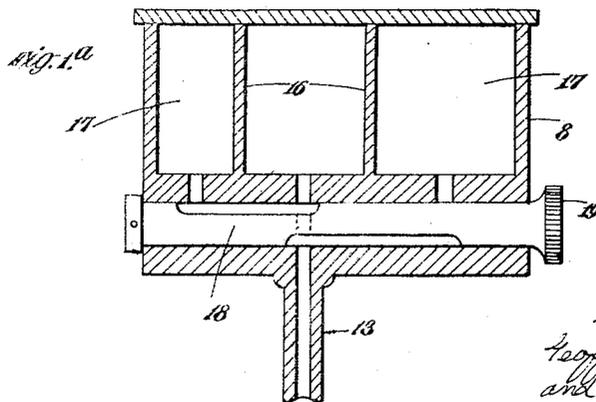
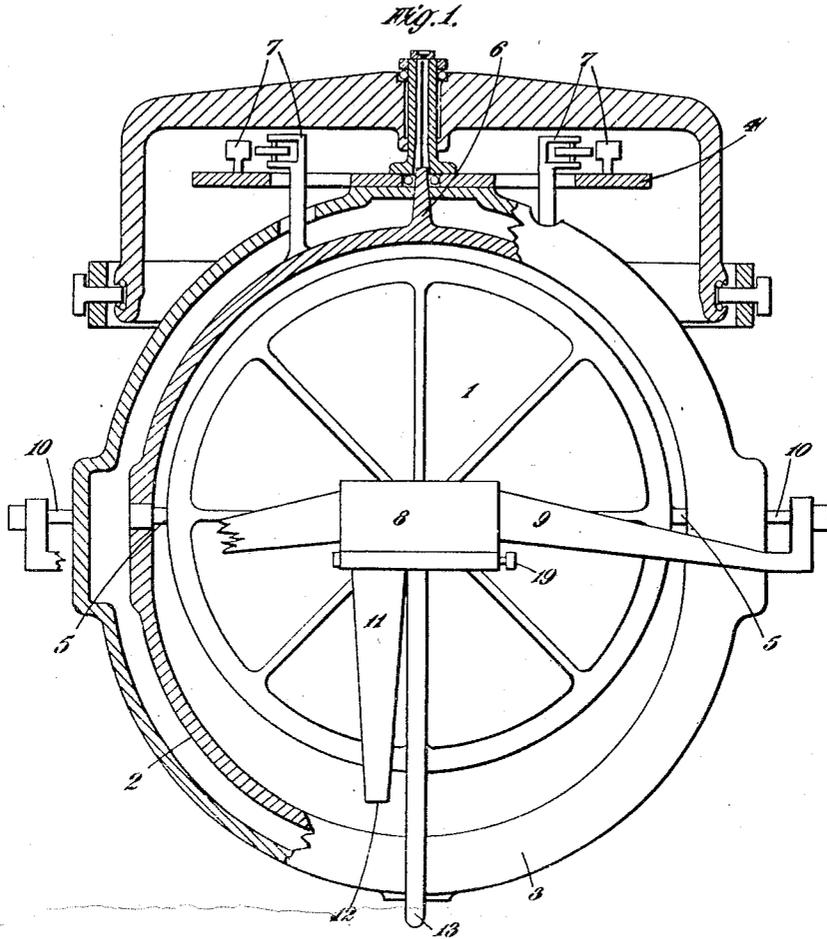


G. B. HARRISON AND A. L. RAWLINGS.
 GYROSCOPIC COMPASS.
 APPLICATION FILED AUG. 9, 1919.

1,362,940.

Patented Dec. 21, 1920.
 2 SHEETS—SHEET 1.

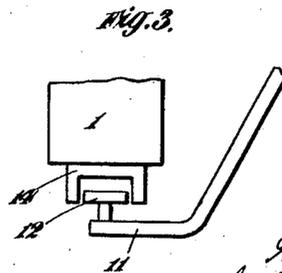
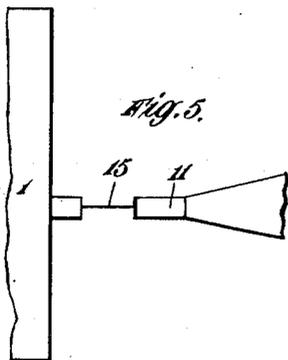
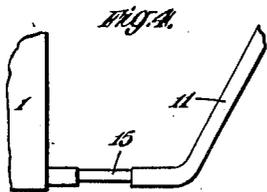
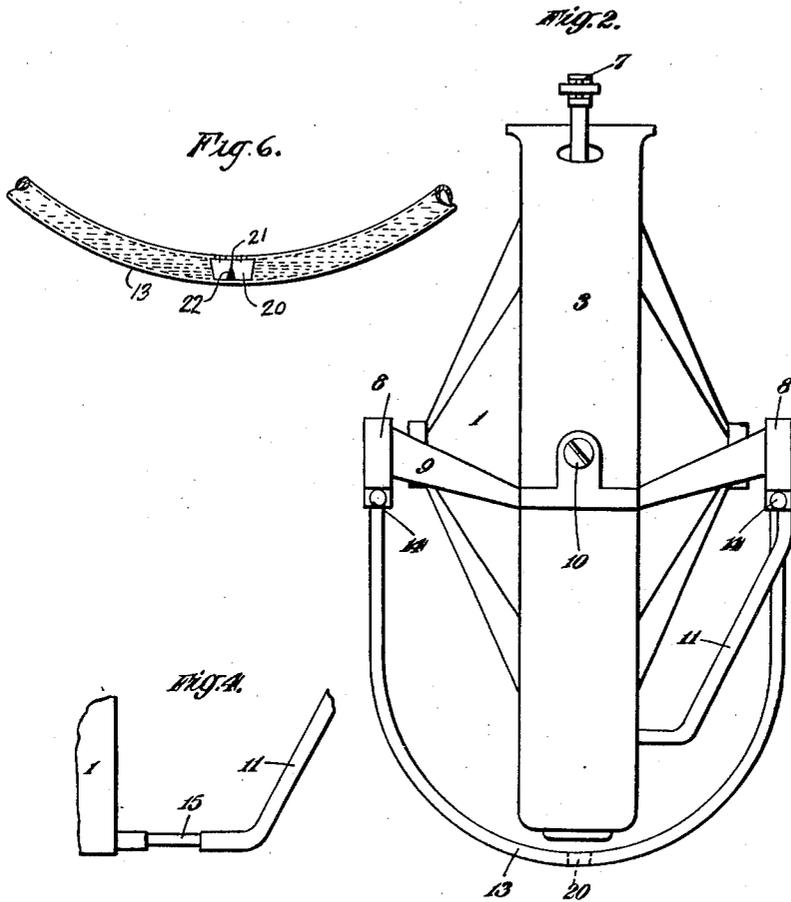


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UNITED STATES PATENT OFFICE.

GEOFFREY BRANCKER HARRISON AND ARTHUR LIONEL RAWLINGS, OF SLOUGH, ENGLAND, ASSIGNORS TO THE SPERRY GYROSCOPE COMPANY, OF BROOKLYN, NEW YORK.

GYROSCOPIC COMPASS.

1,362,940.

Specification of Letters Patent. Patented Dec. 21, 1920.

Application filed August 9, 1919. Serial No. 316,484.

To all whom it may concern:

Be it known that we, GEOFFREY BRANCKER HARRISON and ARTHUR LIONEL RAWLINGS, both subjects of the King of Great Britain, residing at Admiralty Compass Observatory, Slough, in the county of Buckingham, England, have invented certain new and useful Improvements in Gyroscopic Compasses, of which the following is a specification.

The invention relates to gyro compasses and more particularly to compasses which are not pendulous, or at least not sufficiently so to impart meridian seeking properties thereto, but in which meridian seeking properties are largely obtained by causing a flow of liquid between the north and south sides of the gyro when the spinning axis of the gyro is tilted.

Compasses approaching this principle have already been proposed in which the flow is caused by an air blast controlled by a valve operated by the tilting of the gyro casing. It has also been proposed to use a level connected to the gyroscope by a yielding attachment and capable of movement relatively thereto, in order to exert a controlling torque on the gyroscope.

In such compasses also liquid has been forced to the high side of the gyroscope by the air blast so that the compass behaves as an ordinary pendulous gyroscope.

In either of these arrangements when the compass is carried in a rolling ship the liquid is liable to surge from side to side and introduce torques around the vertical axis of the compass, resulting in deviations when the ship is not on a cardinal course. It has been proposed to prevent this surging by using a viscous fluid and a capillary tube or constriction in the level, but this prevents the compass from having a correct ballistic deflection on change of speed in latitude, which results in oscillations of the compass in azimuth after alterations in the course or speed of the ship and which also interferes with the meridian seeking properties of the compass.

In the present invention, which is equally applicable whether the liquid or other laterally movable mass is forced to the higher side of the gyroscope or flows by gravity to the lower side, but in employing which I prefer and have illustrated the latter em-

bodiment. Novel means is employed to prevent the level of the liquid in the N—S direction from being disturbed to any effective extent by the rolling of the ship, while at the same time the liquid is sensitive to those accelerations which produce the required ballistic deflection.

According to this invention the containing vessel for the liquid is so formed and arranged on the gyroscope that the liquid has a natural period of oscillation between north and south very different in period and preferably greater than the longest period of roll of the ship, so that synchronism between the two is never maintained for any appreciable time.

It is known that in the case of a common U tube containing a column of liquid of uniform cross section, the period of oscillation of the liquid (neglecting friction) is proportional to the square root of the length of the column. To obtain the period required in a gyro compass with a uniform column of liquid would involve an inconveniently long tube, but by making the U tube bell mouthed or terminating in boxes or enlarged ends of suitable type so that the cross sectional area at the ends of the column is greater than that of the connecting portion, the period of oscillation can be increased in the ratio of these two areas. In addition to this, there is in practice a considerable lengthening of the period due to friction of the liquid in the pipe so that the period may easily be lengthened to infinity, when the motion becomes dead-beat.

In applying this to the compass, two boxes and a connecting pipe form the equivalent of a bell-mouthed U-tube and the pipe must be of such a cross section compared with the size of the boxes and of such a length that the natural period of oscillation of the liquid from one box to the other shall be rather more than twice the period of roll of the ship on which the compass is to be used. No difficulty is found in having a tube sufficiently long to give a period of half a minute to the liquid, the pipe being coiled or doubled back, if necessary. In consequence of this long period the disturbance of the liquid due to rolling of the ship is reduced to a very small amount, and further it is made to differ in phase by about a quarter period from the disturbing

force. When the ship is rolling on an intercardinal or other course there is therefore no persistent torque around the vertical axis of the compass to cause deviation.

5 At the same time the period of oscillation of the liquid is not so slow as to make the compass insensible to the more enduring effects of acceleration due to changes in the speed or course of the ship. This compass, 10 therefore, has a ballistic deflection on change of speed or latitude or both. By suitably choosing the moment of the couple given by the liquid for a given tilt, this ballistic deflection can be made equal to the 15 corresponding change of speed error.

Also in compasses employing the principle of liquid transfer as hereinbefore described it has been thought necessary to provide a separate and distinct damping means for 20 the gyroscope operating to transfer a separate supply of liquid out of phase with the principal mass of the liquid. We have found, however, that such complications may be entirely eliminated by mounting 25 the liquid container in such a manner as to bring into action the damping torque whenever the liquid in the two containers becomes unbalanced. By this means a compass of extreme simplicity is produced 30 employing no extraneous forces or elements other than the usual follow-up system and force of gravity.

In order that the said invention may be clearly understood and readily carried into 35 effect, we will describe the same more fully with reference to the accompanying drawings, in which:—

40 Figure 1 is a north elevation partly in section of a compass embodying this invention.

Fig. 1^a is a sectional detail view of a liquid box.

Fig. 2 shows part of the compass in east elevation.

45 Fig. 3 is a detail view showing one method of connecting an arm from the gravity controlling device to the gyro casing; and

Figs. 4 and 5 show another method of connection.

50 Fig. 6 is a detail view of an inclination indicator.

The gyro, which is preferably electrically driven in the ordinary way, is contained in the casing 1, supported in a vertical gimbal ring 2 by the horizontal trunnions 5, 5. 55 This vertical ring 2 is itself supported in a phantom or follow-up element 3 by the vertical bearings 6, 6; this phantom element carries the card 4 and is electrically power driven in the well known manner employed 60 in the type of compass shown in the Sperry Patent 1,279,471 of September 17, 1918, so as to maintain its plane coincident with the plane of the vertical ring 2. To this end the 65 motor is controlled by pairs of contacts 7

carried on the vertical ring and phantom element respectively, making a follow-up system of the usual kind.

Supported by horizontal bearings 10, 10 in the phantom ring 3 is a framework 9 carrying two boxes 8, 8. This frame is connected to the gyro case 1 by the arm 11 and a flexible joint 12 which may take the form of a roller, link or spring; this flexible joint 70 allows the frame 9 to have a small movement in azimuth relatively to the case 1 but obliges the case and frame to tilt together around the axes 5, 5, and 10, 10 respectively, these two axes lying normally in one straight line. 80

One form of this flexible joint is shown in Fig. 3, where a roller 12 is pivoted on the arm 11 and engages with a channel piece 14 fixed to the bottom of the gyro case 1. The groove of the channel is parallel to the plane 85 of the gyro wheel and is of the same width as the diameter of the roller so as to allow free relative movement in azimuth between the gyro case and the arm 11 but no relative tilting movement. 90

An alternative form of this flexible joint is shown in Figs. 4 and 5 in elevation and plan. In this case the connection is made by a flat ribbon spring 15, such as a short length of clock spring, with its plane vertical. One end of the spring is connected to the case 1 and the other end to the arm 11. The spring is stiff enough to oblige these two parts to tilt together but is sufficiently flexible to allow of a small relative movement in azimuth. 100

The boxes 8, 8 are about half filled with oil, mercury or other liquid and their bottoms are connected by a pipe 13 so that when the frame 9 is tilted the liquid may flow by 105 gravity from the higher box to the lower. As long as the compass is horizontal, however, no torque is applied by the liquid. As soon, however, as the compass becomes inclined, due to the rotation of the earth, the 110 liquid running to the low side of the compass will exert a torque around the horizontal axis thereof. Even though only a comparatively small quantity of liquid is transferred it will exert an appreciable 115 torque on the compass owing to the long lever arm equal to the distance of the axis 10 from either container 8 so that even when off the meridian and inclined the compass is actually less pendulous than the ordinary 120 pendulous compass as a smaller force may be employed by reason of the longer lever arm. The connecting pipe 13 may conveniently be made as the lower part of the frame 9 and the upper part of the frame may also 125 be formed as a second pipe joining the tops of the boxes to allow the air displaced by the liquid to flow from one box to the other.

The boxes and connecting pipes are so designed in accordance with the foregoing 130

principles that the level of the liquid may be practically undisturbed by the rolling of the ship and will respond only to the longer period accelerations due to change of speed and latitude to give the required ballistic deflection. The compass, therefore, having no unbalanced or pendulous element connected thereto remains unaffected by the rolling and pitching of the ship since deflection of gyro compasses as constructed prior to our invention has been found to be due substantially entirely to the acceleration pressures acting on a pendulously supported element connected to or forming a part of the gyroscope or sensitive element.

Owing to the variation in the speed error in different latitudes the ballistic deflection is required to have a greater value in high latitudes than in positions near the equator. It has been the practice, hitherto, to design gyro compasses so that the ballistic deflection may be of the correct amount in some single mean latitude, leaving a residual uncorrected error in all other latitudes. Under unfavorable circumstances, when the compass is used in a latitude widely differing from that it was designed for, this residual error causes a serious temporary deviation of the compass.

In the present gyro compass, therefore, an adjustment is embodied by which the correct ballistic deflection may be obtained in any navigable latitude. The amount of the ballistic deflection depends, in this case, upon the area of the horizontal cross-section of the boxes, 8, 8 containing the liquid.

The area is made variable by any convenient means. In the particular method shown in Fig. 1^a the box 8 is divided by the partitions 16 into a number of separate chambers 17 (three chambers are shown) of different sizes and communication between the tubes 13 and any one, two or three of such chambers is controlled by the cock or valve 18 provided with a milled head 19 by which it can be turned from outside. The chambers 17 to be employed for any given latitude are determined in accordance with the characteristics of the compass and the necessary adjustments of the valve 18 are made as occasion requires. With proper adjustment the ballistic deflection after any change of speed or course may be made equal to the difference between the error due to the speed and course preceding the change and the error due to the new speed and course subsequent to the change. The compass then moves practically dead beat to the new settling position on change of speed or course, without oscillation in azimuth.

The compass is caused to seek the meridian by the couple about the horizontal axis due to the preponderance of liquid in one of the boxes 8, whenever the gyro axle is

not level. The direction of this couple is opposite to that which is produced in the ordinary pendulous gyro, since, under the influence of gravity, the liquid will flow to the low side of the casing, and consequently that end of the gyro axle which would point north in a pendulous compass points south in this compass, that is to say, the compass settles with its gyro wheel spinning clockwise as seen from the north side.

The damping is effected by an extremely simple expedient and without the employment of any additional or extraneous means whatever. For this purpose the frame 9 is connected to the gyro case at a point which is a little to the east of the center of the gyro. The couple given by the frame 9 and boxes 8 therefore acts in a plane which is not entirely vertical and the component in the horizontal plane causes the gyro to precess so as constantly to reduce its tilt at a rate depending on the tilt itself. Such a damper is only brought into action by the means imparting meridian seeking properties to the gyroscope, which being normally non-pendulous or substantially so is unaffected by the rolling and pitching of the ship as hereinbefore explained.

In order to enable the tilt of the gyroscope to be measured so as to afford an indication of the deviation of the compass, a small piston 20 may be provided to slide in the pipe 13 which connects the bottoms of the two boxes 8. The pipe may be of glass, and graduated as indicated by graduations which cooperate with index 22 on the piston so that, as the piston is moved along by the liquid, its position indicates the tilt of the gyro axis. As the liquid is substantially undisturbed by the rolling of the ship, the position of the piston is similarly undisturbed, which is not the case with a spirit level.

What we claim and desire to secure by Letters Patent of the United States is:—

1. In a gyroscopic compass of the type referred to, the combination with a gyroscope casing, of a follow up member surrounding the gyroscope casing, and a liquid containing vessel pivotally supported upon said follow up member and adapted to give a natural period of movement to the liquid therein which is substantially longer than the period of rolling of the vessel.

2. In a gyroscopic compass, the combination with a gyroscope casing, of a power driven follow up member, and a liquid containing vessel pivotally supported upon the follow up member and having a connection with said casing for imparting meridian seeking properties thereto.

3. In a gyroscopic compass of the type referred to, the combination with a gyroscope casing and liquid containing means adapted to transfer liquid from one side

of an axis of said casing to another to impart meridian seeking properties, of a level indicating device controlled by said liquid and adapted to indicate the inclination of the gyroscope axis regardless of the rolling of a vessel.

4. In a gyroscopic compass of the type referred to, the combination with a gyroscope casing, of a U-shaped liquid containing tube adapted to permit the transfer of liquid from one side of an axis to another, and an indicator arranged within the tube and moving with the liquid, for the purpose specified.

5. In a gyroscopic compass of the type referred to, the combination with a gyroscope casing, of means for permitting the transfer of liquid from one side of an axis of said casing to another, including a liquid container and adjustable means associated with said container for regulating the mass of liquid causing ballistic deflection according to the latitude of the location of the compass.

6. In a gyroscopic compass, the combination with a gyroscope casing, of means for transferring liquid from one side of an axis of said casing to another including two containing vessels and a duct connecting them, the form of said vessels being such that the ends of the liquid column are of larger cross sectional area than the intermediate connecting body, and means by which the effective cross sectional area of the ends of the liquid column in the two vessels may be adjusted.

7. In a gyroscopic compass, the combination with a gyroscope casing, of means for transferring liquid from one side of an axis of said casing to another including two containing vessels and a duct connecting them, the form of said vessels being such that the ends of the liquid column are of larger cross sectional area than the intermediate connecting body, partitions dividing the liquid vessels into a plurality of chambers, and means for shutting off liquid confined by one or more of said partitions from the main body of liquid.

8. In a gyroscopic compass, the combination with a gyroscope casing, of means for transferring liquid from one side of an axis of said casing to another including two containing vessels and a duct connecting them, the form of said vessels being such that the ends of the liquid column are of larger cross sectional area than the intermediate connecting body, partitions dividing the liquid vessels into a plurality of chambers, and a controlling valve adapted to place the duct connecting the vessels in communication with any desired number of said chambers.

9. In a gyroscopic compass, the combination with a gyroscope, of means for mounting the same near its center of gravity for oscillation about a horizontal axis, and for

turning about a vertical axis, a follow-up element adapted to turn with said gyroscope about said vertical axis and a liquid containing means pivotally secured to said element and having an eccentric connection with said gyroscope for both imparting meridian seeking properties to the gyroscope and damping the oscillations thereof.

10. In a gyroscopic compass, the combination with a gyroscope casing and means for mounting the same for oscillation about a horizontal axis and turning about a vertical axis, of a follow-up member constrained to follow the movements of said casing about the vertical axis, means for imparting directive power to said casing comprising a mass movable laterally with respect to said horizontal axis on inclination of said casing and supported on said follow-up member, said mass being connected to said casing about an axis inclined to the horizontal.

11. The combination with a gyroscopic compass having a gyroscope and means for supporting the same in substantially neutral equilibrium about a horizontal axis, of a container mounted at each side of the axis of said gyroscope and adapted to contain a liquid, a connection permitting interchange of liquid between said containers, said containers being also connected to said gyroscope to exert a torque thereon about both a horizontal and a vertical axis as the liquid flows from one container to the other.

12. In a gyroscopic compass, the combination with a gyroscope casing and means for mounting the same for oscillation about a horizontal axis and turning about a vertical axis, of a follow-up member constrained to follow the movements of said casing about the vertical axis, means for imparting directive power to said casing comprising a mass freely movable laterally with respect to said horizontal axis on inclination of said casing and supported on said follow-up member, said mass being connected to said casing about an axis inclined to the horizontal.

13. In a gyroscopic compass of the type referred to, the combination with a gyroscope casing, of a follow-up member surrounding the gyroscope casing, and a liquid containing vessel pivotally supported upon said follow-up member and having a connection with said casing to impart meridian seeking properties thereto.

14. The combination with a gyroscopic compass mounted for oscillation about a horizontal axis, of means for imparting directive power thereto comprising a mass freely movable laterally with respect to said axis so as to cause a gravitational torque to be applied thereon on inclination of the gyroscope, and adjustable means for varying the weight of said movable mass whereby the

proper deflection of the compass for different latitudes may be obtained.

15 15. In a gyroscopic compass, the combination with a gyroscope casing, of means for transferring liquid from one side of an axis of said casing to another including two containing vessels and a duct connecting them, the form of said vessels being such that the ends of the liquid column are of larger cross
10 sectional area than the intermediate connecting body, and adjustable means for varying the quantity of liquid having communication with both vessels.

15 16. In a gyro-compass, the combination with a rotating wheel and means for mounting the same in substantial equilibrium for oscillation about a horizontal axis and turning about a vertical axis, of laterally shiftable means for imparting directional or
20 meridional seeking properties thereto and means for damping the oscillations thereof about either or both of said axes, said damping means being brought into action by said first named means.

25 17. In a gyro-compass, the combination with a rotating wheel and means for mounting the same in substantial equilibrium for oscillation about a horizontal axis and turning about a vertical axis, of means having
30 a substantially horizontal lever arm for imparting directional or meridional seeking properties thereto and for damping the oscillations thereof about either or both of said axes.

15 18. In a gyro-compass, the combination

with a rotating wheel and means for mounting the same in substantial equilibrium for oscillation about a horizontal axis and turning about a vertical axis, of normally non-pendulous means for imparting directional
40 or meridional seeking properties thereto and means for damping the oscillations thereof about either or both of said axes, said damping means being brought into action by said first named means. 45

19. In a gyro-compass, the combination with a rotating wheel and means for mounting the same in substantial equilibrium for oscillation about a horizontal axis and turning about a vertical axis, of normally non-
50 pendulous means responsive to the inclination of said wheel for imparting directional or meridional seeking properties thereto and for damping the oscillations thereof about either or both of said axes, said
55 damping means being brought into action by said first named means.

20. In a gyro-compass, the combination with a rotating wheel and means for mounting the same in substantial equilibrium for
60 oscillation about a horizontal axis and turning about a vertical axis, of independently supported normally non-pendulous means for imparting directional or meridional seeking properties thereto, and a connection
65 between said means and wheel of such a character as to damp the oscillations of the compass.

**GEOFFREY BRANCKER HARRISON.
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