L. BRENNAN.

MEANS FOR IMPARTING STABILITY TO UNSTABLE BODIES.

APPLICATION FILED JAN. 4, 1910.

1,183,530.

Patented May 16, 1916.

5 SHEETS—SHEET 1.

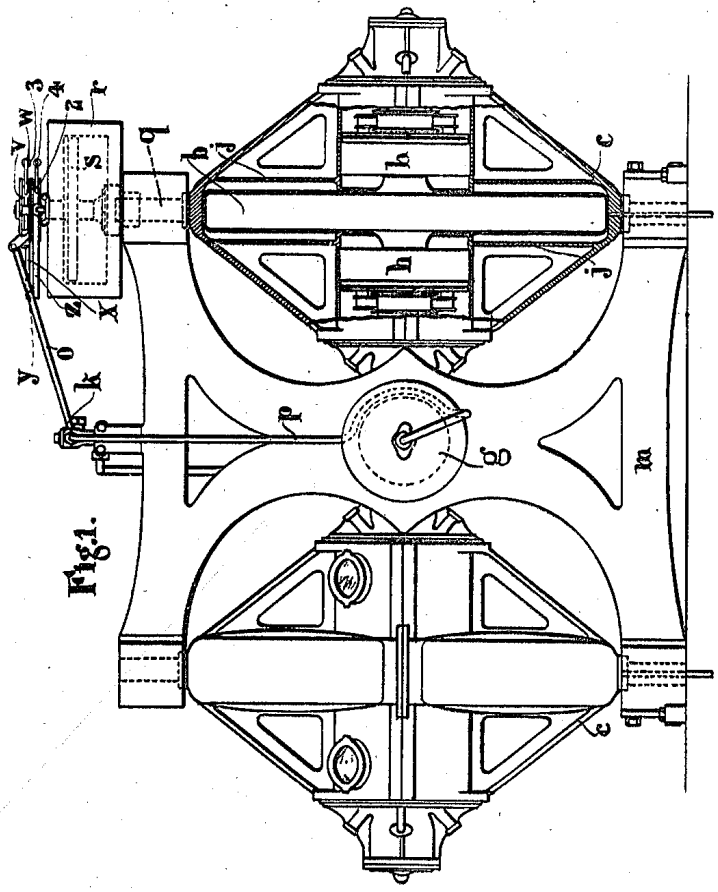

Fig. 1.

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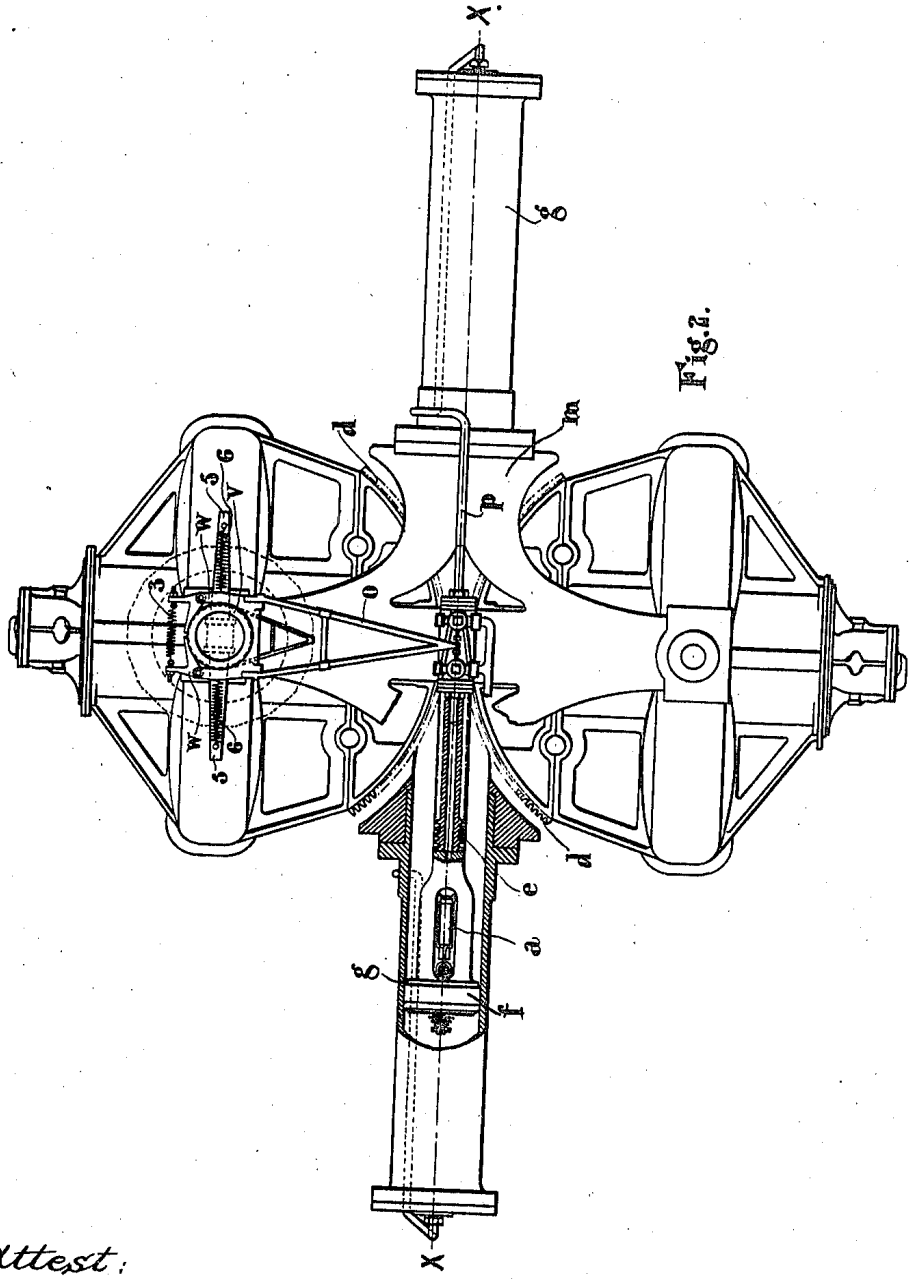

Fig. 2.

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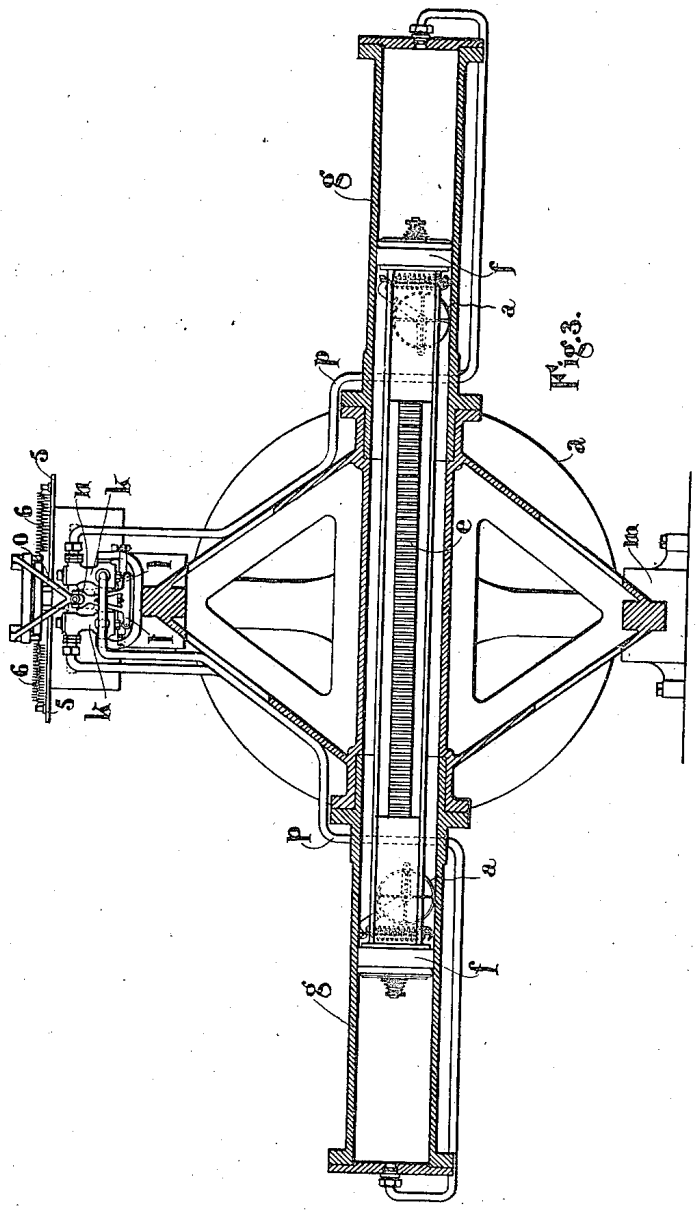

Fig. 3.

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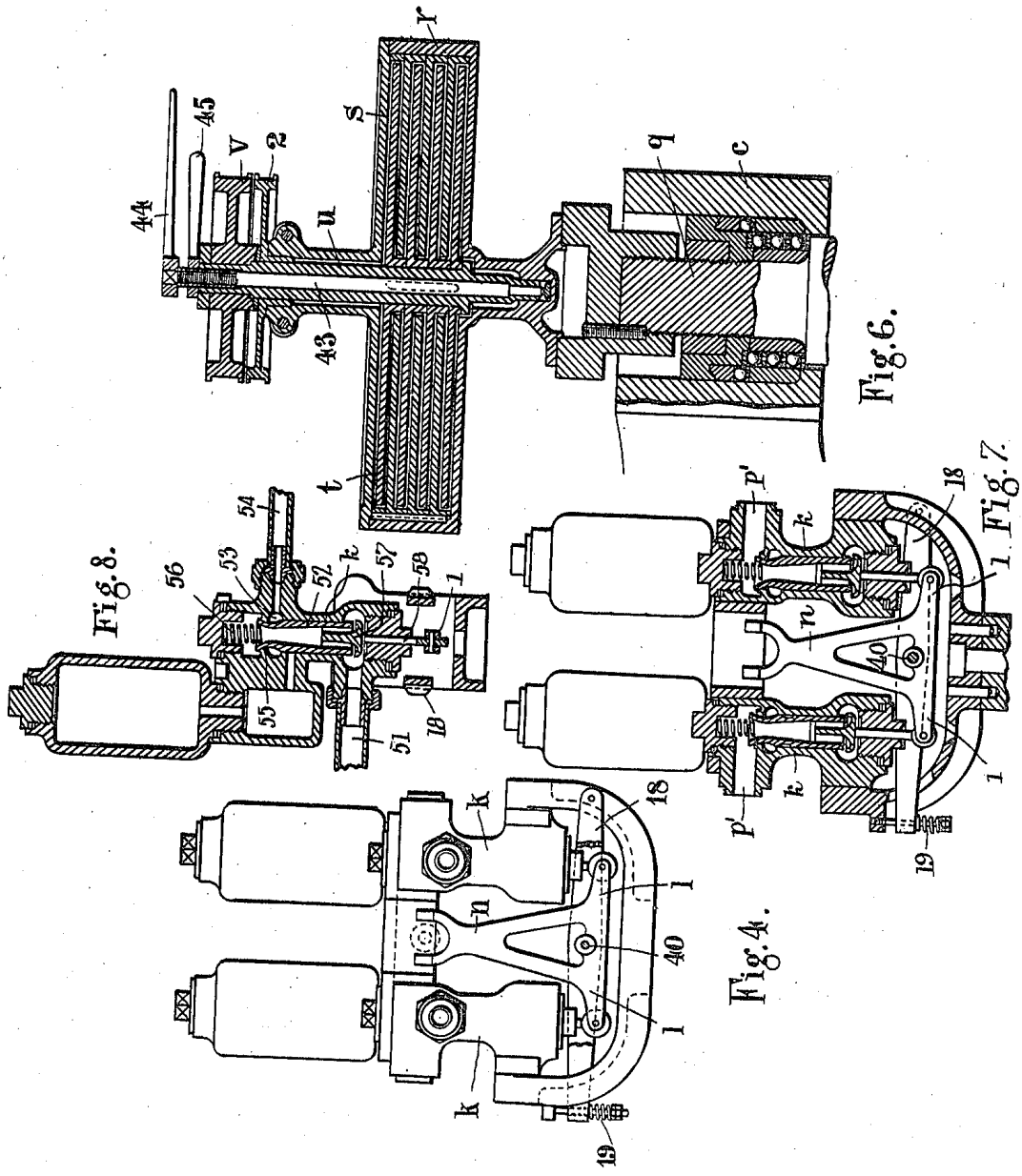

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 4.

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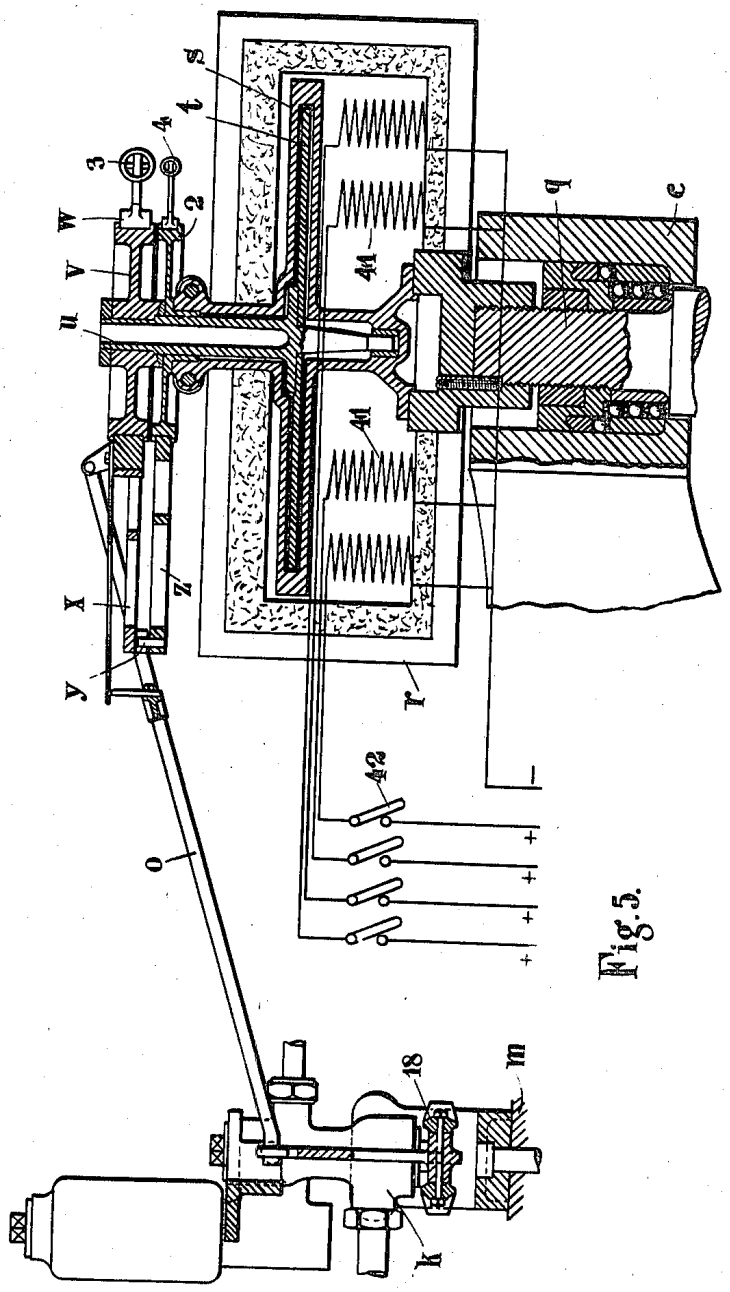

Fig. 5.

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UNITED STATES PATENT OFFICE.

LOUIS BRENNAN, OF GILLINGHAM, ENGLAND.

MEANS FOR IMPARTING STABILITY TO UNSTABLE BODIES.

1,183,530. Specification of Letters Patent. Patented May 16, 1916.

Application filed January 4, 1910. Serial No. 536,311.

To all whom it may concern:

Be it known that I, LOUIS BRENNAN, C. B., a subject of the King of Great Britain and Ireland, and residing at "Woodlands," Gillingham, in the county of Kent, England, have invented certain new and useful Improvements in Means for Imparting Stability to Unstable Bodies, of which the following is a specification.

This invention relates to methods and devices for imparting stability to bodies which are naturally unstable, including such methods as are described in my Patent No. 796893.

The present invention also relates to methods which have previously been proposed in my Patent No. 796893 for maintaining equilibrium by effecting shifts of the center of gravity of the unstable body relatively to its supporting means, said shifts being effected, for example, by means of fluid pressure.

According to the invention described in my said patent, one or more gyrostats are mounted on the body in such a manner that precession of the gyrostat or gyrostats can take place when the equilibrium of the body is disturbed, and control of the precessional movement is employed so as to cause the gyrostats to restore equilibrium, or the restoration of equilibrium is effected by change of the center of gravity.

According to my present invention, I derive forces one of which is proportional to the couple tending to disturb the body, another force proportional to the time integral of the said disturbing couple and a further force to compensate for unavoidable friction occurring in the precessional movement, these forces being employed to control other powerful forces adapted either to influence the precession of the gyrostats or to effect shifts of the center of gravity of the body relatively to its point of support. I have found that the above-mentioned force, depending as to its magnitude and duration upon the disturbing couple, may conveniently be derived either from the reaction or stress occurring between the gyrostat frame and its support upon the application of the disturbing couple to the said support or from the precessional movement of the gyrostat arising from the application of said disturbing couple, and that the force depending upon the time integral of the disturbing couple may be derived either from the reaction between the gyrostat frame and its support or from the displacement or acceleration of the gyrostat from its central position under the continued application of a disturbing couple; further, that the force depending upon the unavoidable friction occurring in the precessional movement may be derived from the precessional movement of the gyrostat itself by suitable friction coupling means.

Referring now to the accompanying drawings, Figure 1 is an elevation view showing two gyrostats mounted on a common frame and arranged so that their precession about vertical axes can be controlled; Fig. 2 is a part sectional plan showing the precession control devices; Fig. 3 is a cross sectional side elevation view of Fig. 1 on the line X X of Fig. 2 showing the arrangement of the precession controlling rack and the pistons operating the same; Fig. 4 shows the valves and the three-armed lever which operates their spindles, also the spring-controlled fulcrum lever; Fig. 5 is a part sectional view through the viscous fluid coupling showing the temperature controlling devices, safety clutch devices and friction loss compensating devices and the arm applying the controlling forces to the valve operating lever; Fig. 6 is a cross sectional view through a modified form of viscous fluid coupling; Fig. 7 is a transverse section through the two valves; while Fig. 8 is a section at right angles to Fig. 7 through one of the valves.

In carrying the invention into effect according to one modification which is described as applied to a monorail vehicle, and in the case in which equilibrium of the unstable body is maintained by acceleration of the precession of the gyrostat or gyrostats, I mount on a suitable framework *m* (see Figs. 1, 2, 3) which is rigid with the vehicle a pair of gyrostats, free to precess about vertical axes and having their heavy wheels *b*, rotating in opposite directions. The frames *c c* in which the heavy wheels *b b* rotate are provided with gears *d d* adapted to engage with a double rack capable of sliding longitudinally, and operated by means of pistons *f f* moving respectively in cylinders *g g* arranged co-axially on opposite sides of the gyrostats. The heavy wheels *b b* and electromotors *h h* by which they are driven are inclosed air-tight in casings *j j* in which a high degree of vacuum is maintained.

The pistons *f f* have spring supported rollers *a a* arranged to roll on the lower side of the cylinders to reduce friction.

The admission and exhaust of compressed air or other working fluid from the cylinders *g g* to turn the gyrostats about vertical axes are controlled by means of suitable valves *k k* (Figs. 4 and 5) connected to the cylinders by pipes *p p*, which valves are adapted to allow an amount of pressure fluid to pass to the working cylinders proportional to the pressure exerted on the valve spindle to operate the valve. The valves *k k* for the two cylinders are respectively operated by two arms *l l* of a three-armed lever, on the third arm of which a fork *n* is provided in which the actuating lever *o* works. These valves *k*, *k*, may be of the known type described in my British Patent No. 7177 of 1902, two sections at right angles being shown at Figs. 7 and 8. The valves are connected to the hydraulic cylinders *g* by pipes *p* connected to the passages *p'*. In each valve there is provided a hollow cylindrical piston 52, operating in the cylindrical valve casing, at one end of which is provided an annular passage 53, surrounding the piston 52. This passage is connected by a pipe 54 to a source of high pressure fluid. A valve seat 55 is formed at one end of the cylindrical valve casing *k*, and a conical valve surface to fit this seat is formed on the cylindrical piston 52. This valve is held on its seat by a light spring 56. The valve opens into the passage *p'*, from which fluid at a regulated pressure is supplied to one of the hydraulic cylinders *g* through the pipe *p*. The other end of the cylindrical casing of the valve *k* contains a lift valve 57, which is passed upon a seat formed on the end of the hollow piston 52. This valve opens into the discharge pipe 51. The operation of this valve is as follows:—Assuming that a pressure is applied to the exhaust valve 57 by means of a rod 58 passing through a gland in the end of the casing of the valve *k*, this pressure forces the exhaust valve 57 on to its seat on the end of the hollow piston 52, and if the pressure be sufficient, the hollow piston will be thrust inward, and the valve surface at the other end will be moved off its seat 55 against the pressure of the spring 56, plus whatever pressure may be in the pipe *p*. The fluid under pressure then flows from the supply pipe 54, and is fed to the pipe *p* and hydraulic cylinder *g* at a regulated pressure. When the pressure in the cylinder *g* is nearly equal to the pressure applied to the discharge valve, the spring 56 closes the valve by thrusting the hollow piston along, and at the same time moving the exhaust valve 57 with it. So far the action is that of an ordinary reducing valve. If, however, the pressure upon the discharge valve by the rod 58 be further reduced, the fluid contents from the receiving chamber will flow through the hollow piston 52, lift the discharge valve 57, and escape to the exhaust pipe 51, until the pressure in the hydraulic cylinder *g* just balances the pressure applied to the discharge valve by the rod 58. In this manner, the pressure within the cylinder *g* rises or falls with the force applied to the spindle 58, which controls both the discharge and piston valves. It will be seen that by this means the hydraulic cylinder may be maintained at a varying pressure, which rises or falls according as the force acting on the valve through the spindle 58 increases or diminishes.

In order to provide sufficient exhaust from the cylinders when the actuating lever causes the valve to open only a slight distance the three-armed lever carrying the valve tappets operating the valve spindles is fulcrumed at 40 (see Fig. 4) on a pivoted arm 18 held at one end by a spring 19 so that the fulcrum yields to a slight extent when the operating arm *o* is moved, causing the exhaust to open to a greater extent than would otherwise be the case.

The actuating lever is operated by three separate forces all of which originate in the precessional movement of the gyrostats. The vertical spindle *q* of one of the gyrostat frames projects upward through its upper bearing and carries a casing *r* (Figs. 5 and 6) having a circular chamber *s* in which a disk *t* can rotate. The circular chamber *s* is filled with a viscous fluid, and the spindle *u* carrying the disk *t* is thus caused to move by a force whose magnitude is substantially proportional to the velocity of movement of the gyrostat about the vertical axis. The spindle *u* carries at its upper end a circular disk or drum *v* to which an operating arm *o* by which the valves *k k* are operated is attached by a friction clutch *w* composed of blocks tightened on the drum *v* by a spring 3, this clutch being provided to prevent breakage of the valve controlling gear if too rapid movement of the gyrostats occurs. Depending from the clutch blocks *w* there is provided an arm *x* engaging a projection *y* on the arm *z* which is carried by a pair of blocks which bear against a disk 2 attached to the chamber *s* moving with the gyrostats, and by these blocks a force proportional to the unavoidable friction occurring in the precessional movement is impressed on the operating arm *o*. This friction clutch is so regulated by adjusting the spring 4 that the friction occurring in the precessional movement is compensated for.

There are secured to the chamber *s* a pair of horizontally projecting arms 5 5, the ends of which are attached by springs 6 6 to the clutch blocks *w*. The effect of these springs 6 6 is to cause the gyrostats to exert

on the operating arm *o* a force proportional to the displacement of the gyrostats from their central position, this force always acting in the direction to bring the gyrostats back to their central position. It will thus be seen that the valves *k k* controlling the admission of pressure fluid to the cylinders *g g* which operate the rack *e* controlling the precessional movement are acted on by three forces, one force due to the springs 6 6 and proportional to the displacement of the gyrostats from the central position, a second force due to the viscous coupling *s t* which causes to be transmitted to the valves a force proportional to the velocity of precession of the gyrostats or substantially proportional thereto, and a third force proportional to the resistance due to the unavoidable mechanical friction of the parts occurring in the precessional movement of the gyrostat. The effect of these forces acting on the valves is simply multiplied to the required extent by the elastic fluid cylinders *g g* and caused to act directly on the gyrostats through the rack *e* and toothed sectors *d d* which operate to turn the gyrostats about vertical axes.

In order to maintain the viscous fluid contained in the receptacle *s* (Fig. 5) at the proper viscosity irrespective of the climate variations I line the casing *r* with a non-conducting substance and insert within the casing *r* and in proximity to the chamber *s* resistance coils 41 controlled by switches 42 and so arranged that by the passage of an electric current the right degree of temperature may be maintained. The current may be controlled if desired by a thermostat or the like.

Fig. 6 illustrates a modified construction of the viscous coupling shown in Fig. 5. In the construction shown in Fig. 6 a number of plates *t* are employed, each plate being contained within separate chambers *s*. The chambers *s* of this modification are formed by disks having downwardly turned rims, the width of the rims being so chosen that each disk is supported from the next, such a distance as to form a chamber for one of the disks *t*. It is to be understood that the disks *t* are keyed to the spindle *u* while the disks forming the chambers *s* are secured to the casing *r* to prevent further rotation.

In order to position the disks *t* at the proper distance from the surfaces on the disks forming the chambers *s* I provide within the spindle *u* a spindle 43 having a fine thread cut upon its upper end, this thread engaging an internal thread cut upon the inside of the spindle *u*. The spindle 43 carries a handle 44 and is provided at its lower extremity with a reduced portion adapted to bear upon a suitable thrust piece. By rotating the spindle 43 by means of the handle 44, the spindle *u* is raised or lowered with respect to the casing *r* and when the correct adjustment has been made the spindle 43 is locked in position by means of the locking device 45.

The operation of my invention as applied to the stabilizing of vehicles, such as monorail cars, vessels, aeroplanes and the like is as follows: As soon as the equilibrium of the vehicle becomes disturbed, a force is applied to the gyroscopes through the vertical pivots *g* in frames *m*, causing precession about said pivots. As soon as this movement starts, the controlling means secured to the end of axle *q* are brought into action, causing a compound force to be exerted on rod *o*, which is the resultant of the force due to the viscosity of the liquid in chamber *s*, the force exerted by springs 6 and the force due to friction blocks *w*. These forces, it will be remembered, are approximately proportional to the velocity of precession, the displacement of the gyros from their central position and the friction around the vertical axes, respectively. The valves K are moved by rod *o* in proportion to the force exerted thereon and govern the fluid pressure cylinders so that they multiply the force and apply it to the gyros, causing acceleration of the precession and the consequent righting of the vehicle.

Each of the constituent forces is of importance in securing a highly efficient device. By employing a righting force on the vehicle which is responsive to the velocity of precession of the gyro, a highly accurate and efficient governor is obtained, since the velocity of precession is directly proportional to the disturbing force acting on the body. Again, it is equally important in unstable bodies, that the righting force be increased in proportion to the length of time the disturbing force acts. This is accomplished by governing the righting force according to the amount of precession of the gyro. The destroying of the effect of friction around the precession axis is also important, as this always results in the impairment of the righting couple exerted by the gyroscope.

In accordance with the provisions of the patent statutes, I have herein described the principle of operation of my invention, together with the apparatus which I now consider to represent the best embodiment therefor, but I desire to have it understood that the apparatus shown is only illustrative and that the invention can be carried out by other means. Also, while it is designed to use the various features and elements in the combination and relations described, some of these may be altered and others omitted without interfering with the more general results outlined, and the invention extends to such use.

Having now described my invention, what

I claim as new and desire to secure by Letters Patent is:—

1. The combination with a vehicle, of a stabilizing gyroscope therefor, a variable torque applying means for accelerating the precession of said gyro, and means brought into action by said precession and governed by the velocity of precession for controlling said torque applying means.

2. The combination with a vehicle, of a stabilizing gyroscope mounted thereon, means for automatically accelerating the precession of said gyro comprising a governing member adapted to exert a force proportional to the displacement of the gyro from its central position and a force multiplying device connected to said governing member for applying a torque on the gyro in the direction of the existing precession.

3. In gyroscopic apparatus, the combination of a gyroscope and a precessional frame therefor, of means for overcoming the effect of friction about the precessional axis comprising a frictional member adapted to be moved by precession of the gyro, and a device controlled by said member for applying a positive torque on the gyro about said axis.

4. The combination with a vehicle, of a stabilizing gyroscope mounted thereon, means for automatically accelerating the precession of said gyro comprising a governing member adapted to exert a force proportional to the displacement of the gyro from its central position a second member for exerting a force proportional to the velocity of precession of the gyro, and a force multiplying device connected to both of said governing members for applying a torque on the gyro in the direction of the existing precession.

5. The combination with a vehicle, of a stabilizing gyroscope mounted thereon, means for automatically accelerating the precession of said gyro comprising a governing member adapted to exert a force proportional to the displacement of the gyro from its central position, a second member for exerting a force proportional to the friction about the precessional axis, and a force multiplying device connected to both of said governing members for applying a torque on the gyro in the direction of the existing precession.

6. The combination with a vehicle, of a stabilizing gyroscope mounted thereon, means for automatically accelerating the precession of said gyro comprising a governing member adapted to exert a force proportional to the displacement of the gyro from its central position, a second member for exerting a force proportional to the velocity of precession of the gyro, a third member for exerting a force proportional to the friction about the precession axis and a force multiplying device connected to all of said governing members for applying a torque on the gyro in the direction of the existing precession.

7. The combination with a vehicle, of a stabilizing gyroscope therefor, fluid pressure means for exerting powerful forces about the precession axis of said gyroscope, and controlling means for said first means comprising a valve adapted to vary the pressure of said first means according to the pressure exerted thereon and means responsive to the velocity of precession of the gyro for governing the pressure on said valve.

8. The combination with a vehicle, of a stabilizing gyroscope therefor, fluid pressure means for exerting powerful forces about the precession axis of said gyroscope, and controlling means for said first means comprising a valve adapted to vary the pressure of said first means according to the pressure exerted thereon and a spring controlled member acting on said valves proportionally to the displacement of the gyroscope from its normal position.

9. The combination with a vehicle, of a stabilizing gyroscope therefor, fluid pressure means for exerting powerful forces about the precession axis of said gyroscope, and controlling means for said first means comprising a valve adapted to vary the pressure of said first means according to the pressure exerted thereon and means responsive to the friction developed about the precession axes for governing the pressure on said valve.

10. The combination with a vehicle, of a stabilizing gyroscope therefor, fluid pressure means for exerting powerful forces about the precession axis of said gyroscope, and controlling means for said first means comprising a valve adapted to vary the pressure of said first means according to the pressure exerted thereon and compouund means responsive to the combinative influence of the velocity and amount of precession of the gyro for governing the pressure on said valve.

11. The combination with a vehicle, of a stabilizing gyroscope therefor, fluid pressure means for exerting powerful forces about the precession axis of said gyroscope, and controlling means for said first means comprising a valve adapted to vary the pressure of said first means according to the pressure exerted thereon and compound means responsive to the combinative influence of the velocity of precession and to the friction about the precessional axis of the gyro for governing the pressure on said valve.

12. The combination with a vehicle, of a stabilizing gyroscope therefor, fluid pressure means for exerting powerful forces about the precession axis of said gyroscope, and controlling means for said first means comprising a valve adapted to vary the pressure of said

first means according to the pressure exerted thereon and compound means responsive to the combinative influence of the velocity and amount of precession and to the friction about the precessional axis of the gyro for governing the pressure on said valve.

13. In an unstable body carrying a gyrostat or gyrostats, means for exerting forces to preserve equilibrium of said body, including fluid pressure cylinders, and valves allowing an amount of pressure fluid to pass to working cylinders proportional to pressure exerted to operate said valves, and means to exert pressure to operate said valves actuated by said gyrostat or gyrostats, as set forth.

14. In combination, in an unstable body, a frame rigidly connected to said body, a pair of gyrostats pivotally mounted about vertical axes in said frame, fluid pressure cylinders rigidly mounted in said frame, pistons in said hydraulic cylinders, a rack connecting said pistons, segments on said gyrostat frames coöperating with said rack, valves controlling the flow of fluid to said cylinders, in such a manner that the pressure in said cylinders is proportional to the pressure exerted to operate said valves, a member mounted on the precession axle of one of said gyrostats, a member coöperating with said member, and connected thereto by a viscous coupling, a connection between said second member and said valves, a spring controlled member acting on said valves, proportionally to the displacement of said gyrostats from the central position, and means acting on said valves proportionally to the friction of the precessional movement, as set forth.

15. The combination with a vehicle, of a stabilizing gyroscope therefor, a variable torque applying means for controlling the precession of said gyroscope, and means brought into action by said precession and governed by the velocity of precession for controlling said torque applying means.

16. The combination with a vehicle, of a stabilizing gyroscope therefor, a governing member adapted to exert forces proportional to the displacement of the gyroscope from its central position, and a force multiplying device connected to said governing member for applying torques on the gyroscope adapted to control the precession.

17. The combination with a vehicle, of a stabilizing gyroscope mounted thereon, means for controlling the precession of said gyro comprising a governing member adapted to exert a force proportional to the displacement of the gyro from its central position, a second member for exerting a force proportional to the velocity of precession of the gyro, and a force multiplying device connected to both of said governing members for applying a torque on the gyro for controlling precession.

In testimony whereof I affix my signature in presence of two witnesses.

LOUIS BRENNAN.

Witnesses:
J. PHILLIPS CRAWLEY,
AUBREY T. EVANS.