wheel 30 will be immediately present. This closely simulates the loading placed upon the wheel of a plane in actual flight when the wheel is moved ahead of its neutral position.

When the wheel 30 is in its neutral fore and aft position, the valve 63 is in its neutral position. Should the wheel 30 then be moved by the student to the rear of the neutral position, the upper leaf 68 is rotated in the counterclockwise direction. Simultaneously, excess vacuum is applied to the forward bellows 52*b* and atmosphere to the rear bellows 52*a*. Thus a force is immediately present to resist the movement of the wheel 30 rearward from its neutral position, just as in the case of a plane in actual flight.

Assuming that with the wheel 30 and valve 63 in their neutral positions, the student pulls back on the wheel 30, excess vacuum is admitted to the forward bellows 52*b* and atmosphere to the rear bellows 52*a*. If then the student merely releases the wheel 30, the vacuum in the bellows 52*b* and atmosphere in the bellows 52*a* will move the common center member 56 toward the head of the trainer. The moving of the member 56 in this direction moves the wheel 30 ahead to its neutral position and simultaneously rotates the leaf 68 back to its neutral position. When the leaf 68 reaches its neutral position, the bellows 52*a* and 52*b* become quickly neutralized, and the wheel

30, member 56 and leaf 68 remain in their neutral positions. On the other hand should the student push the wheel 30 ahead of its neutral position, excess vacuum is admitted to bellows 52a and air to bellows 52b. If then the student releases the wheel 30, the bellows 52a and 52b move the member 56 and wheel 30 to the rear. The movement of member 56 simultaneously rotates leaf 68 to its neutral position, and when it reaches this position, the bellows 52a and 52b quickly become neutralized, and the wheel 30, member 56 and leaf 68 will be retained in their respective neutral positions.

In view of the foregoing disclosure the conclusion may be drawn that this invention discloses novel means whereby the control wheel 30 may have a force applied thereto tending to resist movement of the wheel in either direction from its neutral position. Also, when the wheel is moved from its neutral position and released, the wheel will return to its neutral position. Those skilled in the art of flying will appreciate that the bellows 52a and 52b act upon the control wheel 30 in the same manner that the slip stream of a plane in actual flight acts upon the wheel in the plane through its effect upon the elevator of the plane, to which the control wheel is connected.

It will be appreciated by those skilled in the art of flying and in the field of aviation trainers that as soon as the student moves the wheel 30 to the rear of its neutral position, the fuselage 12 should assume a climbing position and that when the student moves the wheel 30 ahead of its neutral position, the fuselage should assume a diving attitude. This response is obtained simultaneously with the loading of the wheel as described above by means of apparatus shown in part in Fig. 2. In that figure it will be seen that the link 110 is pivotally attached to the right vertical member 38 and the rear end of arm 110 is pivotally attached to the upper end of the lever 111. Lever 111 is pivotally connected to the rotor of the shock absorber 112 which is fixedly mounted upon the upstanding members 40 integral with the bracket 42. To the lower end of the lever 111 is pivotally connected the forward end of the link 113, the rear end of which is pivotally connected, as seen in Fig. 6, to the lower end of lever 113a which is pivotally mounted upon the fixed rod 113b. To the upper end of lever 113a is pivotally connected the rear end of link 113c, the forward end of which is pivotally connected to the outer end of arm 114 affixed to the upper leaf 356 of the elevator valve designated generally by 115. Reference is now made to Fig. 7 which shows in detail the construction of the elevator valve 115.

In Fig. 7 it will be seen that there is provided a hollow metallic manifold 114a fixedly mounted within fuselage 12 and connected by means of the vacuum line 114b with the turbine 84 seen in Fig. 1. As seen in Fig. 5, the vacuum connection 114b passes through the universal joint 14 and inside the main spindle 15 to the turbine. As seen in Fig. 1, manifold 114a is located to the right of the universal joint 14 inside fuselage 12. Manifold 114a is always evacuated to a reduced pressure by the turbine 84 or, as is often stated herein for convenience, is always provided with vacuum. In the center of the upper surface of the manifold 114a is the hole 350 adapted to receive in an air-tight fashion the central stem 351 of the elevator valve 115. The lower leaf of the elevator valve is designated 352 and this leaf

is fixedly mounted upon the top of manifold 114a by means of the screws 353 which fit into the top of manifold 114a by virtue of the tapped holes 354. Elevator valve 115 also comprises a center leaf 355 and a top leaf 356 and when assembled, the upper and lower flat surfaces of the center leaf 355 lie against the flat lower surface of upper leaf 356 and the flat upper surface of leaf 352, respectively. The lower leaf 352 has two vertical ports 357 and 358 which open through the upper surface of leaf 352. Port 357 is in communication with the horizontal fitting 359 which is connected by means of the flexible tubing 360 which the forward pitching bellows 17 shown in Fig. 1. Similarly, port 358 communicates with fitting 361 which is connected by means of flexible tubing 362 with the rear pitching bellows 18, seen in Fig. 1.

Center leaf 355 of the elevator valve is provided with a central bore 363, the lower portion of which is adapted to fit around the boss 364 integral with lower leaf 352. A pair of vertical ports 365 and 366 extend completely through the center leaf 355. An arcuate counter-bore 367 is placed in the lower surface of center leaf 355, this counter-bore having one end commonly formed with the lower end of port 365. A second counter-bore 368 bears a similar relation to the leaf 355 and vertical port 366.

The upper leaf 356 is provided with an integral cylindrical boss 369 and a port 370 is drilled completely through the upper leaf. A plug 371 is inserted in the upper end of port 370. The upper portion of central stem 351 is provided with a plurality of ports 372 so that the central vertical port 370 of the upper leaf 356 is at all times supplied with vacuum. Communicating with the central port 370 is the duct 373 which has an upper portion extending horizontally within leaf 356 and a lower vertical portion, also within leaf 356, communicating with the arcuate counter bore 374 placed in the lower face of leaf 356.

Also placed within the leaf 356 are the ports 375 and 376. Each of these ports has an upper horizontal portion emerging through the side of leaf 356 and a lower vertical portion emerging through the lower face of this leaf. Each of the ports 375 and 376 is therefore at all times in communication with the atmosphere.

In Fig. 7, the leaves 352, 355 and 356 are shown in their neutral rotative positions. When the leaves are in their operative assembled position, the arcuate counter-bore 374 slightly overlaps the ports 365 and 366. Also, the end of the counter-bore 367 slightly overlaps the port 357 and the end of counter-bore 368 slightly overlaps the port 358. Also, when the leaves are in their neutral positions, the lower end of port 375 is slightly displaced from port 365 and the lower end of port 376 is slightly displaced from port 366. Consequently, when the leaves of the elevator valve 115 are in their neutral positions the overlap of counter-bore 374 with respect to the ports 365 and 366 and the overlap of counter-bores 367 and 368 with respect to the ports 357 and 358 result in the application of a limited amount of vacuum to both the forward and rear pitching bellows 17 and 18. The bellows 17 and 18 are therefore equalized and the trainer fuselage 12 is longitudinally level.

It has been previously explained that the wheel 30 is connected to the upper leaf 356 of the elevator valve 115. At this point it may be stated that when the wheel 30 is in its fore-and-aft neutral position, the upper leaf 356 is in its neutral rota-

tional position. However, as seen in Fig. 2, when the wheel 30 is moved ahead of its neutral position, the link 113 moves to the rear. In Fig. 6, the reversing action of lever 113a results in a forward movement of link 113c and the upper leaf 356 of the elevator valve is rotated clockwise from its neutral position. Accordingly, as seen in Fig. 7, the counter-bore 374 overlaps port 365 by a greater amount and increased vacuum is applied to port 365. Through counter-bore 367 this increase of vacuum is applied to port 357 and by means of connector 359 and tubing 360 the increased vacuum is applied to the forward pitching bellows 17. Simultaneously therewith, the counter-bore 374 becomes out of engagement with the port 369 and the port 376 is brought into overlapping relation with the port 366. Atmosphere therefore is admitted to the port 366 and passes through the counter-bore 368, port 358, the connector 361 and flexible hose 362 to the rear pitching bellows 18. Consequently, a movement of the control wheel 30 ahead of its neutral position admits increased vacuum to the forward pitching bellows 17 and stops the application of vacuum to the rear bellows 18, applying to the rear bellows atmosphere. The forward bellows is therefore collapsed and the rear bellows is expanded, resulting in a lowering of the fore end of the fuselage 12 and a raising of the rear end of the fuselage. The fuselage therefore assumes a position simulating the diving attitude of a plane in actual flight. A real airplane, of course, assumes a diving attitude when the control wheel is pushed ahead of its neutral position.

On the other hand, assuming that the control wheel 30 is in its neutral position, the upper leaf 356 of the elevator valve 115 will be positioned in its previously described neutral position. A rearward movement of the control wheel from the neutral position will result in a counterclockwise rotation of upper leaf 356, causing counterbore 374 to move out of overlapping position relative to port 365 and causing atmosphere port 375 to overlap port 365. Consequently atmosphere will be applied to the fore pitching bellows 17. Simultaneously, counterbore 374 will be brought into greater overlapping position relative to port 366 and greater vacuum will be applied to rear pitching bellows 18. Bellows 18 is collapsed, bellows 17 expanded, and fuselage 12 assumes a climbing attitude.

For future reference it might be underscored at this point that when the control wheel 30 moves ahead of its neutral position, the leaf 356 is rotated clockwise from its neutral position, and when the control wheel 30 is moved to the rear of its neutral position, the leaf 356 is rotated counterclockwise from its neutral position.

Thus the conclusion may be drawn that as soon as the student in the fuselage moves the control wheel 30 ahead or to the rear of its neutral position, the fuselage assumes the proper diving or climbing attitude, and that a force is present to resist the movement of the control wheel from its neutral position, both of which responses occur in the case of a plane in actual flight. Assuming that the student in the fuselage has moved the wheel 30 from its neutral position, vacuum will be admitted to one of the bellows 52a or 52b and atmosphere to the other and the upper leaf of the elevator valve will be properly turned so that the fuselage will assume the correct pitching (climbing or diving) attitude. In the absence of other factors, as will be later explained, if the student merely releases the wheel 30, the bellows 52a and 52b will return the wheel 30 to its neutral position and at the same time the upper leaf of the elevator valve will also be returned to its neutral position. Simultaneously the upper leaf 68 of the elevator centering valve 63 will be returned to its neutral position. Consequently the fuselage will assume the level flight position, the wheel will be returned to its neutral position and the loading upon the wheel will disappear. This closely simulates the three responses which occur when the pilot of a plane in actual flight, having moved the wheel from its neutral position, merely releases the wheel. The shock absorber 112 dampens the return of the control column to its neutral position under the influence of bellows 52.

Those skilled in the art of flying will appreciate that the load which is placed upon the control wheel in a real plane as it is moved fore and aft of its neutral position increases the farther the wheel is moved from the neutral position. Furthermore, this load increases with an increase in the air speed of the plane. This application also discloses means for simulating these two factors which affect the load upon the wheel of a plane in actual flight as the wheel is moved from its neutral position.

Referring again to Fig. 2, it will be seen that the rear end of the link 116 is pivotally connected to the right upstanding member 38 and the forward end of this link is pivotally connected to the lower end of the lever 117 which is pivotally mounted upon the stud 117a held by bracket 71. To the upper end of lever 117 is pivotally connected the link 118, the fore end of which is pivotally attached to the upper end of the arm 119 which, as best seen in Fig. 2E, has its lower end pivotally attached to the plate 70 by means of stud 120. A stud 121 is integral with the arm 119 and a slide 122 has two slots 123 therein. The studs 120 and 121 pass through the slots 123 in member 122. Another stud 124 is fixedly carried by the upper end of the slide 122 and carried by this stud is the cam roller 125. A cam 126 is pivotally carried by the stud 120 and a spring 127 has its upper end attached to the lower end of slide 122, the lower end of spring 127 being attached to the extension 77a affixed upon the upper movable portion 76 of the bellows 74.

When the wheel 30 and the centering valve 63 are both in the neutral position, the cam roller 124 is centered with respect to the cam 126 and therefore a minimum of tension is exerted upon the spring 127. Consequently the vacuum present within the bellows 74 is at a minimum, e. g., one inch. As soon as the wheel 30 is moved from its neutral position, not only is the upper leaf 68 of the centering valve 63 rotated so as to cause the bellows 52a and 52b to exert a force upon the wheel 30 resisting the movement of the wheel from its neutral position, but simultaneously therewith the link 116 will be moved and through the operation of the lever 117 and link 118 the upper end of arm 119 will simultaneously be moved. The movement of the arm 119 will, by means of stud 121, cause a rotation of the slide 122 about an axis through the stud 120. Inasmuch as the cam 126 remains stationary, roller 125 will move out of the central neutral position with respect to cam 126, e. g., roller 125 will move to the left or right and simultaneously the cam 126 will force this roller upward, increasing the tension upon spring 127. The increased tension upon the spring 127 will result in a greater vacuum within the bellows 74, and consequently more vacuum will be applied to the centering valve 63.

Thus more vacuum will be applied to the bellows 52*a* or 52*b* as the wheel 30 is moved farther from its neutral position. The application of increased vacuum to the bellows 52*a* or 52*b* will, of course, result in an increase in the force resisting the movement of the control wheel 30 away from its neutral position. Consequently the greater the distance the control wheel 30 is moved from its neutral position, the greater will become the force opposing further movement of the control wheel.

For future reference, it should be noted that the cam roller 125 moves in a direction opposite the direction of movement of the wheel 30.

As far as the factor of the assumed air speed of the fuselage affecting the force resisting the movement of the control wheel 30 is concerned, at this point it is simply stated that the greater the assumed air speed of the fuselage the greater is the vacuum within the air speed control loading regulator bellows 82. The greater the vacuum within the bellows 82, the greater will be the vacuum within the bellows 74 and consequently the greater will be the vacuum applied to the bellows 52*a* or 52*b* upon a movement of the control wheel 30 from its neutral position. Consequently the force resisting a movement of the control wheel 30 from its neutral position is dependent upon the vacuum within bellows 82 which in turn is dependent upon the assumed air speed of the fuselage. Means for operating the bellows 82 in response to changes in assumed air speed will hereinafter be disclosed.

The elevator trimming means which may form a part of my invention will now be described. Referring to Fig. 2, it will be seen that the manually rotatable elevator trimming member 130 is provided, this member being affixed within the fuselage for rotation about the horizontal axis 131. By means of a right angle drive 132 the screw 133 may be rotated in response to a rotation of the control 130. Rotation of the screw 133 results in an axial movement of the nut 134 and a corresponding movement of the link 135, the rear end of which is attached to the nut 134 as shown. Movement of the link 135 results in a movement of the arms of bell crank 136 as well as in a movement of the link 137, the rear end of which is pivotally connected to the integral extension 67*a* of the center leaf 67 of the elevator centering valve 63.

Assuming that the student in the trainer finds that he must exert a constant fore or aft pressure upon the control wheel 30 in order to keep the fuselage in the desired climbing or diving position, it will be appreciated that simultaneously with the holding of the control wheel in the necessary position he will have displaced the upper leaf 68 of the elevator centering valve 63 a given distance from its neutral position. Instead of manually holding the control wheel 30 in the necessary off-center position to maintain the desired attitude of the fuselage, the student may hold the wheel 30 as required and simultaneously rotate the elevator trimming control 130 in the correct direction until the center leaf 67 of valve 63 again assumes a neutral position with respect to the upper leaf 68. In order to accomplish this result it will be appreciated that the center leaf 67 must be rotated in the same direction and through the same angle that the leaf 68 was rotated by the manual holding of the control wheel 30 from its neutral position. When the center leaf 67 has been rotated through this angle, it will be appreciated that it will prevent the application of excess vacuum and atmosphere to the

bellows 52*a* and 52*b*. The excess vacuum in the bellows 52*a* or 52*b* is quickly dissipated as soon as this neutral position is reached and the pressure upon the control wheel 30 is relieved. The control wheel remains in the same position in which it was held in by the student while he was rotating the trim control 130, and consequently the fuselage 12 remains in the same climbing, diving or level flight position.

Specifically, it may be stated that if the student finds that he must exert a constant back pressure upon the wheel 30 to maintain the fuselage in the desired pitching position, wheel 130 is rotated counterclockwise, nut 134 travels ahead, and the center leaf 67*a* is rotated counterclockwise until the trimmed position is reached. If the student must exert a constant forward pressure, wheel 130 is rotated clockwise to the correct trimmed position.

Accordingly with the apparatus disclosed in Fig. 2 the student in the trainer may trim the fuselage so that he does not have to exert a constant pressure upon the control wheel 30 in order to keep the fuselage in the desired pitching attitude. It will be appreciated that this trimming of the trainer may be used by the student to climb or dive the trainer at a given angle or to fly the trainer at a constant altitude.

It will be appreciated by those skilled in the art of flying that the trimming of one of the control surfaces to relieve the pressure upon the control associated with that surface establishes a new position for the control at which no pressure is present upon the control. As the control is then moved from this new position, a load is immediately placed upon the control, and the farther the control is moved from the trim-established zero pressure point, the greater becomes the pressure. If the control is released, the control surface and the control connected thereto return to the trim-established zero pressure point and not to the absolute neutral positions. The following means incorporated herein simulate this functioning of the control surfaces and controls of actual aircraft, as far as the elevator and fore and aft position of the wheel are concerned.

Referring to Fig. 2 it will be appreciated that as the nut 134 moves axially of the screw 133, the link 140 moves therewith. The bell crank 141 is turned and the transverse link 142 is moved resulting in a movement of the bell crank 143 and rearwardly extending link 144. The rear end of link 144 is pivotally attached to the lower end of the cam 126 through the universal connector 144*a*, and, consequently, the cam 126 moves whenever the elevator trimming control 130 is rotated. The movement of cam 126 will change the vertical position of roller 125 and consequently the tension upon spring 127.

Let us assume that the student must place the wheel 30 in a position to the rear of its neutral position in order to maintain the fuselage in the desired climbing attitude. In moving the wheel 30 from its neutral position it has been explained that the upper leaf of the valve 63 is rotated so as to admit vacuum to the bellows 52*b* and atmosphere to the bellows 52*a*. The elevator valve 115 is operated to place the trainer in the desired climbing attitude and the movement to the rear of the wheel 30 simultaneously results in a movement toward the head of the trainer of the cam roller 125. The roller 125 is raised and the tension upon spring 127 is increased—the farther the backward movement of wheel 30 the greater the relative motion between the roller 125 and

the cam 126. Then, when the student rotates the elevator trim control 130 counterclockwise in order to move the leaf 67 of valve 63 to relieve the pressure upon the wheel 30, the link 144 simultaneously moves toward the rear of the trainer and the cam 126 rotates clockwise about the pivot 120. This rotation of the cam 126 allows spring 127 to pull the slide 122 and roller 125 downwardly, and when the leaf 67 is positioned by the student in the neutral position with respect to the leaf 68, the roller 125 is in the lowermost position with respect to cam 126. Thus the trimming of the trainer relaxes the tension which is placed upon the spring 127 when the wheel 30 is moved away from its neutral position so that when the elevator is properly trimmed, a normal or neutral tension is placed upon spring 127. As previously explained, the wheel 30 will remain displaced from its absolute neutral position and in the position in which the student had to hold the wheel to maintain the fuselage in the desired climbing position. Consequently, thereafter, should the student desire to move the wheel 30 farther to the rear, the pressure which he must exert upon the wheel is decreased by the amount that he removed when he had previously trimmed the trainer. Thus the trimming of the elevator by the student establishes a new neutral pressure point just as is the case in actual flight.

It will be appreciated that if the student finds he must hold the wheel forward to maintain the fuselage in the desired diving position, when he trims the fuselage he will establish a new zero pressure point.

In a flight of actual aircraft equipped with elevator trimming means, the climbing and diving position of the plane may be controlled by a manipulation of the elevator trimming control. Thus, when it is desired to lower the nose of the plane the trim tab control may be rotated in the proper direction resulting in a movement of the elevator so that the nose drops. As the elevator moves, the control wheel moves to the fore. On the other hand, when it is desired to raise the nose of the plane, the trim control may be rotated in the opposite direction, the elevator moves in the opposite direction, and the nose of the plane rises. The wheel moves to the rear with the movement of the elevator. The previously disclosed simulated elevator trimming means of this invention may also be used to simulate this sometimes used method of controlling the climbing or diving attitude of a plane in actual flight.

Referring to Fig. 2, assuming that the wheel 30 and leaves of valve 63 are centered, if the student rotates the control 130 clockwise, the center leaf 67 of valve 63 is rotated clockwise admitting vacuum to the bellows 52*b* and air to the bellows 52*a*. The central bellows member 56 moves ahead, carrying with it the wheel 30, and the elevator valve 115 is operated to place the fuselage in a diving position. The forward movement of the member 56 simultaneously causes a clockwise rotation of the leaf 68 of valve 63. Bellows 52*b* will be collapsed, moving member 56 ahead and rotating leaf 68 clockwise until this leaf is again neutrally positioned with respect to the leaf 67. When this position is reached the member 56 is stopped, the pressures within bellows 52*a* and 52 become neutralized, and the wheel 30 is held ahead of its neutral position at a point depending upon angular movement of the simulated elevator trim control 130. The nose of the fuselage will be lowered as a result of the rotation of the upper leaf of the elevator valve 115.

An opposite rotation of the simulated elevator trim control 130 will produce reversed movements of the same parts of the apparatus just considered.

In view of the detailed disclosure of the preferred embodiment of my simulated elevator trimming means for use in grounded aviation trainers, is will be understood that I have provided apparatus which accomplishes the following results:

1. In the neutral position there is no load upon the control wheel, but as the wheel is moved ahead or to the rear of the neutral position, a load is immediately placed upon the wheel to resist the movement of the wheel and this load increases the farther the wheel is moved from its neutral position. The fuselage, simultaneously with a movement of the wheel from its neutral position, assumes the proper climbing or diving attitude.

2. When the wheel is moved from its neutral position the load placed upon the wheel is dependent upon the assumed air speed of the trainer—the higher the assumed air speed the greater the load.

3. The student may use the provided simulated elevator trimming means to relieve the pressure from the control wheel when he finds that he must exert a constant pressure upon the wheel in order to keep the trainer in the desired climbing or diving attitude. In using the simulated elevator trimming means the student holds the wheel in the correct position in order to maintain the correct climbing or diving attitude of the fuselage and then operates the simulated elevator trimming means until the pressure has been removed from the wheel, just as he would do in actual flight. When this point is reached the simulated elevator trimming means are properly positioned and the wheel is not moved as a result of the movement of the trimming means. The operation of the simulated elevator trimming means establishes a new neutral point insofar as pressure upon the wheel is concerned.

4. Alternatively, the simulated elevator trimming control may be used by the student to change the pitching attitude of the fuselage, just as the elevator trimming control in a real plane may be used to change the pitching attitude of the plane. When this method of operation is used the fore and aft position of the wheel as well as the position of the upper leaf of the elevator valve changes with the rotation of the simulated trimming control.

Simulated aileron loading and trimming means

Reference is now made to Fig. 3 which discloses in detail the preferred embodiment of the simulated aileron loading and trimming means which may form a part of my invention. In Fig. 3 the wheel 30 and main shaft 32 upon which the wheel is affixed are shown. A bracket 160 is fixedly attached to the interior of the fuselage 12 some distance above the floor thereof and the bracket 161 is fixedly attached to the bracket 160. A plurality of upstanding members 162 integral with bracket 161 support the aileron control loading bellows assembly designated generally by 163. This bellows assembly, for all practical purposes, is identical with the elevator control loading bellows assembly shown in Fig. 2. A pair of side plates 164 are provided, these plates holding in a fixed position the end members 165 of the two

bellows of the assembly. A common central member 166 is provided to form two independent bellows, the left bellows being designated 163a and the right bellows being designated 163b. The vacuum-air line 167 connects bellows 163a with the aileron centering valve designated generally by 168 while the vacuum-air line 169 connects the bellows 163b with the valve 168. The aileron centering valve 168 is of identical construction as the elevator centering valve 63 shown in detail in Fig. 2B.

Still referring to Fig. 3, it will be seen that there is affixed on the shaft 32 a gear 170 meshing with the sector 171. The arm 172 is integral with sector 171 and the lower end of link 173 is pivotally connected to the outer end of arm 172. The upper end of link 173 is pivotally connected to the rear arm of bellcrank 174, this bellcrank being pivotally mounted on the transverse shaft 175 held by the brackets 176 which in turn are held by the rigid sideplates 164. To the upper end of bellcrank 174 is pivotally attached the rear end of link 177, the fore end of which is pivotally connected to the top of the common bellows forming member 166. Link 178 is provided, this link having its fore end attached to the common bellows member 166 through a compensating spring arrangement designated generally by 179, this spring arrangement being identical with that disclosed in Fig. 2D. The rear end of the link 178 is connected to the upper rotatable leaf 180 of the valve 168.

The central stem of the aileron centering valve 168 is connected through the vacuum line 181 to the aileron control loading regulator bellows designated generally by 182. This bellows is constructed the same as the bellows shown in Fig. 2C and is connected through the vacuum line 183 to the airspeed control loading regulator bellows designated generally by 82. As previously described, bellows 82 is connected to the turbine 84.

In view of the marked similarity of the construction shown in Fig. 3 to that previously described in connection with Fig. 2, it should be understood that when the wheel 30 is in its neutral rotational position (to be distinguished from the neutral fore and aft position), the upper rotatable leaf 180 of the aileron centering valve 168 is in its neutral position. When the middle leaf 184 of this valve is also centered, the bellows 163a and 163b have equal pressure therein and consequently there is no load upon the wheel 30. However, assuming that the student in the trainer turns the wheel counterclockwise as he would do to bank the fuselage to the left, through the gear 170, gear sector 171 and arm 172, link 173, bellcrank 174 and link 177, the upper end of the common bellows member 166 would be pushed ahead, member 166 pivoting about the axis 185. This movement of member 166 results in a movement to the head of the fuselage of link 178 and the upper leaf 180 of the aileron centering valve 168 is rotated counterclockwise. Immediately, increased vacuum is applied to the interior of the bellows 163b and air to the interior of the bellows 163a. Consequently, a force is instantly present upon movement of the wheel 30 from its neutral position tending to resist such movement of the wheel.

On the other hand, should the wheel 30 be moved clockwise of its neutral position it will be appreciated that the direction of rotation of the leaf 180 will be reversed and increased vacuum will be applied to the interior of the bellows 163a while atmosphere will be applied to the interior of the bellows 163b. Similarly, as soon as the wheel is moved clockwise of its neutral position the bellows 163a and 163b operate to exert a force resisting the movement of the wheel 30.

If the wheel 30 is rotated from its neutral position it will be appreciated that if the student merely releases the wheel the bellows 163a and 163b will return it to its neutral position. A shock absorber 171a having affixed upon its rotor the arm 171b is provided, arm 171b being actuated by stud 171c affixed to the lower extension 171d of sector 171. This shock absorber dampens the return of wheel 30 to its neutral position under the influence of the bellows 163.

As soon as the wheel 30 is rotated from its central or neutral position, the fuselage should, of course, bank to the left or right, the direction of bank depending upon the direction of rotation of the wheel 30 from its neutral position. This response is accomplished by the following described apparatus. As seen in Fig. 3, affixed to the sector 171 for rotation therewith is the rearwardly extending shaft 188 upon the rear end of which is affixed the arm 189. The upper end of link 190 is pivotally connected to the outer end of arm 189, and as seen in the upper right portion of Fig. 3, to the lower end of the vertical link 190 is pivotally attached the left end of arm 191. The other end of arm 191 is affixed to the fore end of shaft 192 which runs rearwardly to the arm 193, the lower end of which is affixed upon shaft 192. To the upper end of arm 193 is pivotally connected the left end of link 194, the right end of which is pivotally connected to the upper leaf 382 of the aileron valve designated generally by 196. The position of the aileron valve 196 in the trainer fuselage is shown in Fig. 1 and the detailed construction of this valve is shown in Fig. 7, to which reference is now made.

In Fig. 7, it will be seen that the aileron valve is designated generally by 196 and that this valve includes a lower leaf 380, a middle leaf 381 and an upper leaf 382. When assembled in the operative position, the lower leaf 380 is affixed upon the top of manifold 114a by means of the screws 383 (only one shown) which are adapted to fit inside the tapped holes 384 (only one shown). Leaf 380 has a central bore in which fits the central stem 385 which is adapted to fit inside the hole 386 in the top of manifold 114a. Emerging through the upper face of leaf 380 is the port 387 which communicates with the fitting 389 which is connected by means of the flexible hose 390 with the left banking bellows 19. A second port 391 also emerges through the upper face of leaf 380 and is in communication with the fitting 393 which connects with the right banking bellows 20 through the flexible hose 394. A circular boss 395 is integral with the leaf 380 and the central bore 396 of the middle leaf 381 fits around boss 395. A vertical port 397 extends completely through leaf 381 and the lower portion of port 397 is common with the left end of the arcuate counter-bore 398 placed in the bottom of leaf 381. A second vertical port 399 extends completely through leaf 381 and the lower portion of this port is common with the left end of the arcuate counter-bore 400, also formed in the bottom of leaf 381.

Integral with the upper leaf 382 is the boss 401. A vertical port 402 is provided in the center of leaf 382 and a plug 403 is placed in the upper end of this port. The upper portion of

central stem 385 has a plurality of holes 404 drilled therein and it will be seen that the upper portion of this stem extends into the central port 402 of the upper leaf 382. A duct 405 in leaf 382 communicates with central port 402 on the one hand, and with the arcuate counter-bore 406 in the lower face of leaf 382. A port 407 emerges through the side of leaf 382 and is in communication with the port 408 which emerges through the lower face of this leaf. Similarly, a port 409 emerges through the opposite side of leaf 382 and is in communication with the port 410 which emerges through the lower face of leaf 382, 180 degrees from the port 408.

By virtue of the explained construction of the main aileron valve 196, it will be appreciated that vacuum supplied from manifold 114*a* is present at all times in the port 402 in the upper leaf 382, and, also in the arcuate counter-bore 406 of this same leaf. When the three leaves of this valve are in their neutral rotational positions, the channel 406 slightly overlaps the ports 397 and 399, and, in the neutral position, these last two ports coincide with the ports 387 and 391 in the lower leaf 380. The atmosphere ports 408 and 410 are slightly offset from the ports 397 and 399, respectively. Accordingly, with the leaves of this valve in their neutral positions, a slight amount of vacuum is applied at all times through the flexible hoses 390 and 394 to the left and right banking bellows 19 and 20. The fuselage 12 is then transversely level.

However, when the control wheel 30 is rotated counterclockwise from its neutral position, by means of the described linkages, the upper leaf 382 seen in Fig. 7 is rotated counterclockwise. The channel 406 is moved into an increased overlapping position with respect to port 397. Consequently, a greater amount of vacuum is applied to ports 397 and 387. By means of fitting 389 and flexible hosing 390, this increased vacuum is applied to the left banking bellows 19. Simultaneously, the channel 406 is moved out of its overlapping position with respect to port 399 and the atmosphere port 410 is moved into engagement with port 399. Atmosphere passes through port 391 and to the right banking bellows 20 by means of fitting 393 and flexible hose 394. The application of greater vacuum to the left banking bellows 19 and the application of atmosphere to the left bellows 20, instead of the slight vacuum normally applied to bellows 20, results in a contraction of bellows 19 and an expansion of bellows 20. The fuselage 12 is, as a result, banked to the left. Consequently, a rotation of the control wheel 30 from its neutral rotational position results in a rotation of the upper leaf 382 counterclockwise from its neutral rotational position and the fuselage 12 banks to the left, just as a real plane in actual flight banks to the left when the control wheel is rotated counterclockwise from the neutral position.

On the other hand, should the control wheel 30 be rotated clockwise from its neutral position, the upper leaf 382 is rotated clockwise from its neutral position. Increased vacuum is applied to the ports 399 and 391 and consequently to the right banking bellows 20. At the same time, atmosphere port 408 engages port 397 admitting atmosphere to this port and through fitting 389 and flexible hose 390, atmosphere is admitted to the left banking bellows 19. The application of increased vacuum to the right bellows 20 and the application of atmosphere to the left banking bellows 19, instead of the normal slight vacuum

admitted to the left banking bellows 19, results in a banking of the fuselage 12 to the right. Accordingly, a rotation of the control wheel 30 clockwise from its neutral position results in a banking of the fuselage 12 to the right, just as in the case of a real plane in actual flight where the rotation of the control wheel clockwise from its neutral position results in a banking of the plane to the right.

For future reference it might be underscored at this point that when the control wheel 30 is rotated counterclockwise from its neutral position the upper leaf 382 of the aileron valve 196 is rotated counterclockwise from its neutral position, and that a clockwise rotation of the control wheel 30 from its neutral position also results in a clockwise rotation of the upper leaf 382 from its neutral position.

Assuming that the control wheel 30 is in the neutral position and that the leaves of the main aileron valve 196 are similarly positioned, when the student in the trainer rotates the wheel 30 counterclockwise of its neutral position, the bellows 163*a* and 163*b* not only instantly exert a force tending to resist the rotation of the control wheel but simultaneously therewith the upper leaf 382 of the aileron valve 196 is rotated counterclockwise and the trainer banks to the left. On the other hand, should the wheel 30 be rotated clockwise of its neutral position, the bellows 163*a* and 163*b* similarly exert a force tending to resist the movement of the control wheel and simultaneously therewith the upper leaf 382 of the aileron valve 196 is rotated clockwise and the trainer banks to the right.

As explained above in connection with the simulated elevator system of this invention, in the case of actual aircraft as the wheel is moved fore and aft to operate the elevators of the plane the resistance to movement of the wheel caused by the slipstream increases the farther the control wheel is moved from the neutral position. The same is true in actual aircraft as far as movement of the ailerons and aileron control is concerned. The following means may form a part of this invention to simulate this phenomenon of actual flight.

Referring to Fig. 3, it will be seen that the fore end of the link 200 is pivotally connected to the central bellows member 166 and the rear end of this link is pivotally connected to the lower end of lever 201 which is pivotally mounted on the stud 202 carried by the plate 164. The fore end of link 203 is pivotally connected to the upper end of lever 201 and the rear end of this link is pivotally attached to the upper end of arm 204 which is mounted for rotation upon the stud 205 held by the plate 206 which in turn is held by the plates 176 and 207 affixed to the main sideplate 164. Referring to Fig. 3A, the stud 207*a* is carried by arm 204 and passes through a slot 208 in the slide 209. A second slot 210 is in the slide 209, stud 205 passing through the slot 210. Affixed to the lower end of slide 209 is the spring 211, the lower end of which is affixed to the upper movable portion 212 of the aileron control loading regulator bellows 182. This bellows is also carried by the plate 206. The cam 213 is pivotally mounted upon the stud 205 and the upper end of slide 209 carries a stud 214 upon the outer end of which is rotatably mounted the roller 215, roller 215 engaging the surface of cam 213.

It will be appreciated that an arrangement similar to the one just described has been dis-

closed in connection with the simulated elevator system.

Assuming that the control wheel 30 and the leaves of the aileron centering valve 168 are in their respective neutral rotational positions, the roller 215 is in its lowermost position with respect to cam 213. Then assuming that the student moves the control wheel 30 counterclockwise of its neutral position, the fuselage banks through the operation of the aileron valve 196 and simultaneously therewith the link 177 moves the central bellows member 166 ahead. Link 178 moves ahead and the upper leaf 180 of the aileron centering valve 168 is rotated counterclockwise as seen from above, admitting increased vacuum to the bellows 163*b* and atmosphere to the bellows 163*a*, thus producing a force opposing the movement of the wheel 30. Simultaneous with the movement of the bellows member 166, the link 200 moves ahead and the link 203 moves to the rear. The arm 209 rotates clockwise about the stud 205 and by means of the stud 207*a*, the slide 209 is rotated in the same direction about the stud 205. Inasmuch as cam 213 remains stationary, roller 215 is moved upward by its coaction with cam 213 and the tension upon spring 211 is increased. Consequently, the vacuum within the regulator bellows 182 increases and a greater amount of vacuum is applied through the centering valve 168 to the bellows 163*b*. The farther the control wheel 30 is moved from its neutral position the greater becomes the vacuum within bellows 163*b* and consequently the greater becomes the force opposing further movement of the wheel 30. Consequently, as the wheel 30 is moved a greater distance counterclockwise of its neutral position, the greater becomes the vacuum within bellows 163*b* and the greater is the force opposing the movement of the wheel. This simulates the increasing force tending to resist the counterclockwise rotation of the wheel in actual flight as the wheel is moved farther from its neutral position.

On the other hand, should the wheel 30 be moved clockwise of its neutral position, it will be appreciated that the fuselage assumes a right banking position, increased vacuum is admitted to the bellows 163*a* and air to the bellows 163*b*. The movement of the central bellows member 166 simultaneous with a rotation of the wheel 30 results in a counterclockwise rotation of the arm 204 about the axis of stud 205. A similar rotation of the slide 209 will occur and the roller 215 will be forced upward by the cam 213. The tension upon spring 211 will increase as will the vacuum within the regulator bellows 212. Consequently, the vacuum within bellows 163*a* will increase the farther the wheel 30 is moved from its neutral position and thus with increased rotation of the wheel 30 a proportionately greater force is exerted tending to resist the movement of the wheel.

Referring again to the procedures of actual flight for purposes of comparison, if the pilot in the plane finds that he must constantly hold the wheel in a given rotational position in order to keep the plane in the desired banking position he may, if his plane be so equipped, trim the ailerons to relieve the pressure upon the wheel. When this has been done the plane will fly in the desired banking position.

This phase of actual flight may be simulated by the following means which are disclosed by this application. Referring to Fig. 3, the aileron trimming control which is manually operated is designated by 220 and is affixed upon the rear end of the horizontal shaft 221, upon the fore end of which is affixed the gear 222. Gear 222 meshes with the gear 223 which is affixed upon the lower end of the flexible shaft 224 inside the conventional flexible shaft sheathing 224*a*. Referring to the upper center portion of Fig. 3, the continuation of flexible shaft 224 is shown and this flexible shaft drives the screw 225 rotatably mounted in the bracket 226 which is carried by the plate 206. A nut 227 is mounted upon the screw 225, this nut carrying the stud 228 which engages the left end of the rod 229. The other end of rod 229 is connected to the integral extension 184*a* of the middle leaf 184 of the aileron centering valve 168.

In view of the just described arrangement, if the student finds that the wheel 30 must be held in a given counterclockwise rotational position in order to place the trainer in the proper banking position, it will be appreciated that in so holding the wheel he will have moved the upper leaf 180 of the centering valve 168 to a given position counterclockwise of its neutral position. This position of the upper leaf 180 will have admitted increased vacuum to the bellows 163*b* and air to the bellows 163*a* so that a force must be constantly exerted upon the wheel 30 to hold it in the necessary position. The student may then by a counterclockwise rotation of the simulated aileron trim control 220 and the described intermediate connections move the nut 227 to the right along screw 225. In so moving the nut 227 the center leaf 184 of the centering valve 168 is rotated counterclockwise. When the leaf 184 has been rotated counterclockwise of its neutral position through the same angle as the leaf 180 was rotated by the clockwise rotation of wheel 30, the leaves 180 and 184 are neutrally positioned with respect to one another and the same amount of vacuum leaks through the valve 168 into the bellows 163*a* and 163*b*. The pressure within the bellows 163*a* and 163*b* is rapidly equalized and the central bellows member 166 remains in the position in which it was placed by the original counterclockwise rotation of the control wheel 30. Accordingly, the force exerted by the bellows 163*a* and 163*b* upon the central member 166 disappears and the force tending to rotate the wheel 30 clockwise simultaneously disappears. The wheel 30 remains in the position in which it was held by the student before he regulated the simulated aileron trim control 220 and the banking position of the fuselage remains unchanged.

It will be understood without a detailed explanation that should the student find that he must hold the wheel 30 in a given position clockwise from its neutral position in order to maintain the fuselage in the desired position about its longitudinal axis, a clockwise rotation of the simulated aileron trim control 220 through the correct angle will properly position the center leaf 184 of the centering valve 168 relative to the top leaf 180 so that the force exerted by the bellows 163*a* and 163*b* tending to rotate the wheel 30 counterclockwise will disappear, leaving the wheel 30 in the position in which it was being held by the student. Accordingly the pressure is removed from the wheel and the fuselage maintains the banking position in which it was placed by the student holding the control wheel before he manipulated the simulated aileron trim control 220.

Accordingly it will be appreciated that this invention discloses means whereby when the student finds that he must hold the control wheel **30** in a given rotational position in order to maintain the fuselage in the correct banking position, he may, by means of the simulated aileron trim control, relieve the pressure from the wheel just as he would do in actual flight.

It was explained in connection with the simulated elevator trimming means of this application that in actual flight the trimming of the elevators of the plane establishes a new zero point insofar as pressure upon the wheel caused by the slipstream is concerned. The same is true when the ailerons of a real plane in actual flight are trimmed and the following means may form a part of this invention in order to simulate this effect of the trimming of the ailerons of a plane in actual flight. Referring to Fig. 3 it will be seen that the stub **230** is affixed to the nut **227** for movement therewith and that the lower end of this stud engages the right end of the link **231**, the left end of which is pivotally attached to the rear end of the upper arm **232** of the bell crank designated generally **233**. Bell crank **233** is held by the bracket **234** affixed to the stationary plate **206**. The lower member of the bell crank **233** is designated **235** and to this lower arm is pivotally attached the rear end of link **236**, the fore end of which is pivotally connected to the lower end of cam **213**.

It has been explained that when the student rotates the wheel **30** from its neutral position, the farther the wheel is rotated the increasing rotation of the slide **209** results in an upward movement of the roller **215** because of the presence of cam **213**. Consequently the greater the distance wheel **30** is rotated from its neutral position, the greater becomes the tension upon spring **211** and the resultant increase in vacuum within the regulator bellows **182** results in a greater force acting upon the central bellows member **166**. Assuming that the student finds that he must hold the wheel **30** in a given counterclockwise position from its neutral point, it has been explained that the central bellows member **166** will be moved ahead of its neutral position. Link **200** similarly will be moved ahead of its neutral position and link **203** will be moved to the rear. The arm **204** will be rotated clockwise from its neutral position and the roller **215** will be moved to the rear of the center of cam **213**. Then, assuming that the student desires to use the simulated aileron trimming control **220** to remove the pressure upon the wheel **30**, he will rotate the control knob **220** counterclockwise and the nut **227** moves to the right, link **231** will move in the same direction and by means of the bell crank **233**, link **236** will move ahead of its neutral position. Consequently the cam **213** will be rotated clockwise and when the center leaf **184** of the centering valve **168** is neutralized with respect to the upper leaf **180**, the cam **213** will be positioned such that the roller **215** is in the center of this cam. Consequently roller **215** will be in its lowermost position and the tension upon spring **211** will be relaxed to a minimum. Consequently, if the student thereafter desires to manually move the control wheel **30** from the trimmed position, the load which will be instantly placed upon the wheel will not be dependent upon the position of the wheel with respect to the absolute zero position, but will be dependent upon the position of the wheel from the new neutral position established by the trimming of the simulated aileron control. This simulates the establishing of the new zero pressure point when the ailerons of a plane in actual flight are trimmed. It will be appreciated that a new zero pressure point is also established when the simulated aileron trim control **220** is rotated counterclockwise to obviate the necessity of the student's holding the wheel in a given clockwise position from its neutral point in order to maintain the fuselage in the desired banking position.

Without a detailed explanation it should be understood that with the wheel **30** and simulated aileron trim control **220** positioned so that no pressure is upon the wheel, a clockwise rotation of the simulated aileron trim control **220** will result in a clockwise rotation of the wheel **30** and a banking of the fuselage to the left. On the other hand, a counterclockwise rotation of the control **220** will, under the same circumstances, result in a counterclockwise rotation of the wheel **30** and a banking of the fuselage to the right. These rotations of the wheel **30** in response to a rotation of the control **220** occur because the valve **168**, responsive to the control **220**, operates the bellows **163***a* and **163***b* which then moves the wheel **30** through the intermediate connecting members.

The load placed upon the wheel **30** when it is moved from its neutral rotational position is dependent upon the assumed air speed of the fuselage because bellows **182** is connected to the air speed control loading regulator bellows **82** by line **183**.

Insofar as the simulated aileron control trimming means disclosed by this invention is concerned, it will be appreciated that the similarity in structure produces the same novel results as explained in detail toward the end of the discussion of the simulated elevator trimming means.

Simulated rudder loading and trimming means

Reference is now made to Fig. 4 which discloses in detail the simulated rudder loading and trimming means of this application. In Fig 4 it will be seen that there is provided a pair of brackets **250**, these brackets being affixed to the inside of the fuselage a substantial distance above the floor at a point ahead of the student's seat, as seen in Fig. 1. A pair of rods **251** are held by the brackets **250**, and pivotally carried by each of the rods is a ratchet member **253**. Also pivotally carried by each of the rods **251** is a depending U-shaped bracket **254** having rotatably mounted in the lower portion thereof a transverse shaft **255** upon each of which is fixedly mounted one of the rudder pedals **256**. Fixedly attached to the inner end of each of the shafts **255** is an arm **257** to the rear end of each of which is pivotally attached a generally upstanding link **258**, the upper end of each of which is pivotally attached to its associated bracket **250**. An arm **252** is affixed to each of the ratchets **253**, as shown, and pivotally attached to the bottom end of each of the arms **252** is a forwardly extending link **259**, the forward end of each of which is pivotally connected to one end of the rudder bar **260** which is pivotally mounted upon the stud **261** carried by the bracket **262** which is fixed to the bottom of the fuselage floor. A dog **263** is pivotally carried by each of the U-shaped brackets **254**, and it will be appreciated that by selectively positioning the engaging end of each dog with respect to the teeth in the adjoining ratchet **253**, the rudder pedals **256** may be positioned according to the individual re-

quirements of the student using the trainer. The springs 264 assure the constant engagement of the dogs and ratchets.

Affixed to the left depending arm 252 is the rear end of the forwardly extending rod 265 which is affixed to the rear portion 266 of the left rudder control loading bellows designated generally by 267. It will be seen that this bellows comprises a central member 268 and a forward member 269 as well as the suitable covering material 270. A plurality of holes 268a and 268b are drilled through member 268, as shown.

The rod 271 has an enlarged forward end and is fixed to the forward end 269 of bellows 267. The forward end of this rod is pivotally attached to the lower end of the arm 272 carried by the fixed bracket 250. It should be noted that the rear end of the rod 271 passes through the central member 268 of the bellows 267 and telescopes inside the rod 265.

A rod 274, bellows designated generally 275, rod 276 and arm 277 are provided, these parts being constructed exactly like the corresponding members just described. The left rudder control loading bellows 267 is connected by means of the air-vacuum line 278 to the rudder centering valve designated generally by 279 and the right rudder control loading bellows 275 is connected by means of the air-vacuum line 280 to centering valve 279. Valve 279 is of identical construction with the elevator centering valve designated generally by 63 in Fig. 2 and shown in detail in Fig. 2B. In Fig. 4 it will be noted that the upper rotatable leaf 281 of valve 279 has attached thereto the rear end of the link 282, the forward end of which is pivotally connected to the rudder bar 260. It will be noted that the central portion of the valve 279 is connected by means of the vacuum line 283 directly to the turbine 84.

Assuming that the rudder pedals 256 are in their neutral positions and that the leaves of the valve 279 are similarly positioned, should the student desire to turn the fuselage to the left he will of course press forward upon the left rudder pedal. The left link 259 moves ahead, the rudder bar 260 rotates clockwise as seen from above, and simultaneously therewith the right link 259 moves to the rear, thus pushing the right rudder pedal 256 toward the rear of the fuselage. Simultaneously, with the rotation of the rudder bar 260, the link 282 moves ahead and the upper leaf 281 of the valve 279 is moved clockwise. Immediately air is introduced into the bellows 267 through the line 278 and increased vacuum is introduced into the bellows 275 through the line 280. The expansion of the bellows 266 and the contraction of the bellows 275 immediately exert a force tending to oppose the forward movement of the left rudder pedal 256. This opposing force resisting the movement of the rudder pedal 256 simulates the effect upon the slipstream of the rudder of an actual plane when the pilot presses the left rudder pedal forward.

On the other hand, with the rudder pedals 256 in their neutral position should the student push the right rudder pedal 256 forward, it will be appreciated that the rudder bar 260 will rotate counterclockwise, the link 282 will move to the rear and the upper leaf 281 of valve 279 will be rotated counterclockwise. Instantly, air will be admitted to the interior of bellows 275 and increased vacuum to the interior of bellows 267. Both of the bellows will, therefore, resist the forward movement of the right rudder pedal 256, again simulating the load upon the rudder pedals of a plane in actual flight caused by the slipstream.

A capillary is placed in both of the lines 278 and 280 to prevent a sudden over-application of vacuum to the bellows 267 and 275.

It will be appreciated that whenever the rudder pedals 256 are displaced from their neutral positions, the fuselage 12 should rotate with respect to the stationary base 10—to the left when the left rudder pedal is forward and to the right when the right rudder pedal is forward. In Fig. 4 it will be seen that the fore end of link 310 is pivotally connected to the rudder bar 260 and, also referring to Fig. 6, it will be seen that the rear end of link 310 is pivotally connected to the lower end of the lever 415 which is pivotally mounted upon the horizontal stub shaft 416 in turn held by bell crank 417 which is pivotally mounted upon the shaft 418 held by manifold 114a. To the upper end of lever 415 is pivotally connected link 417a, the rear end of which is pivotally attached to the outer end of arm 418 which is fixedly attached to the upper leaf 420 of the rudder valve designated generally by 421.

Reference is now made to Fig. 7 which discloses in detail the construction of the rudder valve designated generally 421. The upper leaf of this valve is designated 420 and the lower leaf is 422. A hollow central stem 423 is provided and fits inside the hole 424 placed in the top of manifold 114a. A pair of screws 425 adapted to coact with the holes 426 (only one of each shown) in the top of manifold 114a fixedly attach the lower leaf 422 to the manifold. An arcuate counterbore 427 is placed in the upper face of leaf 422 and this counterbore 427 connects with the exterior fitting 428 which in turn is connected by means of the hose 430 with the extension 431 of fitting 361 shown to be attached to the lower leaf 352 of the elevator valve 115. The purpose of this connection will be later described.

Emerging through the upper face of leaf 422 of the rudder valve 421 is the port 432 connected by means of the interior duct 433 with the fitting 434 which is connected by means of hose 435 with the extension 436 which is connected to the fitting 359 attached to the lower leaf 352 of the elevator valve 115 shown in Fig. 7. The purpose of this connection will also be later described.

Also emerging through the upper face of leaf 422 are the two ports 437 and 438 which communicate with the exterior fittings 439 and 440 respectively. Fitting 439 is connected by means of hose 441 with one side of the turning motor 22 and fitting 440 is connected to the other side of the turning motor through hose 442.

The peculiar shape of the ports 437 and 438 should be particularly noted. Each of these ports is generally L-shaped, the upstanding portions being relatively large and curved at their upper ends while the outer portions 437a and 438a are thinner and squared at their ends.

Integral with the lower leaf 422 is the circular boss 443 adapted to fit inside the central bore 444 of the upper leaf 420. Integral with the upper leaf 420 is the circular boss 445. The upper end of stem 423 extends through the central port 444 of leaf 421 and a plug 446 is placed in the upper end of port 444 to render the same air-tight. A plurality of holes 446 are placed in the upper end of stem 423.

A pair of vertical ports 447 and 448 extend completely through the upper leaf 420 and are

arranged so that when the leaves are assembled in their neutral operative positions the lower ends of each of the ports **447** and **448** are slightly displaced from the ends of the arcuate counterbore **427** placed in the upper face of lower leaf **422**.

Communicating with the central port **444** in the upper leaf **420** is the interior duct **449** which communicates with both of the ports **450** and **451** which emerge through the lower face of leaf **420**, as also seen in Fig. 7A. The ports **450** and **451** are arranged so that when the upper leaf **420** is neutrally assembled with respect to the lower leaf **422** each of the ports **450** and **451** is slightly displaced from and upon opposite sides of the port **432** which is in the lower leaf.

The interior duct **452** in upper leaf **420** communicates with the port **453** which emerges through the lower face of leaf **420**. In Fig. 7A it will be seen that the port **453** has a round central portion and two generally V-shaped notches **454** and **455**. The points of the V-shaped notches are flush with the lower face of leaf **420** and their upper surfaces slant upwardly to communicate with the central port **453** a slight distance above the face of leaf **420**.

It will be seen that the duct **452** communicates with the counterbore **458** in the lower face of leaf **420** through the restriction **457**. Counterbore **458** is shaped as seen in Fig. 7A.

Still referring to Figs. 7 and 7A, there is provided in upper leaf **420** a port **460** emerging through the side of leaf **420** and communicating with the port **461** emerging through the lower face of leaf **420**. It will be seen that port **462** emerges through the side of leaf **420** opposite port **460**, and port **462** communicates with the port **463** which emerges through the lower face of leaf **420**. The port **461** communicates with the square-ended counterbore **461***a* in the lower face of leaf **420**, and port **463** communicates with a corresponding counterbore **463***a*.

When leaf **420** is in its neutral position, counterbore **461***a* is slightly offset from the straight edge of port **437**, and counterbore **463***a* is slightly off-set from the straight edge of port **438**.

When the leaves of the rudder valve **421** are assembled in their neutral operative position it will be appreciated that atmosphere is at all times present in the ports **447** and **448**, and that vacuum is always present within the counterbores **450** and **451**. When the leaf **420** is neutrally positioned there is no overlap between the ports **447** and **448** and the counterbore **427**, nor is there any overlap between the counterbores **450** and **451** with respect to the port **432**. Consequently, neither vacuum nor air is applied to the hoses **430** and **435**.

Also, it will be appreciated that vacuum is at all times present in the port **453** and its V-shaped notches and in port **458**, but when the upper leaf **420** is neutrally positioned there is no overlap between the port **453** and its V-shaped notches **454** and **455** with respect to the ports **437** and **438**. However, the points of the V-shaped notches **454** and **455** are then only slightly displaced from the main portion of the ports **437** and **438**. Similarly, vacuum is always present within the counterbore **458** in the upper leaf **420**, and when leaf **420** is in its neutral position there is no overlap between the counterbore **458** and the extensions **437***a* and **438***a* of ports **437** and **438**. However, the counterbore **458** is only slightly displaced from the extensions of the ports **437** and **438**.

Further, when the upper leaf **420** is in its neutral position the port **461** is slightly clockwise from port **437** and the port **463** is slightly counterclockwise from port **438**.

In view of the foregoing explanation of the positions of the ports in the upper leaf **420** with respect to the lower leaf **422**, when the upper leaf is in its neutral position it will be realized that no vacuum or air is applied through the hoses **441** and **442** to the turning motor **22**, and consequently the fuselage **12** maintains a constant heading. Furthermore, when the upper leaf **420** is in its central position neither vacuum nor air is applied to the hoses **430** and **435** which connect with the hoses **362** and **360**, which go to the fore and rear banking bellows **17** and **18**.

However, assuming that the student in the fuselage **12** pushes the left rudder pedal **256** slightly ahead of its neutral position, it will be appreciated that the upper leaf **420** of the rudder valve **421** will be rotated clockwise from its neutral position. The knife-edge closure between the counterbore **458** and the extension **437***a* disappears and sufficient vacuum is applied through the restriction **457** to the extension **437***a* of port **437** and thence to the turning motor through hose **441** to overcome the friction in the turning motor and between the main central spindle **15** and stationary base **10**. Consequently, the fuselage **12** rotates very slowly to the left. As the left rudder pedal **256** is pressed farther forward, the notch **454** comes into communication with the port **437** and a larger volume of vacuum is applied to the turning motor through the hose **441**. The speed of rotation of the fuselage **12** is therefore somewhat increased. This increase in the rotation of the speed of the fuselage continues as the left rudder pedal **256** is pressed farther forward until the main port **453** engages with the port **437**, at which time the speed of rotation of the fuselage **12** is a maximum.

With the novel port arrangement incorporated in the rudder valve **421** it will be appreciated that the upper leaf **420** must be exactly centered in order to prevent a rotation of the fuselage **12**. Likewise with only a very slight displacement of the left rudder pedal **256** to the fore, a slight turning of the fuselage **12** only results. As the rudder pedal is pushed farther ahead the proportionate rate of turning of the fuselage **12** is increased. The disclosed rudder valve **421** permits a close simulation of the effect of the positions of the rudder pedals in a plane in actual flight upon the heading of the plane.

When the upper leaf **420** is rotated clockwise from its neutral position, as a consequence of the pressing forward of the left rudder pedal in the fuselage **12**, it will be appreciated that the counterbore **450** will engage the port **432** and that vacuum will be applied through the hose **435** to the fitting **359** which connects through the hose **360** with the forward pitching bellows **17**. At the same time, the port **447** will engage the counterbore **427** and atmosphere will be applied through the connection **430** to the fitting **361** which connects with the rear pitching bellows **18** through the hose **362**. The admission of vacuum to the fore pitching bellows **17** and air to the rear pitching bellows **18** will cause the fore pitching bellows to contract and the rear pitching bellows to expand. The fuselage **12** will therefore assume a diving attitude. The extent of the pitching of the fuselage **12** as a result of the rotation of the upper leaf **420** of the rudder valve **421** will depend upon the amount of rotation of the upper leaf **420** from its neutral posi-

tion, and consequently upon the forward displacement of the left rudder pedal 256 from its neutral position. Consequently, it may be concluded that the fuselage 12 noses down whenever the fuselage 12 rotates to the left and that the extent of the nosing down is proportional to the rate of turn of the fuselage.

On the other hand, should the right rudder pedal 256 be moved ahead on its neutral position, it will be appreciated that the upper leaf 420 will be rotated counterclockwise and counterbore 458 engages the extension 438a of port 438 and vacuum is applied to the opposite side of the turning motor 22. Sufficient vacuum is applied through the restriction 457 and counterbore 458 to overcome the friction in the turning motor and between the main spindle 15 and stationary base 10. The fuselage 12 consequently rotates slowly to the right. A further pressing forward of the right rudder pedal 256 brings the V-shaped notch 455 into engagement with the port 438 and the rate of turning of the fuselage 12 to the right is slightly increased. As the right rudder pedal 456 is pushed farther ahead, the main port 453 engages the port 438 and the rate of turning of fuselage 12 is even greater until when the main port 453 is directly above the port 438 the rotation of the fuselage 12 to the right is a maximum.

The counterclockwise rotation of the leaf 420 from its neutral position, as a result of the pressing forward of the right rudder pedal 256, also brings the port 451 into engagement with the port 432 and again vacuum is applied to the forward pitching bellows 17. At the same time the port 448 comes into engagement with the counterbore 427 and atmosphere is applied to the rear pitching bellows 18. Again, the trainer assumes a diving attitude and the extent of this nosing down of the fuselage 12 is proportional to the rate of turn of the fuselage 12 which depends upon the displacement of the upper leaf 420 from its neutral position.

In view of the above explanation, it will be appreciated that the fuselage 12 rotates to the left or right at a rate dependent upon the displacements from the exact neutral position of the rudder pedals 256, and that the direction of rotation is dependent upon the direction of displacement of the rudder pedals. Further, the fuselage 12 noses down by an amount proportional to the rate of turn of the fuselage.

Also, in the case of actual aircraft when one of the rudder pedals is moved forward, the other moves to the rear, and if the pilot removes his foot from the forward pedal the slipstream pressure upon the rudder centers the rudder, and inasmuch as the rudder pedals are connected to the rudder they also are centered. The apparatus disclosed in Fiy. 4 simulates this response of the rudder pedals in actual flight. If the left rudder pedal 256 is forced ahead of its neutral position, air is admitted to the bellows 267 and excess vacuum to the bellows 275. These two bellows thus exert a force upon both of the rudder pedals tending to return them to their neutral positions. Conseqently, if the student removes his foot from the left rudder pedal, the bellows will return the rudder pedals toward their neutral positions and when they reach their neutral positions the upper leaf 281 of valve 279 will be centered, equalizing the pressure within the bellows and thus preventing further movement of the rudder pedals.

Without a detailed explanation it will be understood that should the right rudder pedal be moved forward and the left rudder pedal moved to the rear, when the student releases his foot from the right pedal the bellows will return the pedals and upper leaf 281 to their neutral positions, at which points the rudder pedals remain.

In both cases it will be noted that when the rudder pedals are displaced from their neutral positions the upper leaf 420 of the rudder valve 421 will be displaced from its neutral position in the proper direction so that the trainer turns to the left or right and the nose drops. When the rudder pedals are returned to their neutral positions by the bellows, the upper leaf 421 is simultaneously returned to its neutral position and the turning and nosing down of the fuselage stops.

Under most flying conditions, most planes will not fly perfectly straight with the rudder in the dead center position. If the plane is not equipped with rudder trimming means it is necessary for the pilot to hold the rudder pedals in the correct position in order to keep the plane flying a straight course. Different pressures will have to be applied under different circumstances. For example, on the take-off it may be necessary to apply a great deal of right rudder in order to keep the plane flying straight down the runway. In cruising, left rudder may be necessary. Changes in engine power and air speed, as will be later explained in detail, affect the turning of the plane. In order to render it unnecessary for the pilot to apply a given amount of rudder over a long period of time, in order to keep the plane flying the desired course, aircraft of the type being simulated generally are equipped with rudder trimming means whereby the plane may be trimmed in order to keep it flying the desired course without the pilot's constantly applying a corrective pressure to the rudder pedals.

Simulated rudder trimming means are also provided by this invention and for a disclosure thereof reference is made to Fig. 4 where the simulated manual rudder trimming control is designated by 290. Upon a manual rotation of the knob 290, the right angle drive 291 causes a rotation of the shaft 292 upon the forward end of which is affixed the screw 293. A nut 294 coacts with screw 293 to travel longitudinally thereof upon a rotation of the screw, and stud 295 travels with the nut 294. A bracket 296 is affixed to the interior of the fuselage 12 and the lower end of arm 297 is pivotally mounted upon this bracket. A horizontal extension 298 is integral with arm 297 and pivotally connected to extension 298 is the upper end of the walking beam 299. Walking beam 299 is pivotally mounted on stud 295 as shown. Integral with the lower end of walking beam 299 is the horizontal extension 300, and pivotally mounted upon the right end of this extension is the lower end of arm 301. A pair of links 302 and 303 are pivotally attached to arm 301 and beam 229 as shown. As will be later explained, link 302 is connected to means within the fuselage responsive to changes in the assumed airspeed of the fuselage. Consequently the link 302 always assumes a position dependent upon the assumed airspeed. Also, as will be later explained, link 303 is connected to the simulated throttle lever in the trainer so that it moves in response to changes in the assumed engine power. Insofar as understanding the operation of the simulated rudder trim control of this invention is concerned, at this point the links 302 and 303 may be considered stationary, thus pro-

viding a fixed pivot for the lower end of the walking beam 299.

Affixed to the arm 297 is the rear end of link 304, the forward end of which is affixed to the upper arm of bell crank 305. The left end of link 306 is pivotally attached to the lower arm of bell crank 305 and the right end of this link is pivotally attached to the center leaf 307 of the rudder centering valve 279.

Whenever the student in the fuselage finds that he must apply a constant pressure to one of the rudder pedals in order to maintain the fuselage upon the desired heading, it seems clear that the upper leaf 281 of the valve 279 will be displaced from its neutral position and consequently that the bellows 267 and 275 will exert a constant force tending to return the rudder pedals to their neutral positions. The rudder valve 312 will be positioned so that the fuselage maintains the desired heading.

Instead of so positioning the rudder pedals by means of his feet, the student may by rotating the simulated rudder trim control 290 move the nut 294 in the desired direction. Movement of this nut results in a pivoting of the walking beam 299 about its lower end and the arm 297 is pivoted about its lower end. Link 304 moves in the correct direction, as does link 306, the center leaf 307 of the valve 279 rotates in the correct direction until it is centered with respect to the upper leaf 281. When this point is reached the pressures within the bellows 267 and 275 become quickly neutralized, relieving the pressure upon the rudder pedals, but neither of the bellows is returned to its neutral position. Consequently, the positions of the rudder pedals 256 are not changed and neither is the relative positions of the leaves of the rudder valve 312. Accordingly, the trainer maintains the desired heading.

Specifically, let us assume that the student in order to maintain the fuselage upon the correct heading finds that he must exert a constant pressure upon the left rudder pedal 256. The upper leaf 281 of the control valve 279 will be rotated clockwise a given distance from its neutral position while the upper leaf of the rudder valve 312 will be rotated a given distance counterclockwise from its neutral position. Atmosphere will be admitted to the bellows 267 and vacuum to the bellows 275. The student will then rotate the simulated rudder trim control 290 counterclockwise as seen from above and the nut 294 moves toward the head of the fuselage. The middle leaf 307 of the valve 279 will be rotated clockwise and when this leaf is centered with respect to the upper leaf 281 the pressure within the two bellows 267 and 275 will become quickly neutralized. The position of the rudder pedals 256 and of the upper leaf of the rudder valve 312 will be undisturbed with the releasing of the pressure caused by the bellows upon the rudder pedals.

It should be noted that the load placed upon the simulated rudder pedals, when the pedals are moved from their neutral positions, is independent of the assumed airspeed of the trainer and of the extent which the pedals are moved from from their neutral positions. However, such means may be provided, in view of the above disclosure relating to the aileron and elevator systems, if such means are desired.

Means for producing the factor of assumed manifold pressure

Reference is now made to Fig. 8 which is a schematic drawing of the air speed system which forms an important part of this invention. It will be seen that the legend shows that when a connecting member is designated by the letter "E," the connection is electrical in nature; when the letter "M" is used, the connection is mechanical; and when the letter "V" is used, the connection is a vacuum line.

It will be seen that the throttle lever is connected mechanically to the manifold pressure engine unit; the propeller governor control lever is connected by a vacuum line to the manifold pressure engine unit; and that the altitude tank in the fuselage is connected through a vacuum line to the altitude torque amplifier which is mechanically connected to the manifold pressure valve which in turn is connected through a vacuum line to the altitude follow-up motor. The altitude follow-up motor is mechanically connected to the manifold pressure engine unit. Thus in the apparatus to be disclosed the factors of throttle lever position, propeller governor lever position and assumed altitude are combined by a manifold pressure engine unit whose output represents the factor of assumed manifold pressure. Detailed means for combining these three factors to produce assumed manifold pressure will now be disclosed.

Considering first the factor of throttle lever position, reference is now made to Fig. 4 where the throttle lever is designated 465. Lever 465 is pivotally mounted upon the rod 466 which is affixed inside the fuselage 12 in a proper position relative to the seat. Integral with the throttle lever 465 is the arm 467 to which is pivotally attached the upper end of vertical link 468.

Pivotally attached to the lower end of link 468 is the link 478, the other end of which is also pivotally attached to the fore end of bell crank 479 which is pivotally mounted upon the rod 480 affixed within the interior left side of fuselage 12. To the lower end of bell crank 479 is pivotally attached the forward end of link 481. Referring now to Fig. 6 it will be seen that the rear end of link 481 is pivotally attached to the upper end of arm 482 which is a part of the manifold pressure engine unit designated generally in Fig. 6 by 483.

Reference is now made to Fig. 9 which is a detailed disclosure of the construction of the manifold pressure engine unit designated generally by 483. In Fig. 9 the rear end of the link 481 which is moved by the throttle lever is shown, as is the arm 482. It will be seen that the block 484 is integral with the arm 482 and that block 484 is rotatably mounted upon rod 485 which is fixedly held in the frame 486 shown in Fig. 6. Frame 486 is rigidly attached to the bottom of the fuselage 12. Two shafts 487 and 488 are rotatably mounted in the block 484. Upon the outer end of the shaft 487 is mounted the spur gear 489 while upon the outer ends of the shaft 488 are mounted the spur gears 490 and 491. Meshing with gear 489 is the spur gear 492 which is affixed to the large spur gear 493 which is rotatably mounted upon shaft 485. Gear 493 is driven by the shaft 494 splined at 494*a* and which in turn is driven by motor 495.

A suitable reduction gear train may be interposed between the motor 495 and the spline 494*a*.

Still referring to Fig. 9, rotatably mounted upon the fixed rod 485 and driven by gear 491 is the spur gear 496 which is affixed to the insulating ring 497 to rotate the same. Affixed to the insulating ring 497 are the two split contact segments 498 and 499. Considering now Fig. 9

in conjunction with Fig. 9A, it will be seen that the insulating disc 497 carries the split contact segments 498 and 499 by means of rivets 500. Rotatably mounted upon the fixed rod 485 is the drum 501 carrying the contact segment 502. A string 503 has its forward end wound around the drum 501 and attached thereto, while the rear end of this string is attached to the spring 504 which has its rear end attached to the arm 505, which in turn is attached to the frame 486 of the unit.

Integral with the drum 501 is the gear 506 which is positioned by the gear sector 507. The gear sector 507 is pivotally mounted upon the circular block 508 integral with the rod 509 which is affixed in frame 486. Spring 504 and string 503 bias drum 501 to remove the backlash between gear 506 and sector 507. A second spring 516 is affixed to the fixed member 505 as shown, and affixed to the spring is the string 517 which winds around and is anchored to the drum 518 which is affixed to the contact segments 498 and 499. This spring and string arrangement biases the segments 498 and 499 to remove the backlash between these segments and motor 495.

A pair of contacts 510 and 511 are carried by the insulating members 519 in turn held by frame 486 so as to engage the contact segments 498 and 499 as better seen in Fig. 9A. Each of the contact segments 510 and 511 is connected to motor 495 by one of the conductors 512 and 513, and the contact 502 is grounded. Motor 495 is of the type that when contact 502 is in engagement with both of the contact segments 498 and 499 the motor is deenergized. When the contact 502 engages only the contact segment 498, motor 495 is energized to turn in one direction, and when contact 502 engages only the other contact 499, motor 495 is energized to turn in the opposite direction.

Assuming that the contact 502 is engaging both of the contact segments 498 and 499, the motor 495 will be at rest. If the throttle lever 465 is then pushed ahead, i. e., that is to the left in Fig. 4, the link 468 moves upwardly with the movement of the throttle lever. The upward movement of link 468 results in a movement ahead of link 481, and referring to Fig. 9 the arm 482 and block 484 are rotated counterclockwise about the rod 485. Accordingly, gears 489, 490 and 491 and shafts 487 and 488 are likewise rotated counterclockwise about rod 485. Gear 492 remains stationary, and the coaction of gears 489 and 492 results in a rotation of the gear 489 upon the shaft 487, and consequently, the gears 490 and 491 are rotated resulting in a rotation of the gear 496 which is fixed to the insulating block 497. The rotation of gear 496 results in a counterclockwise rotation of the insulating block 497 and contact segments 498 and 499.

The counterclockwise rotation of the contact segments 498 and 499 will disengage the contact 502 from engagement with the contact segment 499 and the contact 502 will engage only segment 498. As a result motor 495 will be energized so that the shaft 494 rotates clockwise as seen from the left. The running of motor 495 will result in a rotation of the gears 493, 492, 489, 490, 491 and 496, and the rotation of gear 496 will rotate the insulating disc 497 and contact segments 498 and 499 clockwise. The motor 495 will continue to run until it has rotated the contact segments 498 and 499 through the same angle but in the opposite direction from which they were rotated as a result of the movement of the throttle lever and link 481. When the contact segments 498 and 499 have been rotated through this angle, the contact 502 will again engage both of the contact segments and motor 495 will stop. On the other hand, assuming that the contact 502 engages both of the contact segments 498 and 499, if the throttle lever 465 is moved to the rear, link 468 moves downwardly and link 481 moves toward the rear of the trainer. Arm 482 is rotated clockwise as is block 484 and the movement of block 484 carries with it the shafts 487 and 488 and the gears 489, 490 and 491. The coaction of gear 489 with gear 492 which remains stationary results in a rotation of gear 489 and the rotation of this gear is imparted to the gear 496. The rotation of gear 496 is in a clockwise direction and the contact segments 498 and 499 move therewith. Contact 502 will become disengaged from segment 498 but will remain in engagement with segment 499. The motor 495 is as a result energized and the splined shaft 494 is rotated in a counterclockwise direction. The running of motor 495 through the gears 493, 492, 489, 490, 491 and 496 results in a counterclockwise rotation of the split contact segments 498 and 499. The running of the motor continues until these two contact segments again are both in engagement with the contact 502. At this point motor 495 stops.

It will therefore be appreciated that the direction and running time of motor 495 is dependent upon the setting of throttle lever 465 and consequently the anguluar position of shaft 494 with respect to a predetermined zero position is dependent upon the position of throttle lever 465. Accordingly, the angular position of shaft 494 with respect to an initial zero position may be taken as a measure of assumed manifold pressure, and this factor is responsive to changes in the setting of the throttle lever.

In the above reference to Fig. 8 it has been mentioned that the setting of the propeller governor control lever also affects the assumed manifold pressure. Means for introducing this effect will now be described.

In Fig. 4 the simulated propeller governor control lever is designated 521 and it will be seen that this lever is pivotally mounted upon the rod 466 which is fixed inside fuselage 12. To the lower end of lever 521 is pivotally connected the link 522, the forward end of which is pivotally connected to the lower end of arm 523. Pivotally connected to arm 523 is the link 524, the other end of which is pivotally connected to the lower end of the operating arm 525 of the propeller governor lever manifold pressure valve 526.

Reference is now made to Fig. 10 which schematically shows the relation of the propeller governor lever manifold pressure valve 526 to the manifold pressure engine unit 493. In Fig. 10 it will be seen that a vacuum pump 530 is provided. This pump is placed in housing 25a seen in Fig. 1 and furnishes a relatively high vacuum. By means of hose 531 the pump 530 is connected to the step-down bellows 532, and lines 533 and 534 connect the propeller governor lever manifold pressure valve 526 with the step-down bellows 532. Valve 526 is connected to the manifold pressure engine unit 493 by vacuum line 535. The detailed construction of the propeller governor lever manifold pressure valve 526 is shown in Fig. 11, to which reference is now made. It will be seen that valve 526 comprises a main body portion 536 having integral therewith an extension 537 which is threaded in a slightly tapered fashion

upon its outside and is threaded within its inner side. Lock nut 537*a* is provided. The stem of the valve is designated 538 and integral with this stem are the threads 539 which coact with the threads within extension 537. The operating arm 525 is fixedly attached to the outer end of stem 538.

Integral with the stem 538 is the needle 540, tapered as shown. The plug 541 holds the seat 542 of the valve in place, plug 541 being hollow to permit the passage of vacuum therethrough. The capillary and bleed hole fitting assembly comprises a main body portion 543 having integral therewith the threaded extension 544 which fits inside the interiorly threaded left end of the main body portion 536. The body portion 543 is drilled at 545 to permit the passage of vacuum therethrough and the capillary 546 connects the drilled portion 545 with the exterior fitting 547 which is connected with the manifold pressure engine unit through the vacuum line 535 seen in Fig. 10. Bleed hole 548 connects the capillary 546 at all times with the atmosphere through the cup 549 which is filled with a suitable straining material 550, such as cotton. The propeller governor lever manifold pressure valve 526 is connected through the line 535 with the interior of the hollow, expansible and contractible metal bellows 551 which forms a part of the manifold pressure engine assembly 483 shown in Fig. 9. Bellows 551 is airtight in construction and therefore by changing the pressure within this bellows it may be made to expand or contract.

Referring again to Fig. 11 it will be appreciated that atmosphere enters the bellows 551 at all times by virtue of the bleed hole 548. In the absence of other controlling factors, therefore, the pressure within bellows 551 would at all times be equal to the atmospheric pressure. However it will be appreciated that the position of needle 540 relative to seat 542 depends upon the position of the operating arm 525 which, as previously explained in connection with Fig. 4, depends upon the position of the propeller governor lever 521. When propeller governor lever 521 is positioned so that the valve formed by needle 540 and seat 542 is closed, the propeller governor lever manifold pressure valve 526 would have no effect upon the bellows 551. The propeller governor lever manifold pressure valve 526 is arranged to be closed whenever propeller governor lever 521 is in its retarded position. However, as the propeller governor lever 521 is moved toward the head of the fuselage 12, the operating arm 525 is rotated counterclockwise as seen in Fig. 4 and referring to Fig. 11 it will be seen that the needle 540 will be removed from the seat 542 by an amount dependent upon the displacement of the propeller governor lever 521 from its retarded position. Vacuum will therefore be admitted through the line 534, through the needle valve and capillary 546 and connection 535 to the bellows 551. The bellows 551 will therefore be contracted by an amount dependent upon the setting of the propeller governor lever 521. On the other hand, should the bellows 551 be contracted a given amount as the result of the application of vacuum thereto, a retarding of the propeller governor lever 521 will result in a closing of the propeller governor manifold pressure valve 526 and the consequent decrease in the application of vacuum to the interior of bellows 551 results in an expansion of the bellows 551.

Inasmuch as the manifold pressure of a plane in actual flight drops slightly with an increase in the setting of the propeller governor control lever, it will be appreciated that the collapsing of bellows 551 as a result of a forward movement of lever 521 and an expanding of the bellows 551 as a result of a retarding of the lever may be used as a measure of the change in the assumed manifold pressure caused by changes in the setting of the propeller governor control 521.

As previously stated, the third factor which affects the manifold pressure of a plane in actual flight is the altitude of the plane—the higher the altitude the lower becomes the manifold pressure. Means for collapsing and expanding the bellows 551 in accordance with changes in the assumed altitude will now be explained.

Reference is now made to Fig. 12 which is a schematic view of the altitude system of this invention. In Fig. 12 the conventional altitude tank which is well known to the prior art and is disclosed in U. S. Patent 2,099,857 is designated 555. At this point the statement is simply made that the pressure within altitude tank 555 varies inversely with the assumed altitude of the trainer, i. e., the higher the assumed altitude, the lower is the pressure within the tank. Means for varying the pressure within the tank in response to factors corresponding to the factors which affect the real altitude of a plane in actual flight will be hereinafter described in detail. In Fig. 12 it will be seen that the altitude tank is connected through line 556, connector 557 and lines 558 and 559 to the bellows 560 which forms a part of the altitude torque amplifier designated generally by 561 and shown in detail in Fig. 13 to which reference is now made. It will be seen in Fig. 13 that pivotally attached to the top of bellows 560 is the link 562, the upper end of which is pivotally attached to the rear end of the gear sector 563. Gear sector 563 is pivotally mounted upon the enlarged portion 564 of the transverse rod 567 which is fixed in the frame 561*a* of the unit, frame 561*a* being fixedly attached to the floor of the fuselage 12 as seen in Fig. 6.

Still referring to Fig. 13, it will be seen that the altitude torque amplifier 561 includes a reversible drive motor 568 driving the shaft 569 which is splined at 569*a* and 569*b*. The spline 569*a* drives the gear 570 which is rotatably mounted upon the rod 571 which is also fixed in the frame 561*a* of the unit. An insulating disc 570*a* is affixed to gear 570 for rotation therewith, and a pair of contact segments 572 and 573 are affixed to the insulating disc 570*a*. A drum 575 is also rotatably mounted upon the fixed rod 571, the inner flange 575*a* of drum 575 carrying the contact 574. The outer flange of drum 575 is designated 575*b*, and as shown, this flange is in the form of a gear. A pair of contacts 576 and 577 are held by the insulators 577*a* in turn held by frame 561*a* so as to engage the contact segments 572 and 573. Each of the contacts 576 and 577 is connected to the motor 568 through one of the conductors 578 or 579.

A detailed view of the gear 570, insulating disc 570*a*, contact segments 572 and 573, contact 574 and contacts 576 and 577 is not deemed necessary because this arrangement is similar to that shown in Fig. 9A.

When the pressure within the altitude tank 555 shown in Fig. 12 decreases as a result of an increase in assumed altitude, it will be appreciated that the bellows 560 in Fig. 13 is collapsed by an amount dependent upon the decrease in pressure within the tank. Link 562 moves downwardly and the fore end of sector 563 is moved up,

rotating drum 575 counterclockwise. Assuming that the contact 574 was previously in engagement with both of the segments 572 and 573, in which case motor 568 would be at rest, it will be appreciated that the rotation of drum 575 will move contact 574 out of engagement with the segment 572 and the motor 568 will be energized to rotate the shaft 569 clockwise. The clockwise rotation of shaft 569 results in a counterclockwise rotation of the gear 570, insulating disc 570a, and contact segments 572 and 573. The energization of the motor and the turning of the output shaft 569 and of the contact segments 572 and 573 continues until the contact segments are again both engaged by the contact 574. At this instant the motor 568 stops.

On the other hand should the pressure within the altitude tank 555 be increased, the increase in the pressure within bellows 560 will result in an expansion of this bellows. The fore end of sector 563 moves downwardly and the drum 575 is rotated clockwise. Contact 574 is moved out of engagement with contact segment 573, energizing motor 568 so that it rotates the output shaft 569 counterclockwise. The gear 570 is rotated clockwise carrying with it the insulating disc 570a and contact segments 572 and 573, and when the contact segments 572 and 573 are again both brought into engagement with the contact 574, motor 568 stops.

In view of this explanation it will be appreciated that the output shaft 569 is rotated clockwise in response to a decrease in the pressure within altitude tank 555 while shaft 569 is rotated counterclockwise in response to an increase within tank 555. In both cases the total angular rotation of the shaft 569 will be proportional to the magnitude of the change of the pressure within tank 555. Accordingly, shaft 569 is always angularly positioned from a predetermined neutral position according to the assumed altitude of the trainer. The angular position of this shaft may, therefore, be utilized to introduce into the manifold pressure engine unit 483 the factor of assumed altitude, so that the output of the manifold pressure engine unit 483 will be dependent upon assumed altitude.

Still referring to Fig. 13, it will be seen that the gear 580 is arranged to be rotated by the spline 569b. This gear is affixed upon shaft 581 which is rotatably mounted in the frame 561a of the altitude torque amplifier 561. Affixed upon the right end of shaft 581 is the arm 582, to the upper end of which is pivotally connected the rear end of link 583. Referring now to Fig. 6 it will be seen that the fore end of link 583 is pivotally connected to the operating arm 584 of the manifold pressure valve 585. Referring to Fig. 10 it will be seen that the manifold pressure valve 585 is operated by the altitude torque amplifier 561, as just explained. Valve 585 in identical in construction with the valve shown in Fig. 11 and therefore a detailed description of the same is not given at this point. It is sufficient to know, as seen in Fig. 10, that the manifold pressure valve 585 is supplied with vacuum through the line 587 and is connected through the lines 586 and 535 to the bellows 551 of the manifold pressure engine unit 483.

Inasmuch as the output shaft 569 of the altitude torque amplifier in Fig. 13 is always positioned according to assumed altitude, through gear 580, shaft 581, arm 582, link 583 and valve operating arm 584 shown in Fig. 6, manifold pressure valve 585 is always opened by an amount dependent upon assumed altitude—the greater the assumed altitude, the more valve 585 is open. Accordingly, the greater the assumed altitude, the more vacuum manifold pressure valve 585 admits to the interior of the bellows 551 of the manifold pressure unit shown in Fig. 9, to which reference is again made. Consequently bellows 551 is contracted in response to an increase in assumed altitude, and expanded in response to a decrease in assumed altitude.

Previously in this description it has been explained that the bellows 551 of the manifold pressure unit is contracted whenever the propeller governor lever 521 is moved ahead because valve 526 in Fig. 4 is opened to admit more vacuum, and bellows 551 is expanded whenever the propeller governor lever is retarded because such a movement tends to close valve 526. Also it has just been explained that the bellows 551 is contracted whenever an increase in the assumed altitude of the trainer occurs, and that this bellows is expanded whenever a decrease in the assumed altitude of the trainer occurs. In a plane in actual flight, manifold pressure decreases with a forward movement of the propeller governor lever and with an increase in altitude, and manifold pressure increases with a rearward movement of the propeller governor lever and with a decrease in altitude. It will therefore be appreciated that the expansion and contraction of the bellows 551 may be used as a measure of changes in the assumed manifold pressure insofar as the assumed manifold pressure is dependent upon propeller governor lever setting and assumed altitude.

Bearing in mind the earlier detailed construction of the manifold pressure engine unit shown in Fig. 9, it will be appreciated that whenever the bellows 551 is collapsed, as may occur with an increase in assumed altitude or a forward movement of the propeller governor lever 521, the link 552 which has its lower end pivotally attached to the top of bellows 551 will be moved downwardly and inasmuch as the upper end of this link is pivotally connected to the rear end of sector 507, the rear end of sector 507 will also move downwardly, sector 507 pivoting upon the boss 508 integral with the shaft 509 fixed in the frame 486 of the unit. The fore end of sector 507 will move upwardly, and drum 501 will be rotated counterclockwise and the contact 502 will be moved in the same direction and out of engagement with contact segment 498. Motor 495 will therefore be energized in such a direction that the output shaft 494 is rotated counterclockwise. The counterclockwise rotation of the output shaft 494 will result in a counterclockwise rotation of the contact segments 498, 499 and motor 495 will continue this rotation until both of the contact segments 498 and 499 are again engaged by the contact 502. At this instant motor 495 will stop. It will be appreciated that the angular rotation of the output shaft 494 will be dependent upon the extent of the collapsing of the bellows 551 which is dependent upon the magnitude of the change in assumed manifold pressure caused by a change in the propeller governor lever setting or assumed altitude.

It should be noted that whenever the throttle lever 465 shown in Fig. 4 is moved to the rear, the output shaft 494 is rotated counterclockwise by motor 495, and that when the bellows 551 is collapsed as a result of a rearward movement of the propeller governor lever or an increase in assumed altitude, the output shaft 494 also rotates counterclockwise. It will therefore be appre-

ciated that the output shaft 494 is always rotated counterclockwise by the motor 495 in response to a positioning to the rear of the throttle lever 465, a forward movement of the propeller governor lever 521, and an increase in assumed altitude. Accordingly, the shaft 494 is rotated counterclockwise through an angle proportional to decreases in the assumed manifold pressure.

On the other hand, should the bellows 551 be expanded as a result of an increase in the pressure within the altitude tank 555, which increase would occur as a result of a decrease in the altitude of the trainer, or as a result of a rearward movement of the propeller governor lever 521, it will be appreciated without a detailed explanatain, that the contact segment 502 will be rotated clockwise and that the motor 495 will be energized to rotate the shaft 494 in a clockwise direction until the two contact segments 498 and 499 again both engage the contact 502. The angular rotation of shaft 494 in this direction will depend upon the amount of expansion of the bellows 551 which will depend upon the extent of the rearward movement of the propeller governor lever or decrease in assumed altitude. It will be recalled that the output shaft 494 is also rotated clockwise in response to a forward movement of the throttle lever 465. Accordingly, the output shaft 494 is always rotated clockwise through an angle proportional to changes to decreases in the assumed manifold pressure, and the instant assumed manifold pressure may always be measured by the angular position of shaft 494 relative to a predetermined neutral position.

Parenthetically, at this point it should be noted that a notch 498*a* is placed in contact segment 498 seen in Fig. 9A. In the operation of the unit in question the contact segments 498 and 499 are never rotated in response to a movement of the throttle lever so far as to move notch 498*a* opposite the contact 511. Notch 498*a* is therefore provided to limit the clockwise rotation of the contact segments when motor 495 is energized as a result of the clockwise rotation of contact 502 caused by an expansion of bellows 551. When contact 511 is opposite notch 498*a*, motor 495 will not run to rotate the contact segments further clockwise.

Still referring to Fig. 9 it will be seen that the gear 590 is arranged to be rotated by the shaft 494, gear 590 being fixedly mounted upon the shaft 591 which is rotatably mounted in the frame 486 of the unit 483. Upon the left end of shaft 591 is mounted the arm 592 to which is pivotally connected the rear end of link 593. Reference is now made to Fig. 6 where the link 593 is shown to have its fore end pivotally connected to the pitch action walking beam 594 which is pivotally mounted upon the shaft 595, the right end of which is rigidly held by the arm 596. To the lower end of the pitch action walking beam 594 is pivotally connected the link 597, the rear end of which is pivotally connected to the operating arm 598 of the air speed valve designated generally by 599.

By virtue of the just explained arrangement, it will be clear that the link 597 is always positioned according to the angular position of shaft 494, which as explained, is a measure of the instant assumed manifold pressure. An increase in assumed manifold pressure moves link 597 to the rear, while a decrease moves it ahead.

In Fig. 9 it will be seen that the gear 493*a* drives gear 493*b* which is affixed upon the input shaft of the self-synchronous transmitter 493*c* which is connected by electrical cable 493*d* to a self-synchronous receiver forming a part of the simulated manifold pressure indicator 493*e* mounted upon the instrument panel 29 in Fig. 1. As is well known to the prior art, indicator 493*e* comprises a needle mounted upon the output shaft of the self-synchronous receiver and arranged to move over a dial graduated in terms of manifold pressure to indicate the assumed manifold pressure. As will be understood by those skilled in the art, the output shaft of the receiver always positions the needle in accordance with the position of the input shaft of the transmitter which in turn is positioned by gear 493*a*. Inasmuch as gear 493*a* is always positioned by motor 495 which positions shaft 494 according to the assumed manifold pressure, it is clear that the indicator 493*e* always indicates to the student the instant assumed manifold pressure.

Means for combining the factor of assumed manifold pressure with the pitch attitude of the fuselage to produce assumed air speed

Means will now be described for introducing the factor of climbing and diving movements (pitching) of the fuselage and combining this factor with the assumed manifold pressure to produce assumed air speed.

Means for introducing the factor of climbing and diving of the fuselage 12 are shown in detail in Fig. 5, to which reference is now made. In Fig. 5 the fuselage floor is designated 12*a* and it will be seen that this floor rests upon the plate 600 which is atached to the upper yoke 601 of the universal joint 14. The gimbal ring of universal joint 14 is designated 602, this gimbal ring being free to rock about the axis 603, pedestal 13 holding ring 602. Yoke 601 is free to rock about an axis through ring 602 at right angles to the axis 603. Axis 603 extends transversely of the fuselage 12 and is the axis about which the fuselage moves whenever its climbing or diving attitude is changed. Affixed to the yoke 601 is the rearwardly extending rod 604 upon which is movably mounted the carriage 605 which is provided with rollers 606 for easy movement therealong. The link 607 is pivotally connected to the pedestal 13, as shown, and the upper end of this link is pivotally connected to the carriage 605.

The upper end of carriage 605 is slotted as shown, and within this slot is the stud 608 which is affixed to the pitch action sector 609. The upper end of sector 609 is affixed to the transverse shaft 610 which is rotatably held by suitable brackets affixed to the floor 12*a*. Whenever the fuselage 12 assumes a diving attitude, it will be appreciated that the rear end of rod 604 is moved upwardly and that the carriage 605 moves toward the head of the fuselage, or to the left in Fig. 5. The lower end of arm 609 is moved ahead and the shaft 610 is rotated clockwise. On the other hand, whenever the fuselage 12 assumes a climbing attitude, the carriage 605 moves to the rear of rod 604 and the shaft 610 is rotated counterclockwise.

Referring now to Fig. 6, it will be seen that mounted upon the left end of shaft 610 is the arm 596, to which reference has been previously made. When the fuselage 12 assumes a diving attitude, the arm 596 is rotated clockwise as seen in Fig. 6 and the shaft 595 is moved toward the rear of the fuselage 12. The pitch action walking beam 594 will be pivoted about the point at which link 593 is attached thereto, and consequently the lower end of arm 594 will move toward the

rear of the fuselage. Link 597 moves in the same direction.

On the other hand, should the fuselage 12 assume a climbing attitude, arm 596 will be rotated counterclockwise as seen in Fig. 6. Shaft 595 will be moved ahead and pitch action walking beam 594 will be pivoted about the point at which link 593 is attached thereto. The lower end of walking beam 594 will be moved ahead, as will the link 597.

It will therefore be appreciated that the pitch action walking beam 594 differentially combines the two factors of assumed manifold pressure and climbing and diving attitude of the fuselage and that it positions link 597 in accordance with these two factors. In the case of a plane in actual flight an increase in manifold pressure as well as a diving of the plane results in an increase in air speed. It should be noted that whenever an increase in the assumed manifold pressure occurs or when the fuselage 12 is placed in a diving position, the link 597 moves to the rear. Also, when a decrease in the assumed manifold pressure or a climbing attitude of the fuselage 12 occurs, link 597 moves ahead. Consequently, the position of link 597 may be taken as a measure of the assumed air speed.

The air speed system

Reference is now made to Fig. 15 which is a view of a portion of the air speed system, including the air speed regulating valve assembly designated generally by 599 and of the air speed transmitter designated generally by 621. In Fig. 15 it will be seen that the operating arm 598 is rotatably mounted upon the rod 611 held by the frame 612 which is affixed to the floor 12*a* of the fuselage. The cam 613 is pivotally mounted upon the arm 598 by means of the screw 614, a slot and screw arrangement 615 being provided to permit correct positioning of the cam relative to the arm 598. The air speed valve housing is designated 616 and the spring biased operating arm is numbered 618. Carried by the lower end of the operating arm 618 is the roller 619, arranged to be engaged by the face of cam 613. Air speed valve 616 is in its internal construction similar to the valve shown in Fig. 11 except that this valve has no capillary nor bleed hole. The air speed regulating valve includes a port 622 and is connected to the step-down bellows 532 through line 622*b*. Line 623 connects the other port 622*a* of the air speed regulator valve with the bellows 620 of the air speed transmitter. The needle within the air speed regulating valve 599 is operated by the arm 618 and this needle is positioned between the port 622 which connects with the source of vacuum 530 and the seat of the valve which is connected to the other port 622*a* and line 623 which runs to the bellows 620 of the air speed transmitter assembly. This arrangement, it will be recalled, is similar to that shown in Fig. 11.

Referring back to Fig. 6, it has been explained that the position of link 597 may be taken as a measure of the assumed air speed. As the assumed air speed changes, the link 597 moves ahead or to the rear and the arm 598 in Fig. 15 is accordingly rotated. The rotation of arm 598 results in a movement of cam 613, and the eccentricity of this cam results in a rotation of the operating arm 618 by coaction with roller 619. Thus the valve 616 is opened to an extent directly proportional to the assumed air speed of the trainer, and the farther open this valve becomes the greater will be the vacuum applied to the interior of the bellows 620 of the air speed transmitter 621. A suitable bleed hole 623*a* is placed in the line 623 which connects the valve 599 with the bellows 620.

At this point it may be pointed out that the provision of the cam-operated air speed regulating valve is a marked improvement over the prior art method of actuation comprising a spring and bellows. With the use of the old conventional spring and bellows arrangement, the springs were hard to set up and adjust to give the correct basic reading. The springs were responsive to temperature and the bellows were responsive to the prevailing atmospheric pressure, so that daily or more frequent adjustments had to be made to the springs. With the employment of the just described cam-operated valve, these difficulties are not encountered. Furthermore, with the use of the cam-operated valve, the valve may be very precisely operated, and the cam may be shaped to give the desired responses to assumed power and attitude in any simulated type of aircraft.

The construction and operation of the air speed transmitter 621 is known to the prior art and therefore a short explanation of the same will suffice at this point. For a more detailed explanation, reference is made to my copending patent application, Serial No. 485,573, filed May 4, 1943. This application has since matured into Patent No. 2,465,158 dated March 22, 1949. It will be seen that this transmitter includes a collapsible-expansible bellows 620, and the right end of this bellows is fixed in a suitable frame member (not shown) which is attached to the interior of the fuselage 12. To the left movable end of this bellows is attached a flexible link in the form of string 627 which encircles the shaft 628 and continues to the left around pulley 627*a*. The right end of string 627 is attached to one end of spring 629, the other end of which is attached to the frame of the unit. The shaft 628, coupled at 628*a*, form the input shafts of the two self-synchronous transmitters 630 and 631. The housings of both transmitters 630 and 631 are mounted in the frame of the unit. The transmitter 631 is connected by the electrical cable 637 to the simulated air speed indicators 638. One of the air speed indicators 638 is positioned upon the instrument panel 29 within the fuselage while the other is positioned upon the instructor's desk shown in Fig. 16. The other self-synchronous transmitter 630 is connected by means of the electrical cable 639 to the self-synchronous receiver 640, for a purpose soon to be described.

As is well known in the prior art, a collapsing of the bellows 620 as a result of an increase in the assumed air speed results in a rotation of the shaft 628 which is the input shaft of the transmitter 631. A rotation of this input shaft results in a movement of the needle 641 of each of the air speed indicators 638 clockwise over the associated dial 642 to visually indicate an increase in the assumed air speed. As is well known in the prior art, each of the air speed indicators 638 comprises a self-synchronous receiver connected to the self-synchronous transmitter 631, and the needle 641 of each of these instruments is mounted upon the output shaft of each of these self-synchronous receivers. When the bellows 620 is collapsed, as a result of an increase in the assumed air speed, the input shaft of the transmitter 631 is rotated in a given direction and through a given angle. The output shafts of each of the receivers connected to this

transmitter are rotated through an equal angle and in such a direction that the needles 641 move over the dials 642 to indicate the correct increase in assumed air speed. On the other hand, should the bellows 620 expand as a result of a closing of the air speed regulator valve because of a decrease in assumed air speed, the spring 629 causes a rotation of the input shaft 628 in the opposite direction. The output shaft of each of the receivers associated with the instrument 638 will rotate through the same angle and in such a direction that the needles 641 move counterclockwise to indicate a decrease in assumed air speed.

At the same time, the output shaft 643 of the self-synchronous receiver 640 is rotated through the same angle as and in a direction dependent upon the direction of rotation of the input shaft 628.

It will therefore be appreciated that the indication given by the simulated air speed indicators 638, and that the position of the output shaft 643 of the self-synchronous receiver 640 is at all times in accordance with the assumed air speed of the trainer. The assumed air speed is dependent upon the combined factor of climbing or diving position of the fuselage 12, and the assumed manifold pressure. The assumed manifold pressure, in turn, depends upon the three factors of throttle lever setting, propeller governor lever setting and assumed altitude. The factors which affect assumed altitude have not as yet been explained.

Reference is now made to Fig. 14, which is a detailed disclosure of the air speed unit 645 of which the self-synchronous receiver 640 forms a part. In Fig. 14 the output shaft 643 of the receiver 640 is shown, and upon this output shaft is affixed the spur gear 646. The rod 647 is rigidly mounted in the frame of the unit (not shown) which is affixed to the floor of the fuselage. Rotatably mounted upon rod 647 is the gear 649 carrying the contact 650. A pair of split contact segments 651 and 652 are affixed to the insulating disc 653 which, in turn, is affixed to the gear 654 driven by the output shaft 655 of the reversible follow-up motor 656. Gear 654, insulating disc 653 and contact segments 651 and 652 are all mounted for rotation as a unit upon the fixed rod 647. A pair of contacts 657 and 658 are held by the frame of the unit so as to bear against the contact segments 651 and 652. Each of the spring contacts 657 and 658 is connected to the motor 656 through one of the conductors 659 or 660. Contact 650 is grounded to the frame of the unit.

Whenever an increase in the assumed air speed occurs as a result of a change in assumed manifold pressure or in the pitching attitude of the fuselage, the gear 646 upon the output shaft 643 of the receiver 640 is rotated counterclockwise, and the contact 650 is rotated clockwise. Assuming that previous to the change in the assumed air speed, the contact 650 was in engagement with both of the contact segments 651 and 652, the motor 656 will be energized and its output shaft 655 will be rotated counterclockwise. Gear 654, insulating disc 653 and the contact segments 651 and 652 will be rotated clockwise, motor 656 continuing to run to rotate these elements until both of the contact segments 651 and 652 are again in engagement with the contact 650. At this point, motor 656 will stop. As a result of the clockwise rotation of gear 654, the gear 661 which is affixed upon shaft 662 which in turn is rotatably mounted in brackets held by the floor 12a of fuselage 12 will be rotated counterclockwise.

On the other hand, should a decrease in the assumed air speed occur, the gear 646 will be rotated clockwise as seen in Fig. 14. Contact 650 will be rotated counterclockwise and will then engage only the contact segment 651. Motor 656 will be energized to rotate its output shaft 655 clockwise and the gear 654, insulating disc 653 and contact segments 651 and 652 will all be rotated counterclockwise until the segments 651 and 652 again are in engagement with contact 650. At this instant, motor 656 will stop. The counterclockwise rotation of gear 654 will result in a clockwise rotation of the gear 661.

Consequently, the statement may be made that the gear 661 is rotated counterclockwise in response to an increase in the assumed air speed and that the angle through which this gear is so rotated is proportional to the magnitude of the change in air speed. Also, gear 661 is rotated clockwise in response to a decrease in assumed air speed and the angle through which it is so rotated is proportional to the magnitude of the change in assumed air speed. Accordingly, the gear 661 is always positioned in rotation from a predetermined initial point according to the instant assumed air speed, so the position of this gear may be taken as a measure of the instant assumed air speed.

Reference is now made to Fig. 8 which is the schematic view of the air speed system. In Fig. 8 it will be seen that the air speed unit is mechanically connected to six different units in the trainer to operate these units in response to changes in assumed air speed. These six units are, in the order shown, the wind-drift unit, the air speed control loading regulator bellows, the center leaf of the elevator valve, the rudder valve, the climb dive valves and the mush valve. The operation of each of these units by the air speed unit will be discussed in that order.

First, regarding the connection between the air speed unit 645 and the wind drift unit, reference is made to Fig. 6 in conjunction with Fig. 14 where it will be seen that affixed upon the inner or right end of shaft 662 is the arm 665, to the upper end of which is affixed the block 666 which fixedly holds the end of the flexible cable 667 which in turn passes through the sheathing 668. At this point, the sheathing 668 may be considered to be held stationary within the trainer fuselage. Referring now to Fig. 5 it will be seen that the flexible cable 667 and sheathing 668 passes down through the universal joint 14 inside the vacuum line 114b. Sheathing 668 is fixedly held within line 114b, but cable 667 is free to slide within the sheathing. Cable 667 emerges through the lower end of a vacuum line 114b and runs to the wind drift unit 670 as shown in Fig. 1. Reference is now made to Fig. 16 which shows the relationship of the wind drift unit 670 to the recorder 671 which is conventionally used with trainers of the type being described and is connected to the wind drift unit by cable 672.

For a detailed explanation of the construction and operation of the wind drift unit 670, reference is made to the co-pending application, Serial No. 406,056 filed August 8, 1941 in the name of Gunne Lowkrantz and myself. For present purposes it is sufficient to know, as is well known to the prior art, that the wind drift unit 670 combines the four factors of assumed air speed, trainer heading, assumed wind speed and assumed wind direc-

tion, producing an output of assumed ground speed and assumed track in accordance with the four input factors.

For a detailed explanation of the construction and operation of the recorder 671, reference is made to U. S. Patent 2,179,663 granted to Edwin A. Link. The recorder 671 is connected to the wind drift instrument 670 by cable 672 so that the recorder travels in a direction over the surface of the chart 674 placed upon the top of desk 673 in accordance with the assumed track as determined by the wind drift instrument 670, and the recorder 671 travels over chart 674 at a rate dependent upon the assumed ground speed, also as determined by the wind drift instrument.

For present purposes, it is sufficient to know, as it well known to the prior art, that as the cable 667 is pulled away from the wind drift instrument 670, mechanism within the wind drift instrument is operated to increase the input factor of assumed air speed. Consequently, the output of assumed ground speed is increased and the recorder 671 moves over chart 674 at a greater rate. Also, the track of the recorder 671 over chart 674 may be altered because a change in assumed air speed may result in a change in track. On the other hand, if the end of cable 667 away from the wind drift instrument is released, a take-up mechanism within the instrument keeps cable 667 taut and the mechanism within the instrument operates to introduce a smaller assumed air speed. The output factor of assumed ground speed is therefore lesser and recorder 671 has its rate of travel over chart 674 reduced. Also, the direction of travel of recorder 671 over chart 674 may be altered because track under certain wind conditions depends upon assumed air speed.

Referring now to Figs. 6 and 14, it will be recalled that gear 661 is rotated counterclockwise in response to an increase in assumed air speed. Cable 667 is therefore pulled away from wind drift instrument 670 and the rate of recorded travel as well as its direction of movement over chart 674 is properly affected. On the other hand, it has been explained that gear 661 rotates in a clockwise direction in response to a decrease in assumed air speed. In response to such rotation, cable 667 moves toward the wind drift instrument 670, and, as just explained, the rate and direction of travel of recorder 671 over chart 674 will be properly affected.

In Fig. 8, the second output of the air speed unit 645 is shown to affect the operation of the air speed control loading regulator bellows. It will be recalled that this bellows is designated by 82 in Figs. 1, 2 and 3 and that the purpose of this bellows is to place upon the wheel 30 a load dependent upon the assumed air speed when the wheel is moved fore and aft of its neutral position or is rotated clockwise or counterclockwise from its neutral rotational position. Means for operating the bellows 82 in response to changes in assumed air speed will now be described.

Referring to Figs. 6, 14 and 17, it will be seen that affixed upon the left or near end of shaft 662 is the arm 675, and pivotally connected to the lower end of this arm is the link 676, the rear end of which is pivotally attached to the upper end of arm 677, best seen in Fig. 17. Arm 677 is pivotally mounted upon rod 678 which is held in the frame 679 of the mush valve assembly designated generally by 680. Frame 679 is attached to the floor 12a of the fuselage. (The purpose of the mush valve assembly will be later described.) Attached to the lower end of arm 677 is the block 681 which holds the upper end of the adjustable link 682. The lower end of link 682 holds the upper end of spring 683, the lower end of which is attached to the bracket 684 affixed to the upper movable portion 685 of the bellows 82. Bellows 82 is constructed in the same manner as the bellows shown in Fig. 2C, its lower portion 686 being attached to the floor 12a of fuselage. Bellows 82 is connected by line 83 to the turbine 84 and is connected through the line 81 to the regulator bellows 74 in Fig. 2 and 182 in Fig. 3.

Referring now to Figs. 14 and 17, whenever an increase in assumed air speed occurs the gear 661 will be rotated counterclockwise as will the arm 675. Link 676 will move toward the rear and the lower end of arm 677 will be raised. The tension upon spring 683 will be increased and the pressure within bellows 82 will drop. This decreased pressure or higher vacuum will affect the bellows 74 in Fig. 2 and bellows 182 in Fig. 3, and, consequently, whenever the wheel 30 is moved ahead or to the rear of its neutral fore and aft position, or whenever this wheel is rotated from its neutral position, the bellows 52 or 163, as the case may be, will exert a greater force opposing the movement of the wheel.

On the other hand, should the gear 661 be rotated clockwise, as a result of a decrease in assumed air speed, it will be appreciated that link 676 will move toward the head of the trainer. The tension upon spring 683 will be decreased and a higher pressure will be present within bellows 82. This higher pressure will manifest itself in bellows 74 and 182, and when the wheel is moved fore and aft of its neutral position, or is rotated from its neutral position, a lesser pressure will be exerted by the bellows 52 and 163 opposing the movement of the wheel.

As shown in Fig. 8, the third output from the air speed unit 645 goes to the center leaf of the elevator valve. For a detailed description of the connections employed, reference is made to Figs. 6 and 14. Pivotally connected to the lower end of arm 665 is the rear end of link 690, the fore end of which is pivotally attached to the left end of walking beam 691 which has its inner end pivotally mounted upon the vertical stub shaft 692, the lower end of which is held by walking beam 693. Fixedly attached to the walking beam 691 is the vertical stub shaft 694 upon which is pivotally mounted the arm 695 which has attached to its left end the link 696, the purpose of which will be later fully described but which may, for present purposes, be considered to be stationary. The right end of arm 695 is pivotally mounted upon the stub shaft 697 which is held by the bracket 698 which in turn is affixed to the floor of the fuselage 12. Pivotally connected to the left end of walking beam 693 is the fore end of link 699 which, as seen in Fig. 6, is pivotally connected to the upper end of arm 596. The purpose of link 699 will also be later described in detail, it being satisfactory at this point to consider link 699 as stationary. (The walking beams 691 and 693 and the arm 695 as well as their associated members collectively form the unit 703 which is sometimes termed the trim compound differential.) Pivotally attached to the right end of walking beam 693 is the rearwardly extending link 700, the rear end of which is attached to the lower arm 701 of the bell crank designated generally 702. The upper arm 704 of bell crank 702 has pivotally connected thereto the left end of link 705, the right

end of which, as seen in Fig. 6, is connected to the center leaf 355 of the elevator valve 115.

Referring to Fig. 14, it will be appreciated that whenever gear 661 rotates counterclockwise in response to an increase in assumed air speed, the link 690 moves to the rear pulling the left end of walking beam 691 in the same direction. Inasmuch as link 696 remains stationary arm 695 also does not move. Walking beam 691 will therefore be pivoted about the axis of shaft 694 and consequently the right end of walking beam 691 and the shaft 692 move toward the head of the fuselage. Inasmuch as link 699 is in effect stationary, the right end of walking beam 693 also moves toward the head of the fuselage and link 700 moves in the same direction. Bell crank 702 moves link 705, as better seen in Fig. 6, toward the right side of the fuselage and the center leaf 355 of the elevator valve 115 is rotated clockwise. Assuming that the leaves 355 and 356 of the elevator valve 115, as shown in Fig. 7, were neutrally positioned before the increase in assumed air speed occurred, as previously explained during the detailed description of the elevator valve 115, a slight amount of vacuum is applied from the counterbore 374 through the ports 365 and 366 to the hoses 360 and 362 which connect with the fore and aft pitching bellows 17 and 18. Fuselage 12 is therefore longitudinally level. However, the clockwise rotation of the middle leaf 355 as a result of the increase in assumed air speed moves the port 365 of the center leaf away from the counterbore 374 and the port 365 engages the atmosphere port 375. Atmosphere is therefore admitted through the port 365, port 357, connector 359 and hose 360 to the forward pitching bellows 17. Simultaneously the port 366 comes into increased engagement with the vacuum counterbore 374 and an increased amount of vacuum is applied through port 366 to port 358 and thence to the rear pitching bellows 18 by means of connector 361 and hose 362. The application of atmosphere to the fore pitching bellows 17 causes it to expand and the application of increased vacuum to the rear pitching bellows 18 causes it to collapse. The nose of the trainer is therefore lifted.

On the other hand, assuming that the gear 661 shown in Fig. 14 is rotated clockwise as a result of a decrease in assumed air speed, it will be appreciated that the link 705, as better seen in Fig. 6, will be moved toward the left side of the fuselage 12. The middle leaf 355 of the elevator valve 115 will be rotated counterclockwise. Assuming that before the increase in assumed air speed occurred, the leaves 355 and 356 of elevator valve 115 were neutral with respect to one another, the counterclockwise rotation of the leaf 355 will cause the port 365 to overlap the vacuum filled counterbore 374 and vacuum will be applied to the fore pitching bellows 17 through port 357, connector 359 and hose 360. Simultaneously, port 366 will engage the atmosphere port 376 in the upper leaf 356 and atmosphere will be applied to the rear pitching bellows 18 through port 357, connector 361 and hose 362. As a result the fore pitching bellows 17 will be collapsed and the rear pitching bellows 18 expanded, resulting in a nosing down of fuselage 12. Consequently, an increase in assumed air speed will result in a raising of the nose of the fuselage, while a decrease in assumed air speed will result in a lowering of the nose.

It should be borne in mind for later reference that whenever an increase in assumed air speed occurs the center leaf 355 of the elevator valve 115 is rotated in the clockwise direction and whenever a decrease in assumed air speed occurs, the center leaf 355 is rotated in a counterclockwise direction.

By referring to Fig. 8, it will be seen that the fourth effect of a change in assumed air speed is the operation of the rudder valve. This effect is incorporated to simulate the air speed effect upon the heading of a plane in actual flight. This effect is sometimes referred to as the air speed torque effect. Referring to Fig. 14 it will be seen that whenever gear 661 is rotated counterclockwise as a result of an increase in assumed air speed, the upper end of arm 675 affixed upon shaft 662 will be moved ahead and the link 302 moves toward the head of the fuselage. Referring to Fig. 4 it will be appreciated that whenever link 302 moves toward the head of fuselage 12, the arm 301 is pivoted about the point at which link 303 is attached thereto. The lower end of walking beam 299 moves ahead, this walking beam pivoting about the point at which it is attached to stub shaft 295. Extension 298 and the upper end of lever 297 are therefore moved to the rear, arm 297 pivoting about the point at which it is attached to the stationary bracket 296. Link 304 therefore moves to the rear, and the link 306 moves toward the left side of the trainer. The center leaf 307 of the rudder centering valve 279 is therefore rotated counterclockwise.

Assuming that before the increase in assumed air speed occurred, the leaves 307 and 281 of the rudder centering valve 279 were neutralized, it will be appreciated, in view of the earlier description of the rudder centering valve 279, that the counterclockwise rotation of the center leaf 307 will admit atmosphere to the bellows 267 and vacuum to the bellows 275. Bellows 267 will expand and bellows 275 will contract resulting in a movement to the rear of the left rudder pedal 256 and a movement ahead of the right rudder pedal 256. The rudder bar 260 will be rotated counterclockwise, link 310 will move ahead, and referring to Fig. 6, the upper leaf 420 of the main rudder valve 421 will be rotated counterclockwise. As a result of the rotation of the upper leaf 420, the fuselage 12 will turn toward the right. The expanding of bellows 267 and collapsing of bellows 275 will result in a rearward movement of left link 259 and a forward movement of right link 259. The rudder bar 260 will therefore be rotated counterclockwise and the upper leaf 281 will also be rotated counterclockwise until leaf 281 has been rotated through the same angle as leaf 307 was rotated in response to the change in assumed air speed. When leaf 281 has been rotated through this angle, the pressure within the bellows 267 and 275 will become equalized but as previously explained, the rudder pedals 256 will not be returned to their neutral position. Consequently, the upper leaf 420 will remain in the position in which it was placed as a result of the increase in assumed air speed and the fuselage will continue to rotate to the right.

On the other hand, should the gear 661 shown in Fig. 14 be rotated clockwise as a result of a decrease in assumed air speed, it will be appreciated that the link 302 will be moved toward the rear. Inasmuch as link 303 will be stationary, the arm 301 will be pivoted about the point at which link 303 is attached thereto and the extension 300 of walking beam 299 will be moved to the rear. The upper end of walking beam

299 and extension 298 of arm 297 will move ahead as will link 304. Link 306 will move to the right and the center leaf 307 of the rudder centering valve 279 will be rotated clockwise. Vacuum will be admitted to the interior of bellows 267 and atmosphere to the interior of bellows 275, resulting in a movement ahead of the left rudder pedal 256 and a movement to the rear of the right rudder pedal 256. Link 310 is moved to the rear, and as seen in Fig. 6, the upper leaf 420 of the rudder valve 421 will therefore rotate clockwise and the fuselage 12 will be rotated toward the left. The contraction of bellows 267 and expansion of bellows 275 will result in a clockwise rotation of upper leaf 281, through the rudder bar 260, and this rotation will continue until the leaf 281 has been rotated through the same angle as the center leaf 307 was rotated in response to a decrease in the assumed air speed. When the leaves 281 and 307 are centered with respect to one another, the pressure within the bellows 267 and 275 will become equalized but they will not return the rudder pedals 256 to their respective neutral positions. Consequently, the clockwise position of the upper leaf 420 of the rudder valve will not be changed and the trainer will continue to rotate to the left.

In view of the above explanation, it will be appreciated that an increase in assumed air speed results in a rotation of the trainer to the right while a decrease in assumed air speed results in a rotation of the trainer toward the left.

Referring to Fig. 8, it will be seen that the fifth effect of a change in assumed air speed is that it operates the climb-dive valves. Inasmuch as the altitude system of the trainer has not been described in detail hereinbefore, it will be necessary at this point to amplify the description previously given of the same. Reference is made to Fig. 12 which shows the various units of the altitude system. In Fig. 12 the conventional altitude tank is designated 555 and as previously mentioned the tank is connected to the connector 557 through hose 556. The conventional differential pressure regulator is designated generally 715. The differential pressure regulator includes the four collapsible-expansible bellows 716, 717, 718 and 719. The bellows 716 is connected to the altitude tank 555 through the connection 720 and the bellows 717 is connected to the altitude tank through the connection 721. Consequently, the interior pressure of both of the bellows 716 and 717 is always the same as the pressure within tank 555. Valve 722 is connected to the pressure outlet of pump 530 by the pressure line 723 and this valve is connected to the vacuum side of pump 530 by vacuum line 727. The shaft 724 is connected to the movable end of each of the bellows 716 and 718 and a spring 725 of predetermined compression is positioned so that it bears against the bellows 718 at all times. Shaft 724 coacts with valve 722 to selectively connect the outlet 726 with the pressure line 723 or vacuum line 727. It will be noted that line 726 also connects with the interior of bellows 718. When the pressure within bellows 718 exceeds the pressure within bellows 716 by more than the compression of spring 725, shaft 724 moves toward the right and the vacuum line 727 is brought into communication with line 726 to reduce the pressure within bellows 718. On the other hand, should the pressure within bellows 718 be greater than the pressure within bellows 716 by an amount less than the compression of spring 725, shaft 724 is moved to the left and the line 726 is brought into communication with the pressure line 723. Accordingly, the pressure within bellows 718 always exceeds the pressure within bellows 716 and tank 555 by an amount equal to the compression of spring 725.

At the same time, the bellows 717 and 719 have a similar valve and spring arrangement and are connected to the vacuum line 727 and to the atmosphere through port 723a in such a manner that the pressure within the outlet line 729 is always less than the pressure within bellows 717 and tank 555 by a predetermined amount.

For a detailed disclosure of the construction and operation of the pressure regulator 715 reference is made to U. S. Patent 2,358,018 issued to Gunne Lowkrantz upon September 12, 1944. For the purposes of the present application it will suffice to bear in mind that the pressure within line 726 is at all times a predetermined amount higher than the pressure within tank 555 and that the pressure within line 729 is at all times a predetermined amount lower than the pressure within tank 555.

Still referring to Fig. 12, the climb-dive valve assembly is designated generally by 730, the climb valve 731 and the dive valve 732 being shown. The intake port of the climb valve is designated 733 and the intake port of the dive valve is designated 734. Inasmuch as line 729 is connected to the intake port of the climb valve it will be appreciated that the pressure within the intake port is always less than the pressure within altitude tank 555 by the previously described predetermined amount. Also, inasmuch as the intake port 734 of the dive valve 732 is connected to the line 726, the pressure within the intake port 734 will always be higher than the pressure within altitude tank 555 by the previously mentioned predetermined amount. Climb valve 731 is connected to the altitude tank 555 through the line 736, connector 737, line 558, connector 557 and line 556. Dive valve 732 is connected to the altitude tank 555 through line 738, connector 737 and the intermediate connecting elements.

It will therefore be appreciated that by opening the climb valve 731 the pressure within tank 555 will be decreased, the total decrease in the pressure within the tank being a function of the degree to which the climb valve is open and the length of time that the valve remains open. On the other hand, it will be appreciated that by opening the dive valve 732 the pressure within tank 555 will be increased, the total increase in pressure being a function of the extent to which the valve is opened as well as the length of time that it remains open.

The construction of the interior of the climb and dive valves is similar to the valve shown in Fig. 11 except that each of these valves has no capillary or bleed hole. Dive valve 732 has a left interior thread, while climb valve 731 has a right interior thread.

Means for operating the climb-dive valves to change the pressure within the altitude tank 555 in response to changes in the assumed air speed will now be explained.

Referring to Fig. 14, whenever gear 661 is rotated counterclockwise in response to an increase in assumed air speed, shaft 662 is rotated in the same direction. The arm 750 which is affixed upon shaft 662 will have its lower end moved toward the rear and link 751 which has its forward end pivotally attached to arm 750 will also move to the rear. Referring now to Fig. 6, it will

be seen that the rear end of link 751 is pivotally attached to the upper end of arm 753, the lower end of which is pivotally mounted upon the rod 752 which is affixed at its other end to the lower end of arm 596. Consequently, when link 751 moves to the rear the upper end of arm 753 moves in the same direction and the link 754 which has its fore end pivotally attached to arm 753 also moves to the rear. Attached to the rear end of link 754 is the sleeve 755 of the compensator spring assembly designated generally by 756. Springs 757 and 758 also form a part of the compensator assembly which is constructed like the assembly shown in Fig. 2D. The rearward movement of link 754 results in a rearward movement of sleeve 755 and spring 757 is compressed resulting in a movement to the rear of the link 759 which is pivotally attached to the lower end of cam 760 of the climb-dive valve assembly designated generally by 730.

Reference is now made to Fig. 18 which is a detailed disclosure of the exterior of the climb-dive valve assembly designated generally by 730. In Fig. 18 the climb valve 731 and dive valve 732 are shown. The port 733 of the climb valve is shown to be connected to the line 729 which it will be recalled is connected to the pressure regulator 715 and is supplied with a constant pressure less than the pressure within the altitude tank 555. The climb valve is also shown to be connected through the line 736 with the connector 737 which is connected to the altitude tank 555. Also the port 734 of the dive valve 732 is shown connected at 735 to the line 726 which is connected to the pressure regulator 715 and is supplied with a constant pressure higher than the pressure within the altitude tank 555. Further, the line 738 is shown to connect the dive valve with the connector 737 which is connected to the altitude tank.

In Fig. 18 it will be seen that the climb valve 731 has an operating arm 761 affixed upon the outer end of the stem 762 which is connected to the needle within the valve. Mounted upon the lower end of arm 761 is the roller 763. A spring 764 has its lower end attached to the stud 766 integral with the arm 761, and the other end of this spring is anchored upon the stud 767 integral with bracket 768 which is held by the frame 769 which in turn is affixed to the floor 12a of the fuselage. Both the climb and dive valves are affixed to frame 769. The operating arm 770 of the dive valve is affixed upon the stem 771 which operates the needle within the valve, and a roller 772 is carried by the lower end of arm 770. Spring 773 has its upper end anchored to the stud 767 and its lower end held by the stud 774 carried by operating arm 770. The rear end of link 759 is pivotally attached to the lower end of arm 774, the upper end of which is pivotally carried at 775 by the bracket 769. Stud 775 has its inner end carried by the frame 769 and cam 760 is centered upon this stud to be rotated about the axis thereof. Screw 776 holds cam 760 upon arm 774.

Cam 760 is shown in Fig. 18 in its neutral position, i. e., when the combined factors which position the link 759 are such that no change in assumed altitude occurs. When cam 760 is in the neutral position the climb valve 731 and the dive valve 732 are both open by an equal amount. This is in contrast to the prior art where, when the factors which affected assumed altitude were such that no change in assumed altitude was occurring, the climb and dive valves were both closed. Inasmuch as the climb valve 731 is opened by a given amount when in the neutral position, the vacuum line 729 is connected to the altitude tank 555 and will therefore exhaust tank 555 at a given rate. However when the climb valve 731 is in its neutral position, the dive valve 732 is also neutrally positioned and opened by an equal amount and the pressure line 726 is also connected to the altitude tank 555. Consequently just enough air will pass through the dive valve into the altitude tank 555 to offset the amount of evacuation of the altitude tank through the climb valve 731. Accordingly when the valves 731 and 732 are in their neutral positions, the pressure within the altitude tank 555 does not vary. This method of stabilizing the pressure within the altitude tank has been found to be far superior over the previously known prior art method because in the use of the old method of closing both of the climb and dive valves, when the factors affecting assumed altitude were such that no change in altitude was occurring, a certain amount of leak occurred through the valves. In the event that the leak through one valve was not exactly equal to the leak through the other, the pressure within the tank would change. Thus an erroneous indication of assumed altitude would occur. Further, if the valves were adjusted so that no leak occurred, a definite deadspot or distance of travel with no change in reading always occurred.

When the link 759 moves to the right in Fig. 18 as a result of an increase in assumed air speed, it will be appreciated that the cam 760 will be rotated counterclockwise. The lobe 777 of cam 760, shown in detail in Fig. 18A, will force roller 763 to the left and the climb valve 731 will be opened to a greater extent. At the same time the roller 772 will be pulled by spring 773 closer toward the center 775 of cam 760 because lobe 778 will also be rotated counterclockwise. Operating arm 770 will therefore be rotated clockwise and a closing of the dive valve 732 will occur. Consequently a greater amount of vacuum will be admitted through climb valve 731 to the altitude tank 555 and at the same time a decreased amount of air will pass through dive valve 732 to the altitude tank 555. Consequently the pressure within altitude tank 555 will drop.

On the other hand referring to Fig. 14, should the gear 661 be rotated clockwise in response to a decrease in assumed air speed, it will be appreciated that the link 759 shown in Figs. 6 and 17 will be moved toward the head of fuselage 12. Cam 760 will therefore be rotated clockwise and lobe 778 bearing against roller 772 will rotate the operating arm 770 of dive valve 732 counterclockwise so that the dive valve will be opened to a greater extent. At the same time, the spring 764 will rotate the operating arm 761 of climb valve 731 counterclockwise, because roller 763 will be kept in contact with lobe 777 and the climb valve 731 will be closed to a greater extent. Accordingly, less vacuum will be applied to the altitude tank 555 and a greater amount of pressure will be applied to that tank. The pressure within tank 555 will therefore increase.

It should be noted the upper portion of the cam 760 above the dotted line 780 in Fig. 18A is circular in outline and therefore whenever the part of the cam above line 780 engages either of the rollers 763 or 772, the opening of the valve associated with that roller is not increased or decreased. At the same time, it should be noted that the lower portion of cam 760 between the

dotted lines 782 and 783 is circular in shape except for the lobe 784. Not considering the lobe 784, when the roller 772 is upon the portion of the cam above dotted line 780, the roller 763 is along the edge of cam 760 between dotted line 782 and lobe 784. Within the just outlined range of movement of the cam 760, the climb and dive valves have constant openings. The same is true when roller 763 is upon the portion of the cam above line 780 and roller 772 is upon the periphery between lines 783 and 780. Thus, a limit is placed upon the opening and closing of the climb and dive valves.

Parenthetically, it may be here pointed out that in the trainer being considered assumed altitude is a function of the combination of diving and climbing position (pitch attitude) of the fuselage 12 and assumed air speed. The factor of assumed air speed has been explained and at this point the factor of climbing and diving positions of the fuselage 12 will be introduced. Referring to Fig. 6, it will be recalled that whenever the fuselage 12 is placed in a diving position the sector 609 moves toward the head of the fuselage. Shaft 601 is therefore rotated clockwise as is the arm 596. The lower end of arm 596 will move ahead as will shaft 752 upon which the lower end of arm 753 is pivotally mounted. The lower end of arm 753 will move ahead, this arm pivoting about the point at which link 751 is pivotally attached thereto. The forward movement of the lower end of arm 753 will result in a movement toward the head of the fuselage of link 754, compensator assembly 756 and link 759. It will be recalled that when link 759 moves toward the head of the fuselage, the cam 760 will be rotated clockwise. Dive valve 732 will therefore be opened to a greater extent, climb valve 731 will be closed and as previously explained, the pressure within altitude tank 555 will be increased.

On the other hand, should the fuselage 12 be placed in a climbing position, it will be understood that link 759 moves toward the rear. Cam 760 is rotated counterclockwise, climb valve 731 is opened and dive valve 732 is closed. The pressure within the altitude tank 555 will be decreased.

It will be understood that if the fuselage 12 is placed in a sufficiently steep climbing position, the link 759 will be moved to the rear sufficiently far that the lobe 784 will press against roller 772. Consequently the dive valve 732 will be opened even though the fuselage is in a climbing position. When lobe 784 opens dive valve 732, the climb valve 731 will remain open by a constant amount because roller 763 is upon that portion of cam 760 above line 780 in Fig. 18A. Consequently, when lobe 784 presses against roller 772, the dive valve 732 is opened to admit pressure to the altitude tank 555, the admission of this pressure offsetting the opening of the climb valve 731 as a result of the placing of the fuselage in a steep climbing position. The rate of decreasing of the pressure within the altitude tank 555 will be offset when this occurs, and instead, the pressure within the tank is increased. This particular arrangement simulates the falling off of a gain in altitude when a plane in actual flight assumes too steep a climbing angle.

In view of the above it will be appreciated that the pressure within altitude tank 555 varies inversely with the assumed altitude of the trainer, and that assumed altitude is dependent upon the combined factors of fuselage attitude and assumed air speed. It has previously been shown that assumed altitude affects manifold pressure which in turn affects assumed air speed. Thus in the invention disclosed in this application, assumed altitude is dependent upon assumed air speed and assumed air speed is dependent upon assumed altitude, just as in the case of a plane in actual flight.

Referring again to Fig. 8, it will be seen that the sixth disclosed effect of assumed air speed is an effect upon the mush valve which is incorporated in the trainer of this application. Referring to Fig. 14 it will be recalled that whenever an increase in assumed air speed occurs, the gear 661 is rotated counterclockwise. The link 676 in Fig. 14 is therefore moved to the rear, and referring to Figs. 6 and 17, it will be seen that the rear end of link 676 is pivotally attached to the upper end of arm 677 which, it will be recalled, is rotatably mounted upon stub shaft 678 held by the frame 679 of the mush valve designated generally by 680. The mush valve itself is numbered 800 and this valve is constructed like the valve shown in Fig. 11 except that it does not have any capillary or bleed hole. The operating arm of mush valve 800 is numbered 801 and is affixed upon the stem 802 which is connected to the needle within valve 800. A spring 803 has its upper end attached to the stud 804 held by frame 679 while its lower end is attached to the operating arm 801, and a roller 805 is rotatably carried by the lower end of operating arm 801. The mush valve cam 806 is adjustably mounted upon the arm 677 by means of the nut and slot arrangement 807 and this cam rotates about the axis of rod 678. Cam 806 has a central lobe 808.

Reference is now made to Fig. 12 which shows the relationship of the mush valve 800 to the altitude system. The port 810 of the mush valve is connected to the pressure line 726 so that this port is supplied at all times with a pressure above the pressure of the altitude tank 555 by the same predetermined amount as is the pressure port of the dive valve. The output side of the mush valve 800 is connected through line 812 and intermediate members to the altitude tank 555.

When the assumed air speed is sufficiently high, the link 676 in Fig. 17 is moved sufficiently far to the rear that the spring 803 rotates the operating arm 801 clockwise and roller 805 engages lobe 808. In this position the mush valve 800 is closed. Consequently it has no effect upon the altitude system. However, when the assumed air speed drops to a predetermined point the forward movement of link 676 results in a counterclockwise rotation of cam 806, the roller 805 is moved counterclockwise by cam 806 and moves off from the lobe 808. The mush valve is opened slightly. A slight amount of pressure from line 726 passes through the mush valve and into the altitude tank to increase the pressure within this tank. As the assumed air speed further decreases, cam 806 is further rotated counterclockwise, the mush valve 800 is further opened and the rate of increase in pressure within tank 555 is increased. This increase in pressure within tank 555 simulates the loss of altitude of a plane in actual flight when its air speed is decreased below a given point.

In order to complete at this time the description of the altitude system, reference is made to Fig. 12 where the altitude tank 555 is shown to be connected through the vacuum line 820 to the vertical speed transmitter 821. The construction

and operation of this transmitter is well known to the prior art, as described in a publication entitled "Link Instrument and Radio Trainer, Type C–5 Handbook," published by Link Aviation Devices, Inc., Binghamton, New York, dated July 1, 1941, at page 1 of section 1 of Chapter 3, and therefore its function only will be described. Transmitter **821** is connected by means of electrical cable **822** to the pilot's vertical speed indicator **823** which is placed upon the instrument panel within fuselage **12** and to the instructors vertical speed indicator **824** which is conventionally positioned upon the desk shown in Fig. 16. As is well known to the prior art, the vertical speed indicator is operated in response to the rate of change of pressure within tank **555** so that the vertical speed indicators **823** and **824** indicate to the student and instructor the assumed rate of ascent or descent. Inasmuch as the assumed altitude is inversely related to the pressure within tank **555**, when the pressure within tank **555** is increasing, the simulated vertical speed indicators indicate an assumed rate of descent. On the other hand, when the pressure within tank **555** is decreasing, the simulated vertical speed indicators **823** and **824** indicate the assumed rate of ascent.

Still referring to Fig. 12, the altimeter transmitter **825** described in the publication mentioned in the preceding paragraph is connected to the altitude tank **555** through the vacuum line **826** and intermediate elements. Transmitter **825** is in turn connected to the simulated altimeters **828** and **829** by means of electrical cable **827**. The construction and operation of transmitter **825** and indicators **828** and **829** is well known to the prior art and consequently their functional purpose will only be given at this time. Simulated altimeter **828** is placed inside the fuselage **12** upon the instrument panel and the companion altimeter **829** is placed upon the desk shown in Fig. 16, where it may be observed by the instructor. Transmitter **825** operates in response to the absolute pressure within tank **555** to cause the simulated altimeters to indicate the assumed altitude of the trainer. The higher the pressure within tank **555** the lower will be the indicated assumed altitude.

Means for introducing a differential between the indications of the simulated air speed indicator and rate of recorder travel to simulate the difference in actual flight between indicated air speed and true air speed

The air speed indicator of a plane in actual flight is designed to indicate to the pilot the speed with which the plane is actually traveling through the mass of air in which it is flying. The actual rate of travel of the plane through the surrounding air mass is known as true air speed. However, inasmuch as the density of the air mass surrounding the plane decreases with an increase in altitude, as the plane gains altitude the air speed indicator indicates an air speed increasingly below the true air speed of the plane. The indication given by the air speed indicator is referred to as the indicated air speed. The difference between true air speed and indicated air speed is therefore a function of altitude—the greater the altitude the greater becomes the difference.

Those skilled in the art will appreciate that the ground speed of a plane in actual flight depends upon true air speed and not upon indicated air speed. Inasmuch as true air speed is one of the four factors which is introduced into the wind drift instrument **670** to determine the rate of travel of the recorder **671**, it will be appreciated that the difference between indicated and true air speed may be simulated in the apparatus of this invention in either one of two ways, viz., by reducing the air speed as indicated by the simulated air speed indicators **638** with an increase in assumed altitude, or by increasing the input factor of air speed of the wind drift instrument **670**. The latter method is disclosed herein and will now be described.

Referring to Fig. 6, the altitude torque unit is designated generally **561** and it will be recalled that the bellows **560** of this unit is connected to the altitude tank **555** so that the bellows expands and contracts in accordance with changes in the pressure within the altitude tank, which changes are inversely related to the assumed altitude. It will be recalled that the drive motor **568** of the altitude torque unit **561** shown in detail in Fig. 13 is operated in response to a collapsing or expanding of the bellows **560**, and that whenever the pressure within the altitude tank **555** is decreased in response to an increase in assumed altitude, the output shaft **569** of the altitude torque unit **561** is rotated clockwise and the lower end of arm **582** moves toward the rear. Link **835** will therefore move to the rear as will the lower end of arm **836**, seen in Fig. 6, which has its upper end affixed upon the right end of transverse shaft **837**. Shaft **837** will therefore be rotated counterclockwise, and the lower end of arm **838** which is affixed upon shaft **837** will be moved to the rear. Link **839** will therefore move in the same direction, as will the upper end of arm **840** to which its fore end is attached. Arm **840** is pivoted at its lower end upon the upper end of bracket **841** which is fixed upon the floor of the fuselage. Affixed upon arm **840** is the block **842**, and affixed in this block is the sheathing **668** of the flexible cable **667**. As the upper end of arm **840** is moved to the rear, in response to an increase in altitude, the block **842** is carried therewith as is the forward end of sheathing **668**. This pushing upon the sheathing **668** results in a "bulging out" of the same, with the result that the cable **667** inside the sheathing is pulled away from the wind-drift instrument. This effect will be better appreciated when it is borne in mind that the outer end of cable **667** is attached to the arm **665**, as seen in Fig. 6, and the sheathing **668** is fixed to the vacuum line **114***b* at the point that it enters this vacuum line, as seen in Fig. 5. Inasmuch as the sheathing **668** remains constant in length, and the length of cable **667** within the sheathing also remains constant in length, when the movable block **842** carrying the forward end of sheathing **668** moves in one direction along cable **667**, the lower end of cable **667** must move an equal distance in the opposite direction. The take-up mechanism within the wind-drift instrument **670** will be operated in response to the pulling upon cable **667** and the result will be the same as though cable **667** were pulled outwardly from the wind drift instrument by movement of the arm **665** seen in Fig. 6, as occurs with an increase in assumed air speed. The rate of travel of recorder **671** over chart **674** is therefore increased, and inasmuch as the rate of travel of recorder **671** over the chart **674** is proportional to assumed ground speed, the recorder will travel at a slightly higher rate than it would if the indicated air speed were equal to the true air speed.

On the other hand, should an increase in the pressure within altitude tank **555** occur, as happens with a decrease in assumed altitude, bellows **560** of the altitude torque unit **561** would be expanded and motor **568** would be energized to move the lower end of arm **582** toward the head of the fuselage. When the lower end of arm **582** moves toward the head of the fuselage, link **835** moves in the same direction as does the upper end of arm **840**. The block **842** is moved ahead and the sheathing **668** around flexible cable **667** is straightened. The straightening of sheathing **668** also results in a straightening of cable **667**, and produces the same effect as though the cable were moved toward the wind drift instrument by a movement of arm **665**. Consequently, the take-up mechanism within the wind drift instrument operates to take up the slack produced in the cable. The operation of the take-up mechanism in turn decreases the input factor of air speed and recorder **671** is slowed down slightly. This slowing down of the recorder makes the ground speed as represented by the rate of travel of the recorder more nearly equal to the indicated air speed, as occurs in actual flight when the altitude of the plane decreases.

Consequently, this invention discloses means whereby the factor of true air speed may be introduced into the wind drift instrument instead of the factor of indicated air speed, and this factor is properly varied from the indicated air speed according to the assumed altitude. Accordingly, assumed ground speed as represented by the rate of the recorder travel over the chart is dependent upon true air speed and not indicated air speed, in the same manner that the ground speed of a plane in actual flight is dependent upon true and not indicated air speed.

Simulated power effect upon turning of fuselage

It has previously been shown that the fuselage **12** turns to the left or right depending upon the positions of the rudder pedals **256**. It has also been shown that the fuselage **12** turns in response to assumed air speed—an increase in air speed causing a rotation of the fuselage to the right and a decrease in air speed causing a rotation to the left. Those skilled in the art of flying will appreciate that the power output of the engine in the plane also affects the heading of the plane. In a conventional single engine plane wherein the propeller rotates counterclockwise with respect to one standing ahead of and facing the plane, the greater the power output the greater becomes the engine torque and this torque tends to turn the plane toward the left. Means for causing the fuselage **12** to turn to the left in response to an increase in power output and to the right in response to a decrease in power output will now be described.

Reference is made to Fig. 4 where it will be seen that link **468** carries a compensator spring assembly designated generally by **469**, this compensating spring assembly being similar to that disclosed in Fig. 2D and comprising a central exterior sleeve **470** and a pair of springs **471** and **472**. The stud **473** is affixed to the sleeve **470** and the rear end of lever **474** is pivotally mounted upon stud **473**. Lever **474** is fixedly mounted upon the rod **475** which is affixed to the interior left side of the fuselage. A pair of vertical piston rods **476** have their upper ends universally attached to the lever **474** while their lower ends actuate the dash pots **477** which are affixed inside

fuselage **12**. The arm **474***a* is integral with lever **474** and has its lower end pivotally connected to the rear end of link **303**, the forward end of which is pivotally connected to the lower end of walking beam **301**.

Referring to Fig. 4, it will be recalled that whenever the throttle lever **465** is moved toward the head of the trainer, which movement represents an increase in assumed power, the link **468** moves upwardly compressing spring **472**. The compression upon spring **472** slowly forces the sleeve **470** upwardly against the resistance of the dash pots **477**, and the arm **474***a* has its lower end moved slowly toward the rear of the trainer. The link **303** will therefore move in the same direction as will the lower end of walking beam **301**. This walking beam pivots about the point at which link **302** is attached thereto, moving extension **300** and the lower end of walking beam **299** toward the rear. Extension **298** and the upper end of lever **297** move ahead as does link **304**. The link **306** moves toward the right side of fuselage **12** and the center leaf **307** of the rudder centering valve **279** is rotated clockwise. As previously explained in connection with the description of the effects of changes in assumed air speed, when link **306** moves toward the right and center leaf **307** is rotated clockwise, the bellows **267** and **275** are operated in such a manner that the upper leaf **420** of the rudder valve **421** is rotated clockwise as seen in Fig. 7 and the fuselage **12** rotates toward the left.

Referring to Fig. 4 it will be appreciated that, if, on the other hand, throttle lever **465** is moved toward the rear, which movement would cause a decrease in power of a plane in actual flight, the link **303** will slowly move ahead and the link **306** will move slowly toward the left side of the fuselage. The center leaf **307** of the rudder centering valve **281** will be rotated counterclockwise and through the same intermediate parts the upper leaf **420** of the rudder valve **421** will be rotated counterclockwise, as seen in Fig. 7, and the trainer fuselage will rotate to the right.

Accordingly, an increase in power tends to rotate the fuselage to the left, and a decrease in power tends to rotate the fuselage to the right. As previously explained, an increase in air speed tends to rotate the fuselage to the right and a decrease in air speed tends to rotate the fuselage to the left. Thus, if the trainer is trimmed for straight flight, when the throttle lever is moved forward, a relatively rapid simulated torque effect occurs, delayed only by the dash-pots, and the trainer tends to rotate to the left. However, as the air speed gradually increases as a result of the increase in power, the increase in air speed tends to cancel out the simulated torque effect which causes a rotation of the trainer to the left. If the student then desires to continue straight flight, he may retrim the trainer by use of the simulated rudder trim control. On the other hand, with the trainer trimmed for straight flight, a decrease in power setting will lessen the simulated torque effect which tends to rotate the fuselage to the left, and the fuselage will rotate to the right. This effect will be delayed only by the action of the dash-pots. Then, as the air speed falls off as a result of the lesser power setting, the tendency of the trainer to rotate to the right as a result of the air speed will decrease, and the rotation of the trainer to the right will be diminished. If the student then desires to continue straight flight, he may retrim the trainer.

Means for affecting pitch attitude of fuselage according to simulated power output

Referring again to Fig. 4 it will be seen that the link **850** is pivotally attached to the sleeve **470** by the stud **473** and the upper end of link **850** has pivotally attached thereto the forward end of bell crank **852**. Bell crank **852** has pivotally attached to its upper arm the forward end of link **853**. Also bell crank **852** is pivotally mounted upon the stud shaft **854** which is held by the arm **855**, the lower end of which is pivotally mounted upon the shaft **856** which is affixed inside the left side of fuselage **12**. Pivotally attached to the upper end of arm **855** is the link **857**, the forward end of which is pivotally attached to the lower end of the propeller governor control lever **521**.

It will be appreciated that as the throttle lever **465** is moved ahead, the simulated engine power is increased and when this happens the link **850** moves upwardly, pivoting the bell crank **852** and forcing link **853** toward the rear. Also when the simulated throttle lever **465** is retarded the link **853** moves ahead. When propeller governor control lever **521** is pushed ahead, the simulated power output is increased slightly and this effect is combined with the movement of the throttle lever **465** by the link **857** which moves to the rear pushing the upper end of arm **855** in the same direction. The bell crank **852** is carried to the rear and it pushes link **853** in the same direction. On the other hand, when the propeller governor lever **521** is retarded, link **853** moves ahead. Consequently, link **853** moves to the rear with an opening or pushing ahead of the throttle lever **465** and a pushing ahead of the propeller governor control lever **521**, and link **853** moves ahead in response to reverse movement of either or both of the throttle lever **465** and propeller governor control lever **521**.

It should be noted that the movement of link **853** is greater in response to a movement of the throttle lever **465** than to a movement of the propeller governor lever **521**. This is because the power output of a plane in actual flight is varied by a much lesser percent of the total by movements of the propeller governor control lever.

Consequently, link **853** moves to the rear in response to an increase in assumed power and it moves ahead in response to a decrease in assumed power. Referring now to Fig. 6 it will be appreciated that whenever link **853** moves to the rear in response to an increase in assumed engine power, the lower end of arm **858** moves in the same direction. Inasmuch as the upper end of this arm is fixedly mounted upon the left end of shaft **859**, shaft **859** will be rotated counterclockwise. The upper end of arm **860** is moved ahead as is link **696**, because the lower end of arm **860** is affixed upon shaft **859**. As better seen in Fig. 14, when link **696** moves toward the head of fuselage **12** in response to an increase in assumed power, the left end of arm **695** moves in the same direction carrying with it shaft **694**. The walking beam **691** is held at the point at which link **690** connects therewith, and consequently the right end of this walking beam carries the shaft **692** ahead. Walking beam **693** remains stationary at its left end where link **699** connects therewith, so its right end moves ahead pulling link **700** in the same direction. Link **705** consequently moves toward the right and, as seen in Fig. 6, the center leaf **355** of the elevator valve **115** is rotated clockwise. Referring to Fig. 7, it will be seen that when center leaf **355** is rotated clockwise, port **366** engages the counterbore **374** and as previously explained vacuum is admitted to the rear pitching bellows **18**. Simultaneously, port **365** engages port **375** and atmosphere is admitted to the forward pitching bellows **17**. Consequently the fuselage **12** assumes a climbing attitude.

On the other hand should the link **853** shown in Fig. 6 be moved toward the head of the fuselage, in response to a decrease in assumed power, it will be appreciated that by virtue of the just explained system the center leaf **355** of the elevator valve **115** will be rotated counterclockwise. Vacuum will be admitted to the forward pitching bellows **17** and atmosphere to the rear pitching bellows **18**, resulting in a lowering of the nose of fuselage **12**.

In view of the above, the apparatus of this invention discloses means whereby the pitch attitude of the fuselage is responsive to the simulated power output—an increase in simulated power output tending to raise the nose of the fuselage and a decrease in simulated power output tending to lower the nose of the fuselage. It will be noted that this effect of simulated power output on attitude is practically immediate because of the direct mechanical connection from the simulated throttle lever and simulated propeller governor control to the elevator valve. At the same time it should be borne in mind that the pitch attitude of the fuselage is also dependent upon the assumed air speed—an increase in assumed air speed resulting in a raising of the nose of the plane and a decrease in air speed resulting in a lowering of the nose of the plane. Air speed is, as previously explained, dependent in part upon simulated engine power.

Effect of pitch on pitch

Referring to Fig. 6, it will be recalled that whenever fuselage **12** assumes a diving attitude, the lower end of sector **609** moves ahead and shaft **610** is rotated clockwise. The upper end of arm **596** is therefore moved to the rear as is link **699**. As better seen in Fig. 14, when link **699** moves to the rear the left end of lever **693** will move in the same direction, lever **693** pivoting about the axis of shaft **692** which remains stationary because links **690** and **696** remain stationary. Link **700** therefore moves ahead and bell crank **702** moves link **705** toward the right. Referring back to Fig. 6, when link **705** moves toward the right the center leaf **355** of the elevator valve **115** is rotated clockwise. Referring to Fig. 7 when the center leaf **355** of the elevator valve is rotated clockwise, the port **366** engages vacuum counterbore **374** and, as previously described, admits vacuum to the rear pitching bellows **18**. Simultaneously, port **365** engages the atmosphere port **375** and admits atmosphere to the fore pitching bellows **17**. The trainer fuselage therefore assumes a climbing attitude. Therefore a diving of fuselage **12** produces a reaction which tends to raise the nose of the fuselage.

It will be appreciated without a detailed explanation that when the fuselage **12** is placed in a climbing position, the just described parts operate in the reverse direction and the center leaf **355** of the elevator valve **115** is operated so that vacuum is admitted to the fore pitching bellows **17** and the rear pitching bellows **18**. Consequently fuselage **12** tends to assume a diving position.

Accordingly a diving of fuselage **12** tends to

raise the nose of the fuselage and a climbing of fuselage tends to lower the nose of the fuselage.

Bank with turn, turn with bank, and interrelation thereof

In the flight of actual aircraft it is well known that when the plane is turned in either direction as a result of the movement of the rudder pedals and rudder, a banking of the plane in the direction of the turning occurs. The following disclosed means cause the fuselage 12 to bank in the direction of the turn.

In Fig. 6, the forward end of link 875 is pivotally attached to the arm 418 affixed to the upper leaf 420 of the rudder valve. The rear end of link 875 is pivotally attached to the walking beam 876, the left end of which is pivotally mounted upon the stub shaft 877 held by the left end of lever 878. Lever 878 is pivotally mounted upon the shaft 879 which is affixed to the floor of the fuselage. To the right end of lever 878 is pivotally attached the rear end of link 880, the forward end of which is pivotally attached to the operating arm 381*a* which is integral with the center leaf 381 of the aileron valve 196. Pivotally attached to the right end of walking beam 876 is the rear end of link 881, the forward end of which is pivotally attached to the upper arm of bell crank 417. The upper end of link 882 is pivotally attached to the forward arm of bell crank 417 and, referring to Fig. 5, the lower end of link 882 passes through the hole 883 in the floor 12*a* and the lower end of this link is pivotally attached to the rod 884, the inner end of which is affixed to pedestal 13. Rod 884 extends transversely of fuselage 12.

Referring back to Fig. 6, when the left rudder pedal is pushed forward it will be recalled the link 310 moves to the rear, link 417*a* moves ahead, and arm 418 and leaf 420 are rotated clockwise, resulting in a turning of the fuselage to the left. At the same time, link 875 moves ahead and the walking beam 876 is pivoted about the point at which the rear end of link 881 attaches thereto. The left end of walking beam 876, stub shaft 877 and the left end of lever 878 therefore move ahead, link 880 moving to the rear. The center leaf 381 of the aileron valve 196 is therefore rotated clockwise, allowing vacuum to pass from counterbore 406 through port 397, port 387, and hose 390 to the left banking bellows. Simultaneously port 399 engages port 410 and atmosphere passes through these two ports into port 391 and through hose 394 to the right banking bellows. The left bellows collapses, the right bellows expands and fuselage 12 banks to the left.

Without a detailed explanation it should be clear that when the upper leaf 420 of the rudder valve 421 is rotated counterclockwise to turn fuselage 12 toward the right, the center leaf 381 of the aileron valve 196 is rotated counterclockwise, admitting vacuum to the right banking bellows 20 and atmosphere to the left banking bellows 19. The fuselage 12 therefore banks to the right.

The conclusion may, therefore, be stated that in the absence of other controlling factors, a turning of the fuselage will simultaneously produce a banking in the direction of the turn. This banking could be prevented by applying opposite aileron.

Again, for purposes of comparison, referring to a plane in actual flight, when the plane is banked to the left or right it also turns in the direction of the bank, in the absence of other controlling factors. This feature of actual aircraft performance is simulated by the following disclosed means. Referring to Figs. 5 and 6, when the trainer fuselage 12 is banked to the right, the distance between rods 884 and 418 is decreased with the result that the forward arm of bell crank 417 is pushed upwardly and the upper arm of this bell crank is moved to the rear, causing link 881 to move in the same direction. At the same time the movement of bell crank 417 results in a movement to the rear of stub shaft 416 and the upper end of walking beam 415 moves to the rear, this walking beam pivoting about the point at which link 310 is attached thereto. Link 417*a* also moves to the rear because of the movement of walking beam 415. The rearward movement of link 417*a* results in a counterclockwise rotation of the upper leaf 420 of the rudder valve 421 seen in Fig. 7 and as previously explained the counterclockwise rotation of leaf 420 results in a turning of fuselage 12 toward the right. Consequently fuselage 12 turns to the right when the fuselage is banked to the right. Again, without a detailed explanation, it should be appreciated that when the fuselage 12 is banked to the left the aforedescribed parts move in the opposite direction and the fuselage 12 will bank to the left.

Accordingly, the conclusion may be drawn that the fuselage 12 turns in the direction of the bank. It has previously been explained that the fuselage banks in the direction of the turn.

Referring again to the case of a plane in actual flight, if the plane is flying straight and level and the wheel is moved to the right and held in a position displaced from its neutral position, the plane banks to the right and as a result of the bank, it turns to the right and as a result of the turn, the nose of the plane drops, assuming that the control wheel is not pulled to the rear. The turn produced by the bank produces more bank which then produces more turn, with the result that the plane will eventually reach a spiraling downward position. With the previously disclosed apparatus the fuselage 12 is moved in such a manner as to simulate this response of a plane in actual flight to a movement of the control wheel. Referring to Figs. 6 and 7, it will be recalled that when the control wheel 30 is rotated clockwise, the upper leaf 382 of the aileron valve is rotated clockwise. This rotation of the upper leaf 382 admits vacuum to the right banking bellows 20 and atmosphere to the left banking bellows 19, causing fuselage 12 to bank to the right. If the wheel is maintained in the right banking position it will be appreciated that the bellows 20 will be collapsed to its fullest extent and the bellows 19 will have an interior pressure equal to the atmosphere and consequently the fuselage 12 will eventually assume its rightmost banking position.

Even though the rudder pedals are not moved, as the fuselage increases its banking to the right, the bank action shaft 882 forces the forward end of bell crank 417 upwardly and link 881 moves to the rear. At the same time the motion of bell crank 417 will move stub shaft 416 to the rear and link 417*a* will move to the rear. The rearward movement of link 417*a* will rotate the upper leaf 420 of rudder valve 421 counterclockwise resulting in a rotation to the right of fuselage 12. The turning of upper leaf 420 counterclockwise as a result of the banking to the right of the fuselage 12 results in a movement toward

the rear of link 875. The left end of walking beam 876 moves to the rear, this walking beam pivoting about the point at which link 881 is attached thereto. Link 880 is moved ahead resulting in a counterclockwise rotation of the middle leaf 381 of the aileron valve 196. The counterclockwise rotation of middle leaf 381 results in a further banking of fuselage 12 to the right. The increased banking of the fuselage to the right will produce more turning which will then produce a greater degree of bank, until eventually the fuselage 12 is banked to the right to the greatest possible extent and it is rotating to the right as rapidly as possible. At the same time it will be appreciated that the extent of nose down with turn depends upon the rate turn and inasmuch as the fuselage is rotating at its maximum rate its nose will be lowered as far as possible.

It should be noted that whenever link 417a moves to the rear as a result of the banking of the fuselage to the right, the link 881 also moves to the rear. The rearward movement of link 881 would, in and of itself rotate the center leaf 381 of the aileron valve 196 clockwise and consequently tend to diminish the banking of the fuselage. However, this tendency is overcome and reversed by the rearward movement of link 875 which moves farther to the rear in response to a banking of the fuselage 12 than does the link 881. Also because of the relative positions of the links 875 and 881 in relation to walking beam 876, movements of the link 875 produce a greater change in the position of lever 878 than do movements of link 881. Accordingly, when the fuselage 12 is banked to the right, the movement of link 881 tends to rotate the center leaf 381 clockwise to eliminate the bank, but the movement of link 875 tends to rotate the center leaf 381 counterclockwise to increase the bank. Link 875 being more effective than link 881, the angle of bank is increased.

If it is then desired to bring the fuselage 12 back to the level flight position, the student may do so by rotating the control wheel 30 to the left as far as possible. This rotation of the control wheel will rotate the upper leaf 382 of the aileron valve 196 counterclockwise beyond the point at which it would be centered with respect to the middle leaf 381 which was also rotated counterclockwise as a result of the turning of the fuselage. Vacuum will be admitted to the left banking bellows 19 and atmosphere to the right banking bellows 20 and the fuselage 12 will assume a level transverse banking position. When the fuselage 12 assumes a level transverse banking position, it will be appreciated that the upper leaf 420 of the rudder valve 421 will be centered and the turning of the fuselage will be eliminated. With the disappearance of the turning the nose down position of the fuselage is also eliminated.

However, the preferred practice in such an event would be to apply opposite aileron, opposite rudder, and to pull back upon the control wheel 30. If these three steps are performed, the fuselage 12 will be returned to the level flight position in a much shorter period of time.

It is deemed unnecessary to give a detailed explanation of the operation of the just described parts of this invention to show that with the fuselage 12 in the level flight position, a movement of the control wheel counterclockwise of its neutral position will produce left bank which in turn will produce left turn which produces nose down with turn, and that the turn produces more bank which in turn produces a greater rate of turn and so forth, until the fuselage is banked as far left as possible, and is rotating to the left with its nose down. Opposite aileron will also return the fuselage to straight and level flight.

In the case of a plane in actual flight, if the pilot moves the aileron control from the neutral position, to the right, and leaves it so positioned until the plane assumes a right bank, the plane will turn to the right and as a result of the turn, the nose of the plane will drop. If the pilot then centers the banking control the plane will nevertheless increase its degree of bank and rate of turn as well as nosing down until the air speed of the plane has increased to the point where the inherent stability of aircraft causes a rising of the nose and leveling of the wings. The apparatus just discussed also simulates this response of a plane to such movements of the aileron control. This is readily perceivable by an inspection of the apparatus disclosed in Figs. 5, 6 and 14, because when the fuselage banks to the right the center leaf 381 of the aileron valve 196 is rotated counterclockwise of its neutral position. A centering of the upper leaf 382 by returning the control wheel to the neutral position will not therefore neutralize the aileron valve 196 and the banking of the fuselage will continue. As previously shown, the banking will cause turn which will result in a nosing down, the turn produces more bank, and the cycle is repeated until the assumed air speed substantially increases. The resulting increase in air speed will result in a nosing up of the trainer, in a cancellation of the turn to the right, and the transverse stability of the fuselage, as explained in the next section hereof, returns the fuselage to a level transverse position.

A movement of the aileron control to the left and a later centering of the same when a left banking position has been reached similarly will produce extreme left bank, left turn, a decrease in air speed, and nose down. However, the decrease in air speed cancels the turning to the left, the nose rises, and the transverse stability returns the trainer to a level transverse position. This operation of the apparatus of this invention accurately simulates the corresponding flight characteristics of a plane in actual flight.

Referring again to the case of a plane in actual flight, if the pilot presses one of the rudder pedals forward, for example, the left pedal, and holds it in that position, the plane will turn to the left. The turning to the left produces a banking in the same direction as well as nosing down. The bank and turn will produce a greater rate of turn which then produces more bank until the plane is spiraling downward. Inasmuch as the previously disclosed apparatus shown in Fig. 6 produces bank with turn and turn with bank as well as nose down with turn, it will be appreciated that should the student within the trainer press the left rudder pedal forward and hold it in the forward position, the fuselage will be increasingly turned to the left, banked to the left, and the nose will continue to drop until the limit of these movements has been reached. The fuselage 12 may be returned to level forward flight by applying opposite rudder, opposite aileron, and pulling back on the control wheel.

Correspondingly, a pressing forward and holding forward of the right rudder pedal will eventually result in a rapid turning to the right, a steep bank to the right and an extreme nosing down. The trainer may then be returned to straight and level flight by the application of

left rudder and left aileron together with a pulling back of the control column.

It should perhaps be stated at this point that in the normal use of the trainer being described the flight controls will be manipulated by the student to prevent the fuselage 12 from assuming extreme positions such as those just described. The student will normally correct any tendency of the fuselage to assume unwanted banking, pitching, or turning movements as soon as they are discovered. The important fact is that if any tendency of the fuselage 12 to move in a given direction is not properly checked, the fuselage 12 will assume an extreme position corresponding to the position that a plane in actual flight would assume under corresponding circumstances. At this point it might be noted that whenever the fuselage turns, from whatever cause, the gyro and turn indicator in the fuselage register to indicate the turn; whenever the fuselage banks the artificial horizon and ball-bank indicator conventionally installed in the fuselage reflect the bank; and whenever the fuselage is pitched the artificial horizon, altimeter, vertical speed indicator and air speed indicator in the fuselage properly respond.

Transverse stability

In the case of a plane in actual flight, if the aileron control is moved off center, for example to the right, the plane banks to the right. If sufficient left rudder is then applied to prevent the plane from turning to the right as a result of the bank, and to prevent the plane from nosing down, should the pilot merely release the aileron control, the equal pressure caused by forward motion of the plane through the air upon the ailerons will return the aileron control to the neutral position and the inherent stability of the plane will return the plane to level transverse flight. It should be noted that to accomplish this stability effect sufficient opposite rudder must be applied in order to prevent the plane from turning and nosing down as a result of the bank. The apparatus disclosed in Figs. 6 and 7 cause the fuselage 12 to simulate this response of a plane in actual flight. It will be appreciated that if the control wheel 30 is moved clockwise so as to produce a right bank of fuselage 12, the upper leaf 382 of the aileron valve 196 is rotated clockwise and the fuselage banks to the right. The banking to the right of the fuselage causes bank action rod 882 to force the forward end of bell crank 417 upwardly and the link 881 moves to the rear. At the same time it will be appreciated that the motion of bell crank 417 will force link 417a to the rear and the upper leaf 420 of the rudder valve 421 will be rotated counterclockwise. However, if sufficient left rudder may be applied so the link 310 will move to the rear and by means of lever 415 the link 417a may be moved ahead. Consequently, enough left rudder may be applied to offset the rotation of the upper leaf 420 of the rudder valve which normally occurs with a banking of fuselage 12. If such an amount of left rudder is applied, it will be appreciated that link 875 will remain stationary. Accordingly, with the aileron control held in the position necessary to give a right bank to the fuselage, and link 875 held stationary by the application of left rudder, the rearward movement of link 881 will result in a rearward movement of link 880. The rearward movement of link 881 as a result of the banking of the fuselage will result in a rearward movement of the right end of walking beam 876, this walking beam pivoting about the point at which link 875 is attached thereto. The left end of lever 878 moves ahead and link 880 moves to the rear rotating the center leaf 381 of the aileron valve clockwise from its neutral position. If then the control wheel 30 is released, the previously described control loading bellows 163a and 163b will operate to return the control wheel 30 to its neutral position. The returning of control wheel 30 to its neutral position will center the upper leaf 382 of the aileron valve 196. However the banking to the right of the fuselage will have placed the center leaf 381 of valve 196 clockwise of its neutral position. Accordingly, vacuum will be admitted to the left banking bellows 19 and atmosphere to the right banking bellows 20 and the fuselage will be moved from a right banking position to a level transverse position. When the level transverse position is reached the center leaf 381 will be neutralized and the fuselage 12 will remain in the level flight position. As the fuselage 12 is moved from the right banking position toward the level flight position, it will be necessary for the student to release the left rudder pedal sufficiently to keep the upper leaf 420 of the rudder valve 421 centered. Otherwise as the banking to the right diminished, a turning to the left of fuselage 12 would occur.

Similarly, if the fuselage is banked to the left and sufficient right rudder is applied to prevent the trainer from turning as a result of the bank, if the control wheel is released the fuselage will return to the level flight position.

Hunting effect

Assuming that a plane in actual flight is flying straight and level and that the pilot pushes ahead on the elevator control and retains it in that position until the plane assumes a gliding angle, if the pilot then releases the elevator control, the elevators and the control will return to their trimmed neutral positions. The airplane will continue to dive, losing altitude and gaining speed, and the forces acting upon the plane will become such that the nose of the plane will slowly rise until the plane is in level flight. When the plane reaches level flight, its air speed will be at a maximum and substantially above that at which it was at the beginning of the maneuver, and its altitude will be substantially below the initial altitude. The increased air speed of the plane will continue to raise the nose of the plane above the level flight attitude and the plane will begin to climb resulting in a loss of air speed. When the plane reaches the approximate altitude which it had when the maneuver was begun, the air speed will be approximately the initial air speed, and the nose of the plane will be raised to a maximum. Consequently the plane will continue to gain altitude, the air speed will continue to drop, and the nose of the plane will start to fall. Finally, the plane will be in level flight at an altitude substantially higher than the initial altitude, but by an amount less than the previously low altitude was below the initial altitude. At this point of level flight the air speed of the plane will be substantially below the initial air speed, but again it will not be as far below the initial air speed as the maximum air speed was above the initial air speed when the plane was at the lowermost altitude. Inasmuch as the air speed is substantially below the initial straight and level flight air speed, the nose

of the plane will then start to drop and the plane will start to lose altitude and gain air speed until it is at the initial altitude, when the air speed will be approximately the initial air speed. However, at this point the nose of the plane will be pointed downwardly, but not so sharply as when the pilot originally placed the nose of the plane downwardly to start the maneuver. Consequently the cycle will be repeated several times, each successive cycle marked by lesser variations in air speed, altitude and attitude, until finally, the plane is again flying straight and level at about the initial air speed and altitude. Of course the altimeter, vertical speed indicator, artificial horizon, etc. reflect the various described changes.

The just described response of a plane in actual flight to a change in attitude of the plane is known as "hunting." It seems clear without a detailed explanation that should a plane in actual flight be placed in a climbing position and the elevator control released, the plane will also go through the previously described phases until it is finally again flying straight and level at approximately the initial air speed and initial altitude. However, in this case the cycles are started at 180 degrees from the points of starting of the cycles when the elevator control is pushed ahead and released.

The previously described apparatus of this application operates to change the attitude of the fuselage **12**, the indicated assumed air speed, and the operation of the other instruments in response to a placing of the fuselage in a climbing or diving position, just as occurs in the hunting of a plane in actual flight. Such operation will now be described.

Referring to Figs. 6 and 7, it will be recalled that when the control wheel **30** is pushed ahead of its neutral position, the upper leaf **356** of the elevator valve **115** is rotated clockwise from its neutral position and vacuum is admitted to the front pitching bellows **17** simultaneous with the admission of atmosphere to the rear pitching bellows **18**. Fuselage **12** therefore assumes a diving attitude. With the fuselage **12** in a diving position, referring to Fig. 6 it will be appreciated that the sector **609** is placed ahead and link **699** is moved to the rear. Link **700** is therefore placed ahead of its neutral position and link **705** is placed to the right of its neutral position, rotating the center leaf **355** of the elevator valve clockwise of its neutral position. Consequently, both the upper leaf **356** and the middle leaf **355** of the elevator valve are rotated clockwise of their neutral positions, but because of the linkage arrangements upper leaf **356** is rotated farther clockwise from its neutral position than is center leaf **355**. Accordingly, vacuum is continued to be admitted to the fore pitching bellows **17** and atmosphere to the rear pitching bellows **18**.

At the same time, referring back to Fig. 6, the forward movement of sector **609** in response to a diving of the fuselage results in a movement to the rear of link **597** and the air speed valve **616** of the air speed valve assembly **599** is opened, admitting a greater amount of vacuum to the interior of the bellows **620** of the air speed transmitter assembly **621**. As previously explained, the collapsing of bellows **620** will operate the air speed assembly **645** to introduce the effect of an increase in assumed air speed upon the six different units, as has been previously explained. At this point it should be noted, however, that there is a substantial lapse of time between the opening of the air speed valve **616** and the collapsing of bellows **620**, and consequently there is a lag between the placing of fuselage **12** in the diving position and the introduction of the air speed effect by the air speed unit **645**. At the same time it should be noted that the movement of the center leaf **355** of the elevator valve **115** in response to a diving of the fuselage **12** is immediate because of the direct mechanical connection. As the assumed air speed increases, gear **661** is rotated counterclockwise, and the center leaf **355** of the aileron valve is given a further clockwise movement, but the upper leaf **356** will still be farther clockwise than center leaf **355**, so that vacuum is still admitted to the front and atmosphere to the rear pitching bellows.

Consequently, the forward movement of wheel **30** and the resultant placing of fuselage **12** in the diving position has three distinct effects, viz., the clockwise rotation of the upper leaf **115** of the elevator valve, the clockwise but lesser rotation of the center leaf **355** of the elevator valve as a result of the diving of the fuselage, and a delayed operation of the air speed unit **645** as a result of the increase in assumed air speed caused by the diving of the fuselage which also imparts a clockwise movement to the center leaf of the elevator valve.

The student having placed fuselage **12** in the diving position may then release the wheel **30** and the bellows **52***a* and **52***b* seen in Fig. 2 will return the wheel **30** to its neutral fore and aft position and simultaneous therewith the upper leaf **356** of the elevator valve will be returned to its neutral position. This releasing of wheel **30** may or may not occur before the air speed unit **645** has been operated by the diving of the fuselage, but, in either event, the center leaf **355** will still be rotated clockwise from its neutral position, and being in such a position it will admit atmosphere to the forward pitching bellows **17** and vacuum to the rearward pitching bellows **18**, tending to raise the nose of fuselage **12**. As the assumed air speed increases, center leaf **355** will be rotated farther clockwise, and the nose of the fuselage will be raised even faster. As the nose of the fuselage is raised, the center leaf **355** is rotated counterclockwise toward its neutral position by the movement to the rear of sector **609**. However, as long as the nose of the fuselage is pointed downwardly the air speed valve **616** will continue to admit more vacuum to the bellows **620** of the air speed transmitter, and the air speed will increase. Consequently, when the fuselage has reached a level flight position, the center leaf **355** of the elevator valve would be centered were it not for the fact that the assumed air speed is higher than the initial air speed, so the center leaf **355** is still rotated clockwise from the neutral position. Atmosphere is still admitted to the forward pitching bellows **17** and vacuum to the rear pitching bellows **18**, resulting in a raising of the nose of the fuselage above the level flight position. As the nose of the fuselage rises above the level flight position, the sector **609** is moved toward the rear and by the direct mechanical connection a further counterclockwise rotation is imparted to the center leaf **355**, tending to overcome the clockwise rotation of this leaf caused by the still present increased air speed. The raising of the nose of the fuselage operates the air speed valve **616** to introduce a lower assumed air speed, and as the air speed drops off the clockwise rotation of the center leaf as a result

of the higher assumed air speed lessens and the tendency of the raised nose to rotate the center leaf counterclockwise is sufficient to overcome the air speed effect. Accordingly, the center leaf slowly moves past center and to a position counterclockwise from neutral, and vacuum is admitted to the front pitching bellows and atmosphere to the rear pitching bellows. The nose of the fuselage tends to drop from the climbing position to the level flight position. The air speed continues to drop until finally the fuselage is in level flight and the assumed air speed is substantially below the initial air speed. The fuselage being level, sector **609** is centered, and insofar as its direct influence upon the center leaf **355** is concerned, the center leaf would be centered. However, at this point the assumed air speed is substantially below the initial air speed, and so the center leaf **355** is positioned counterclockwise of its neutral position, admitting vacuum to the fore pitching bellows and atmosphere to the rear pitching bellows. Accordingly, fuselage **12** assumes a diving attitude, and as it does so, the direct mechanical connection from sector **609** tends to position the center leaf **355** clockwise from its neutral position. However, the low assumed air speed predominates and center leaf **355** is positioned counterclockwise from its neutral position, so the nose of the fuselage continues to drop. When the initial assumed altitude is reached, the nose is pointed downwardly and the air speed has increased to the approximate initial speed. Inasmuch as the same conditions then prevail as at the beginning of the maneuver, it seems clear that the cycle will be repeated.

In view of the above, it will be seen that the direct mechanical connection from sector **609** to the center leaf **355** operates this leaf in such a manner that the fuselage is always returned to the level flight position. If this were the only factor no perceptible hunting would occur. However, the positioning of leaf **355** by the air speed unit which is responsive to changes in fuselage attitude lags behind the changes in fuselage attitude, so that the hunting effect is obtained.

Also, the amplitudes of the successive cycles are progressively diminished until level flight is achieved because the direct mechanical connection from the sector **609** to the center leaf of the elevator valve always operates the center leaf to return the fuselage to level flight against the operation of the air speed system. Inasmuch as the cyclical changes in assumed air speed result from the changes in fuselage attitude, the tendency of the fuselage to always return to the level position will progressively diminish the air speed effect, and level flight will be assumed.

It should be appreciated that not only the simulated air speed indicators, but the simulated altimeters, vertical speed indicator and other instruments such as the artificial horizon in the fuselage properly respond to the changes in fuselage attitude and assumed air speed.

It should be appreciated without a detailed explanation that if the fuselage **12** is in straight and level flight and the student pulls back upon the control wheel to place the fuselage in a climbing position, upon a releasing of the control wheel it is returned to its neutral position. The air speed system is operated to introduce a lower assumed air speed, and, therefore, the hunting effect will be set in operation. Of course, in this case, the first phase of the hunting would be a decrease in air speed and a gain in altitude, rather than an increase in air speed and a loss in altitude.

Again, referring to the case of a plane in actual flight, if the plane is flying straight and level an increase in power setting or a decrease in power setting will also cause the plane to hunt. In case the power setting is increased the first phase of the hunting is an increase in air speed and a raising of the nose of the plane. The plane assumes a climbing attitude and gains altitude, but the gaining of altitude results in a lowering of the air speed and a dropping off of the nose. The plane levels off at a higher altitude and because the air speed has dropped below the initial air speed, the nose of the plane will drop, resulting in a diving of the plane. The dropping of the nose of the plane results in a loss of altitude and an increase in air speed and the increase in air speed results in a raising of the nose of the plane. The hunting continues until the plane remains constant insofar as pitch attitude is concerned, but the nose of the plane will be slightly higher than it was before the applied increase in power. On the other hand if a plane is in straight and level flight, a decrease in power setting will cause the plane to hunt. The first phase of the hunting will be a loss in air speed and then the nose of the plane will drop resulting in a gliding and increase in speed and a raising of the nose, etc. The hunting will eventually terminate with the plane in a constant pitch attitude with the nose of the plane somewhat lower than before the decrease in power setting occurred.

An increase or decrease in assumed power setting of the apparatus of this invention will cause the associated apparatus to operate in a manner to simulate the hunting of a plane in actual flight as a result of a change in power setting. Referring to Fig. 6, assuming that a decrease in power setting occurs, the link **853** will move ahead and by means of arm **858**, shaft **859** and arm **860**, link **696** will move to the rear. The trim compound differential **703** causes link **700** to move toward the rear and link **705** moves toward the left side of the fuselage. The center leaf **355** of the aileron valve **115** is rotated counterclockwise, and as seen in Fig. 7, such a rotation of leaf **355** will result in the admission of vacuum to the front pitching bellows **17** and atmosphere to the rear pitching bellows **18**. Fuselage **12** will therefore assume a slightly nose down attitude. At the same time the decrease in power setting will, as previously explained, result in a decrease in assumed manifold pressure which will result in a closing of the air speed valve **616** of the air speed valve assembly **599**, seen in Fig. 6. Less vacuum is admitted to the bellows **620** of the air speed transmitter assembly **621** and the air speed unit **645** will be operated after an interval of time to rotate the gear **661** clockwise. This rotation of gear **661** will rotate the center leaf **355** counterclockwise admitting more vacuum to the forward pitching bellows **17** and more air to the rear pitching bellows **18**, causing the fuselage **12** to assume a greater diving position. As the fuselage assumes a diving position the sector **609** is moved ahead and in response to this movement of sector **609** the center leaf **355** is rotated clockwise against the counterclockwise rotation caused by the decrease in assumed air speed and the decrease in power setting. However, the air speed and power effects being predominant, the center leaf **355** is still positioned counterclockwise from its neutral position and the

trainer fuselage continues in a nose down position. The nosing down of the trainer fuselage results in an opening of the air speed valve **616** of the air speed valve assembly **599** and bellows **620** is collapsed resulting in the operation of the air speed unit **645** which turns gear **661** counterclockwise resulting in a clockwise rotation of the center leaf **355**. This rotation of the center leaf eventually overcomes the previous counterclockwise rotation of the leaf and the nose of fuselage **12** starts to rise. The increasing air speed and the nose down position of the fuselage both tend to raise the nose of the fuselage until it is in the level flight position. When this position is reached the assumed air speed is higher than the initial air speed so the center leaf **355** is rotated clockwise from the neutral position with respect to the upper leaf **356** and the nose of the fuselage continues to rise. As the nose of the fuselage is raised the sector **609** is moved to the rear resulting in a direct counterclockwise rotation of the center leaf **355**. Also, the assumed air speed drops off as a result of the raising of the nose of the fuselage, and when it has dropped off sufficiently far the climbing attitude of the fuselage and decrease in assumed air speed will have rotated the center leaf counterclockwise from its neutral position and vacuum will be admitted to the fore pitching bellows and atmosphere to the rear pitching bellows. The nose of the fuselage will drop until the fuselage is in the level flight position, at which time the assumed air speed will be substantially below the initial air speed. Accordingly, center leaf **355** will be positioned counterclockwise from neutral, and vacuum will be admitted to the front pitching bellows and atmosphere to the rear pitching bellows. The fuselage will therefore assume a diving attitude and the cycle will be repeated. The amplitude of each cycle will be less than the amplitude of the previous cycle and consequently the hunting will be dampened out, as previously explained. Also the final position of the fuselage will be slightly nosed down with respect to the initial position because of the fact that the link **853** which was moved ahead as a result of the decrease in power setting will finally position the center leaf **355** slightly counterclockwise of its initial position. This nose down position of the fuselage may be "trimmed out" by the student's manipulating the elevator trim control **130**.

On the other hand, assuming that the fuselage **12** is in straight and level flight, an increase in power setting will position the center leaf **355** through the action of link **853** and intermediate connections slightly clockwise of its initial position and consequently the fuselage will have a tendency to nose up. The increase in assumed air speed as a result of the higher power setting will then start the hunting effect and the fuselage will finally be positioned with its nose slightly higher than before the increase in assumed power was applied.

It may be concluded, therefore, that this invention discloses means for simulating the hunting of a plane in actual flight caused by a placing of the plane in a diving or climbing attitude, or by a change in power setting.

At the same time that the fuselage is assuming successive diminishing cyclical changes in climbing and diving positions, in simulation of the hunting of a plane in actual flight, it should be understood that the changes in assumed air speed result in changing tendencies of the fuselage to rotate to the left and right. Also, if the hunting occurs as a result of a change in throttle lever setting, the simulated engine power torque also results in a change in the tendency of the fuselage to rotate to the left or right as a result of simulated engine power torque.

Summary

Summarizing briefly some of the important aspects of this invention, there is provided within the trainer fuselage a simulated throttle lever and a simulated propeller governor lever. A manifold pressure unit is provided, and this unit combines the three factors of throttle lever setting, propeller governor lever setting and assumed altitude to give an output representative of assumed engine power. Assumed engine power is then combined with fuselage attitude to produce assumed air speed. Assumed air speed has six distinct effects, namely, changing the speed of recorder travel, changing the loading upon the flight controls when they are removed from their respective neutral positions, changing the center leaf of the elevator valve to cause a change in fuselage attitude, changing the position of the rudder valve to introduce a simulated torque effect, changing the position of the climb-dive valves to affect assumed altitude, and operating the mush valve to indicate a rapid loss in altitude when the air speed falls below a predetermined point.

The simulated power output also affects the position of the rudder valve to introduce a simulated power effect on torque. Means for simulating the stability and hunting of a plane in actual flight are incorporated.

The air speed and altitude systems are interdependent so that assumed air speed affects assumed altitude, and vice versa. Means are provided to simulate the difference between true and indicated air speeds.

In addition, simulated trim tab means are provided in order that the student in the fuselage may trim the controls in order that the fuselage will remain in the desired flight position. The trimming of the rudder may be rendered necessary because of a change in simulated engine power torque or a change in simulated air speed torque, both of which factors affect the heading of the fuselage. The trimming of the elevator control may be made necessary because of a change in simulated power setting or in assumed air speed, both of which factors affect the pitch attitude of the fuselage.

The rudder valve has been improved to provide a sensitive neutral position as well as proportionate turn control in response to rudder pedal movement. A novel arrangement comprising cams for operating the needle valves conventionally used in the type of trainers being considered has been disclosed. Also, insofar as the conventional climb-dive valves are concerned, a novel centering arrangement has been disclosed.

In view of the many important improvements to the prior art disclosed herein it will be appreciated that many changes may be made in the disclosed preferred embodiment of my invention without departing from the spirit thereof. All such changes are intended to be covered by the following claims.

I claim:

1. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being movably mounted upon a stationary base and having associated therewith

means for moving the fuselage to simulate the pitching movements of a plane in actual flight, a lever in said fuselage simulating the throttle lever of a real plane, and two independently operable and differentially combined means actuated by the movements of said lever for actuating said fuselage-moving means to change the pitching attitude of said fuselage in response to movements of said lever.

2. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being movably mounted upon a stationary base and having associated therewith means for moving the fuselage to simulate the pitching movements of a plane in actual flight, a first lever in said fuselage simulating the throttle lever of a real plane, a second lever in said fuselage simulating the propeller governor control lever of a real plane, and means actuated by the movements of either or both of said levers for actuating said fuselage-moving means to change the pitching attitude of said fuselage in response to the movements of both of said levers.

3. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being movably mounted upon a stationary base and having associated therewith means for moving the fuselage to simulate the pitching movements of a plane in actual flight, a lever in said fuselage simulating the throttle lever of a real plane, a first means actuated by the movements of said lever for actuating said fuselage-moving means to change the pitching attitude of said fuselage in response to movements of said lever, and a second delayed-action means actuated by the movements of said lever for actuating said fuselage-moving means to change the pitching attitude of said fuselage.

4. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being movably mounted upon a stationary base and having associated therewith means for moving said fuselage to simulate the pitching movements of a plane in actual flight, a lever in said fuselage simulating the throttle lever of a real plane, a unit in said trainer having an output changeable in response to changes in the assumed altitude of said fuselage, and means actuated by the movements of said lever and by changes in the output of said unit for actuating said fuselage-moving means to change the pitching attitude of said fuselage.

5. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being movably mounted upon a stationary base and having associated therewith means for moving said fuselage to simulate the pitching movements of a plane in actual flight, a first lever in said fuselage simulating the throttle lever of a real plane, a second lever in said fuselage simulating the propeller governor control lever of a real plane, a unit in said fuselage having an output changeable in response to changes in the assumed altitude of said fuselage, and means actuated by the movements of both of said levers and by changes in the output of said unit for actuating said fuselage-moving means to change the pitching attitude of said fuselage.

6. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being mounted upon a stationary base and having associated therewith means for moving the fuselage to simulate the pitching movements of a real plane, a manual control in said fuselage simulating the elevator control in a real plane, means operable by movements of said manual control for actuating said fuselage-moving means to change the pitching attitude of said fuselage, and means operated by the pitching of said fuselage for actuating said fuselage-moving means to change the pitching attitude of said fuselage.

7. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being mounted upon a stationary base and having associated therewith means for moving the fuselage to simulate the pitching movements of a real plane, a manual control in said fuselage simulating the elevator control in a real plane, means operable by movements of said manual control for actuating said fuselage-moving means to change the pitching attitude of said fuselage, and means operated by the pitching of said fuselage for actuating said fuselage-moving means to return the fuselage to the level pitching position.

8. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being mounted upon a stationary base and having associated therewith means for moving the fuselage to simulate the pitching movements of a real plane, a manual control in said fuselage simulating the elevator control of a real plane, means operable by the movements of said manual control for actuating said fuselage-moving means to change the pitching attitude of said fuselage, a first means operated by the pitching of said fuselage for changing the pitching attitude of said fuselage, and a second means operated by the pitching of said fuselage for actuating said fuselage-moving means to change the pitching attitude of said fuselage.

9. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being mounted upon a stationary base and having associated therewith means for moving the fuselage to simulate the pitching movements of a real plane, a manual control in said fuselage simulating the elevator control of a real plane, means operable by the movements of said manual control for actuating said fuselage-moving means to change the pitching attitude of said fuselage, a first means operated by the pitching of said fuselage for changing the pitching attitude of said fuselage, and a second means including time-delaying means operated by the pitching of said fuselage for actuating said fuselage-moving means to change the pitching attitude of said fuselage.

10. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being mounted upon a stationary base and having associated therewith means for moving the fuselage to simulate the pitching movements of a real plane, a manual control in said fuselage simulating the elevator control of a real plane, means operable by the movements of said manual control for actuating said fuselage-moving means to change the pitching attitude of said fuselage, and means operable upon a displacement of the fuselage from a previously selected attitude by a movement of the manual control and a subsequent releasing of the manual control for causing the fuselage to assume successive climbing and diving positions.

11. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being mounted upon a stationary base and having associated therewith means for mov-

ing the fuselage to simulate the pitching movements of a real plane, a manual control in said fuselage simulating the elevator control of a real plane, means operable by the movements of said manual control for actuating said fuselage-moving means to change the pitching attitude of said fuselage, and means operable upon a displacement of the fuselage from a previously selected attitude by a movement of the manual control and a subsequent releasing of the manual control for causing the fuselage to assume successive diminishing climbing and diving positions.

12. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being mounted upon a stationary base and having associated therewith means for moving the fuselage to simulate the pitching movements of a real plane, a manual control in said fuselage simulating the elevation control of a real plane, means interconnecting said manual control and said fuselage-moving means for changing the pitching attitude of said fuselage upon a movement of said control, means operable upon a displacement of said fuselage from the level flight position and connected to the fuselage-moving means for returning the fuselage to the level pitching position, a unit in said fuselage having an output changeable in response to changes in the assumed air speed of said fuselage, means interconnecting the output of said unit and said fuselage-moving means for changing the pitching position of said fuselage upon a change in the output of said unit, and means responsive to the pitching attitude of said fuselage and including time-delay means for operating said unit, all the foregoing being interrelatingly operable so that when said fuselage is placed in a pitching position displaced from the level flight position by movement of the said manual control and the manual control is then released, the said means for returning the fuselage to the level flight position is operated and later assisted by the operation of said unit to return the fuselage to the level flight position, the delay response of the said unit resulting in a passing through the level flight position of the fuselage to reverse the pitching attitude thereof.

13. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being mounted upon a stationary base and having associated therewith means for moving the fuselage to simulate the pitching movements of a real plane, a lever in said fuselage simulating the throttle control lever of a real plane, and means interconnecting said lever and said fuselage-moving means for causing the fuselage to assume successive climbing and diving positions upon a single movement of said lever.

14. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being mounted upon a stationary base and having associated therewith means for moving the fuselage to simulate the pitching movements of a real plane, a lever in said fuselage simulating the throttle control lever of a real plane, and means interconnecting said lever and said fuselage-moving means for causing the fuselage to assume successive diminishing climbing and diving positions upon a single movement of said lever.

15. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being mounted upon a stationary base and having associated therewith means for moving the fuselage to simulate the pitching movements of a real plane, means operable upon a displacement of said fuselage from the level flight position and connected to said fuselage-moving means for returning the fuselage to the level pitching position, a unit in said fuselage having an output changeable in response to changes in the assumed air speed of said fuselage, means interconnecting the output of said unit and said fuselage-moving means for changing the pitching position of said fuselage upon a change in the output of said unit, means responsive to the displacement of said fuselage from the level pitching position for changing the output of said unit, a lever in said fuselage simulating the throttle control lever of a real plane, means interconnecting said lever and said unit for changing the output of said unit upon a movement of said lever, all the foregoing being interrelatingly operable so that a movement of said lever results in a change in the output of said unit causing an increasingly greater change in the attitude of said fuselage opposed by the operation of the means operable upon a displacement of the fuselage from the level flight position for returning the fuselage to the level pitching position, and eventually overcome by the last-mentioned means assisted by the operation of the said unit by displacement of the fuselage from the level pitching position.

16. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being mounted upon a stationary base and having associated therewith means for moving the fuselage to simulate the pitching movements of a real plane, a manual control in said fuselage simulating the elevator control of a real plane, means operable by the movements of said manual control for actuating said fuselage-moving means to change the pitching attitude of said fuselage, a lever in said fuselage simulating the throttle control lever of a real plane, means operable in response to movements of said lever for actuating said fuselage-moving means to change the pitching attitude of said fuselage, means simulating the trimming means of a real plane connected to said fuselage-moving means whereby the fuselage-moving means may be operated to place the fuselage at a selected pitching attitude, and means operable upon a displacement of the fuselage from the previously selected attitude by a movement of the manual control and subsequent releasing of the manual control for causing the fuselage to assume successive climbing and diving positions.

17. In a grounded aviation trainer the combination of a fuselage rotatably mounted upon a stationary base, means for rotating said fuselage with respect to said base, a lever in said fuselage simulating the throttle control lever of a real plane, means interconnecting said lever and said fuselage-rotating means for actuating said means to rotate said fuselage in a given direction in response to a movement of said lever, and a second means including time-delay means interconnecting said lever and said fuselage-rotating means and operated in response to the same movement of said lever for off-setting at least in part the first-mentioned rotation.

18. In a grounded aviation trainer the combination of a fuselage universally and rotatably mounted upon a stationary base, means for rotating said fuselage with respect to said base and means for pitching said fuselage to respectively simulate the turning and pitching movements of a plane in actual flight, a lever in said fuselage

simulating the throttle lever of a real plane, and means actuated by the movements of said lever for actuating said fuselage-rotating means to rotate said fuselage and for actuating said fuselage-pitching means to change the pitching attitude of said fuselage in response to movements of said lever.

19. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being universally and rotatably mounted upon a stationary base, means for rotating said fuselage with respect to said base and means for pitching said fuselage to respectively simulate the turning and pitching movements of a real plane, a lever in said fuselage simulating the throttle lever of a real plane, and means interconnecting said lever with both said fuselage-rotating means and said fuselage-pitching means for operating said fuselage-rotating means and for causing said fuselage to assume successive climbing and diving positions in response to a single movement of said lever.

20. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being movably mounted upon a stationary base and having associated therewith means for moving the fuselage to simulate the pitching movements of a plane in actual flight, a lever in said fuselage simulating the throttle lever of a real plane, a first means actuated by the movements of said lever for actuating said fuselage-moving means to change the pitching attitude of said fuselage in response to movements of said lever, a second delayed-action means actuated by the movements of said lever for actuating said fuselage-moving means to change the pitching attitude of said fuselage, and means including a manually movable member simulating the elevator trimming control of a real plane operatively connected to said fuselage-moving means for changing the pitching attitude of said fuselage in response to movements of said member.

21. In a grounded aviation trainer the combination of a fuselage having a seat for a student, said fuselage being movably mounted upon a stationary base and having associated therewith means for moving said fuselage to simulate the pitching movements of a plane in actual flight, a lever in said fuselage simulating the throttle lever of a real plane, a unit in said trainer having an output changeable in response to changes in the assumed altitude of said fuselage, means actuated by the movements of said lever and by changes in the output of said unit for actuating said fuselage-moving means to change the pitching attitude of said fuselage, and means including a manually movable member simulating the elevator trimming control of a real plane operatively connected to said fuselage-moving means for changing the pitching attitude of said fuselage in response to movements of said member.

22. In a grounded aviation trainer the combination of a fuselage rotatably mounted upon a stationary base, means for rotating said fuselage with respect to said base, a lever in said fuselage simulating the throttle control lever of a real plane, means interconnecting said lever and said fuselage-rotating means for actuating said means to rotate said fuselage in a given direction in response to a movement of said lever, a second means including time-delay means interconnecting said lever and said fuselage-rotating means and operated in response to the same movement of said lever for off-setting at least in part the first-mentioned rotation, and means including a manually movable member simulating the rudder trimming control of a real plane operatively connected to said fuselage-rotating means for regulating the rotation of said fuselage in response to movements of said member.

23. In a grounded aviation trainer the combination of a fuselage universally and rotatably mounted upon a stationary base, means for rotating said fuselage with respect to said base and means for pitching said fuselage to respectively simulate the turning and pitching movements of a plane in actual flight, a lever in said fuselage simulating the throttle lever of a real plane, means actuated by the movements of said lever for actuating said fuselage-rotating means to rotate said fuselage and for actuating said fuselage-pitching means to change the pitching attitude of said fuselage in response to movements of said lever, a control in said fuselage simulating the rudder trimming control of a real plane operatively connected to said fuselage-rotating means for regulating the rotation of the same, and a control in said fuselage simulating the elevator trimming control of a real plane operatively connected to said fuselage-pitching means for regulating the pitching attitude of the same.

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