PUBLISHED

MAY 11, 1943.

BY A. P. C.

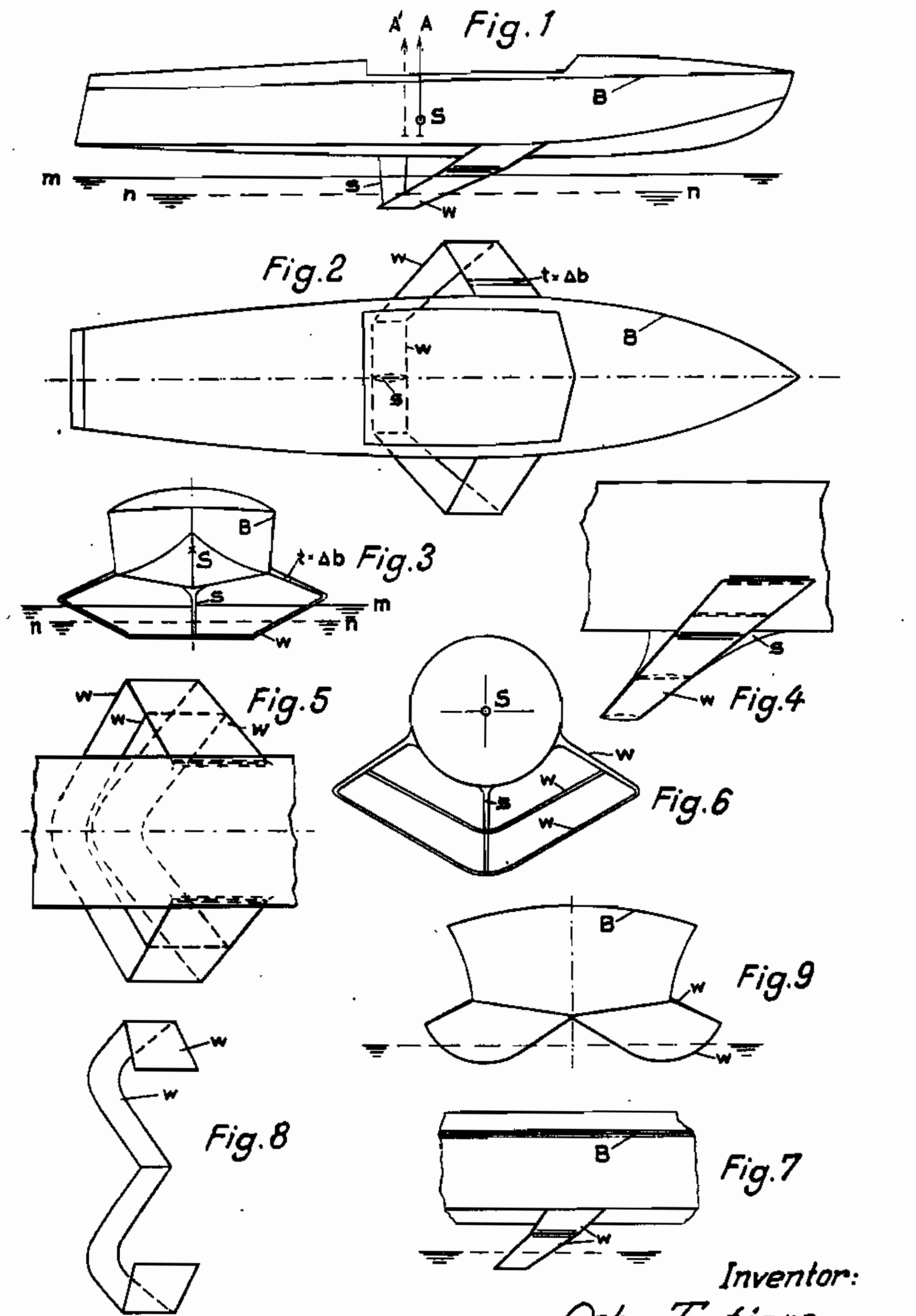
O. TIETJENS

SELF STABILISING BOATS OR OTHER FLOATING BODIES

Filed April 17, 1939

Serial No. 268,421

2 Sheets-Sheet 1



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by his attorneys

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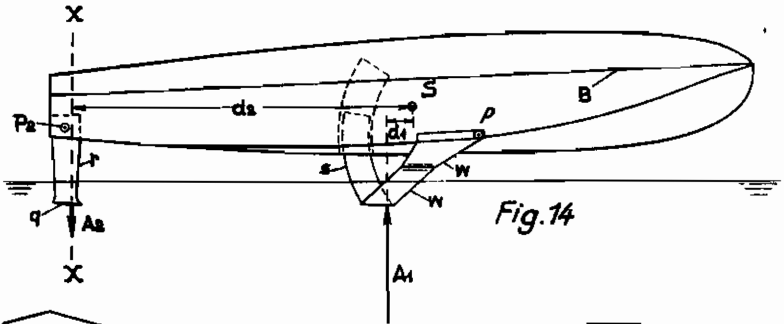


Fig.14

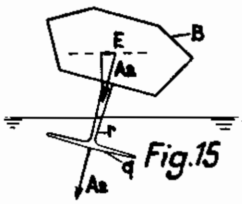
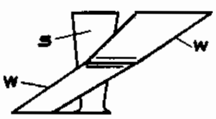


Fig.15

Fig.10



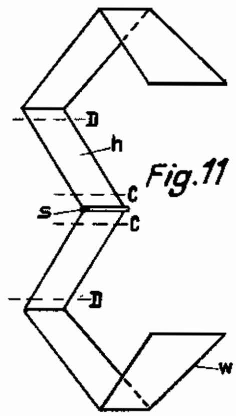


Fig.11

Fig.12

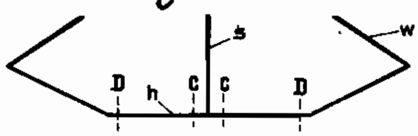


Fig.13

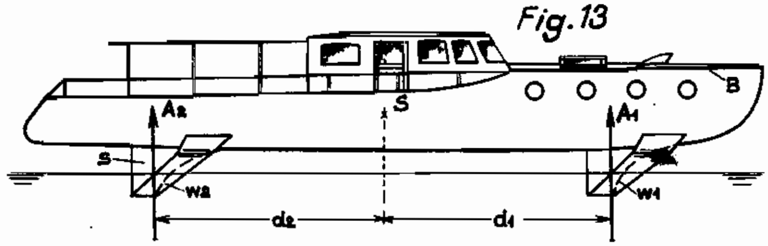
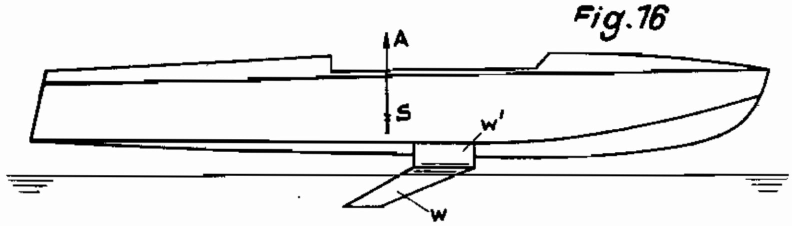


Fig.16



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Published May 11, 1943 **Serial No. 268,421**

ALIEN PROPERTY CUSTODIAN

SELF STABILISING BOATS OR OTHER FLOATING BODIES

Oskar Tietjens, Berlin-Schmockwitz, Germany; vested in the Alien Property Custodian

Application filed April 17, 1939

This invention relates to a water craft or other floating body with one or more water supporting surfaces (designated *w*) extending longitudinally at right angles to the hull and the invention consists in the fact that for the purpose of automatically varying the angle of incidence of the water supporting surface *w* when the speed of the floating body varies the succeeding surface elements of the water supporting surface *w* which extend over the entire depth of surface and cut through the water surface are at a greater distance from the bows of the floating body the deeper they lie, so that the resultant of the hydrodynamic buoyancy forces displaces the water supporting surface elements rearwards as the emergence of the water supporting surfaces *w* from the water increases.

Under these circumstances it is possible to provide only a single water supporting surface, subdivided several times if need be, longitudinally of the floating body, and in this arrangement the height of the moving floating body above the surface of the water can be arbitrarily varied in conjunction with an arrangement for shifting the centre of gravity of the craft.

For the purpose of obtaining a floating body capable of stabilising itself both longitudinally and transversely it may be particularly advantageous, when using supporting surfaces according to this invention which run through athwartships and extend, when the static floating position is departed from, above the surface of the water, for these surfaces to be bent or curved in a manner already suggested by me and in such a way that the horizontal projection of all the supporting parts in the water at any time is surrounded by a minimum circle the centre line of which lies above the axis of the centre of gravity, in all positions of the floating body.

According to a further advantageous embodiment of the present invention the lower part of the water supporting surface *w* which in this case may with advantage be constructed horizontally is given the form of an arrow with a buoyancy number decreasing towards the ends.

Finally the water supporting surface arrangement may be constructed in such a way that additional water supporting surfaces of a kind known per se and of which one or more may be employed, may be provided in addition to the water supporting surface or surfaces according to the present invention, the immersed part of which depends as to size on the height of the floating body, but which must be of such a shape that their superficial area remains the same when the height of the floating body above the surface of the water changes.

The invention relates therefore to a vessel or other floating body, in which by means of water supporting surfaces of a novel kind placed underneath the floating body or in which by means of new kind of cooperation of the water supporting surfaces according to the present invention and of which there may be one or several, with water supporting surfaces known per se, the floating body while in motion is lifted out of the water in such a way that when the speed of the water craft automatically changes a change in the angle of incidence of the water supporting surfaces takes place automatically and without any separate or special means of assistance.

In boats or similar floating bodies, which can be balanced or supported completely by water supporting surfaces while in motion, the hydrodynamic buoyancy increases in general with increasing speed. If the hull of the boat be already lifted right out of the water by the buoyancy force of the water supporting surfaces, the dynamic buoyancy is therefore equal to the weight of the boat, and this buoyancy must also remain the same when the speed of the boat varies, as otherwise the hull of the boat would either sink back into the water again or would be lifted out of the water by the whole of the water supporting surfaces.

Measures are already known and used moreover either alone or in combination, for the purpose of ensuring that the buoyancy shall remain the same when the hull of the boat is lifted right out of the water, when the speed of the boat varies. It has therefore been suggested that the water supporting surfaces should be arranged in such a way that the surface of those parts of the water supporting surfaces which are immersed in the water is smaller or larger according as the hull of the boat in motion is more or less high above the surface of the water. It has also been recommended to vary the angle of incidence of the water supporting surfaces by rocking or rotating them about an axis perpendicular to the direction in which the boat is travelling. A third measure which has been very often described consists in varying the angle of adjustment of the water supporting surfaces by inclining the whole boat and using at the same time special means of assistance.

The first measure, according to which the hull of the boat is lifted higher and higher above the surface of the water as the speed increases, while the surface of those parts of the supporting surface which remain in the water continually decreases, is—it is true—simple per se, but is very limited as to the range within which the speed can be increased. In other words, if the hull of the boat be lifted at a speed away from the surface of the water in a straight line above the surface thereof, the greatest speed attainable will in general not exceed to the desired extent the speed at which the boat is lifted away from the surface of the water if it be desired to avoid lifting the hull of the boat and therefore its centre of gravity to a very great height which would be of great disadvantage as regards the stability of the boat particularly when passing round bends.

The second method of alteration of the angle of incidence of the water supporting surface by rocking or rotating it presupposes a movability of the supporting surface whereby considerable constructional difficulties arise. In any case a rigid attachment of the water supporting surface to the hull of the boat is much to be preferred. Adjustment of the angle of incidence to speed corresponding to the speed at which the boat may be travelling at any particular moment by the driver would always demand his attention and a not inconsiderable amount of skill. If instead of this, as has been variously suggested, an automatic adjustment of the angle of incidence be provided, say by using floats or sliding surfaces sliding on the surface of the water or by making use of the pressure of the water acting on suitable pistons, these arrangements again mean a considerable complication.

The third method of alteration of the angle of incidence of the water supporting surface by inclining the whole boat is connected with arrangements specially provided for this purpose, whether it be for example of such a nature that one of the water supporting surfaces used can have its angle of incidence adjusted by hand or automatically and thereby bring about an inclination of the hull of the boat and consequently a change in the angle of incidence of the remaining water supporting surfaces, or whether it be of such a nature that inclination of the boat is produced by a suitable method of shifting its centre of gravity. In order to enable the angle of incidence of the water supporting surfaces to be adapted to the particular speed of the moment by inclining the hull of the ship, it is also suggested that floats or sliding surfaces connected to the hull be provided at a considerable distance in front of the water supporting surface or in front of centre of gravity, and the hull supported as it were thereby at the front on the surface of the water. Apart from the fact however that if this course be adopted it is very difficult to vary the height of the hull while the speed at which the boat is driven remains the same and for example to the movement of the waves at any particular time, an arrangement of this kind exhibits very uneasy travelling properties. This results from the following: in order to avoid cavitation at the water supporting surfaces, only very low buoyancy numbers that is to say only very small angles of incidence, may be employed as is well known especially at the high speeds which are desirable per se. The result of this is however that even very small variations in the angle of incidence, namely variations of from 1 degree to 2 degrees, have an extraordinary effect on the buoyancy force of the water supporting surface and thereby cause a violent up and down movement of the hull of the boat. Such variations in the angle of incidence are however already produced by the waves which are small in proportion to the length of the boat, even when the supporting float devices are placed a long way in front of the centre of gravity. If the speed of the boat is so great and the waves are so short that owing to the inertia of mass of the hull of the boat it cannot follow the rotation about the transverse axis quickly enough, the float or the sliding surface loses its grip on the surface of the water and strikes repeatedly with great violence against the waves which is accompanied by additional resistance.

In the form and arrangement of the water supporting surfaces according to the present invention all disadvantages of previous measures are avoided. The essential feature of the invention consists in the fact that when the speed of the boat increases a corresponding reduction in the angle of incidence takes place automatically and when the speed of the boat decreases a corresponding increase in the angle of incidence takes place, and this takes place moreover without the hull of the boat having to be lifted to an excessive height above the surface of the water. It also takes place without the water supporting surfaces or a part of them having to be arranged to rock or rotate for this purpose.

The automatic adjustment of the angle of incidence when the speed of the boat varies and also the stabilising action of the water supporting surface according to this invention on the transverse axis of the boat is connected with the fact that the resulting buoyancy force moves towards the rear of the boat as the water supporting surface rises more and more out of the water and towards the bows of the boat as the amount by which the boat is lifted out of the water decreases. It is known to attach a number of separate substantially horizontal water supporting surfaces to a rearwardly inclined strut or to arrange separate water supporting surfaces in a different way, namely an echelon rearwards and downwards in order to thereby prevent as far as possible foreign bodies which may be floating in the water from adhering to the strut or the water supporting surfaces. Such arrangements of separate water supporting surfaces have also the property to a very great extent of forcing the resulting buoyancy force of the of the echelonned water supporting surfaces towards the rear as the amount by which the boat rises out of the water increases. They possess however a number of disadvantages which give rise to difficulties when compared with the water supporting surface according to the present invention. Thus for example the free ends of the rearwardly echelonned separate supporting surfaces which are in the water very easily give rise to cavitation at the great speeds which are desired per se in controdistinction to the water supporting surface according to this invention in which such free supporting surfaces situated in the water do not exist. In particular however the resulting buoyancy force of the supporting surfaces which remain in the water does not move continuously towards the rear when the amount by which the echelonned separate water supporting surfaces rise out of the water increases, as it does according to this invention but moves irregularly and by jerks so that therefore no automatic and accurate adjustment of the angle of incidence to correspond to the speed of the particular moment is possible.

The main feature of the water supporting surface of the present invention consists in the fact that the surface elements $t.\Delta b$ which extend over the surface of the entire surface depth (where t is the surface depth at the particular moment and Δb an element of the span b of the separate coherent water supporting surface,) are a greater distance from the bows of the floating body in comparison with the neighbouring surface element of the water supporting surface in question adjoining them at the particular moment, the deeper they are placed in comparison therewith.

When the water supporting surface according to the present invention rises more and more out of the water, the resultant of the hydrodynamic buoyancy forces of those parts of the supporting surfaces which are in the watet moves towards the rear that is to say in the direction from the bows to the stern of the boat. A particular advantage of the water supporting surface according to the present invention consists also in the fact that even a single such water supporting surface suffices without the use of stabilising surfaces of any other kind for the purpose of ensuring longitudinal stability about the transverse axis through the centre of gravity of the boat. This measure is not possible in any of the water supporting surfaces hitherto known. In all of them at least two either similar or even dissimilar water supporting surfaces are needed longitudinally of the boat. When a single water supporting surface according to the present inveniton is used it is also possible to vary the height of the hull of the boat above the surface of the water by shifting the centre of gravity of the boat horizontally, and by special means if need be, which may be of advantage for the purpose of obtaining a favorable angle of incidence. Any one of the well known transversely stable water supporting surfaces may be taken as a pattern for the construction of the water supporting surface according to this invention as regards its transverse stability, that is to say the stability about the longitudinal axis through the centre of gravity of the boat.

The present invention also provides an arrangement of a plurality of water supporting surfaces according to this invention whereby variation of the angle of incidence with varying speed of the boat takes place in a manner similar to that when a single water supporting surface according to the present invention is used, but in this case variation of the position of the centre of gravity of the boat has not by any means such a great influence on the height of the hull of the boat above the water.

The invention also comprises the use of one or a plurality of water supporting surfaces according to the present invention in combination with one or a number of such water supporting surfaces (known per se) the size of the surface of which remains the same at positions different height of the hull of the boat above the surface of the water. By the cooperation of these two dissimilar forms of water supporting surface it is possible to impart to the water supporting surface of constant area arranged behind the centre of gravity a slightly negative buoyancy, that is to say a repellent action and yet guarantee the automatic adjustment of the angle of incidence of the water supporting surfaces above mentioned. With the help of these supporting surfaces giving a slight repellant action and the attachment strut of which may be used for steering the craft a particularly good transverse stability can be obtained particularly when negotiating bends.

The invention is illustrated by way of example and diagrammatically in the accompanying drawing in which

Figure 1 is a side elevation of the hull of a boat with a water supporting surface according to the present invention.

Figure 2 is a plan of the hull of the boat.

Figure 3 is a front elevation of Figure 1.

Figure 4 is a side elevation of a further constructional form, the movement of the floating body being from left to right.

Figure 5 is a plan of Figure 4, and

Figure 6 a front elevation thereof.

Figures 7, 8 and 9 are views similar to Figures 4, 5 and 6 of a further example.

Figure 10 is a side elevation of a water supporting surface according to the present invention with an arrow-shaped horizontal part, movement from left to right.

Figure 11 is a plan of Figure 10, and

Figure 12 a front elevation thereof.

Figure 13 is a side elevation of a boat in motion with a water supporting surface according to the present invention arranged both in front of and behind the centre of gravity.

Figure 14 is a side elevation of a floating body in motion with a water supporting surface according to the present invention and a water supporting surface of a kind the surface of which remains the same even at different heights of the floating body above the water.

Figure 15 is a transverse section on the line X—X of Figure 14 for the special case in which the supporting surface shown produces a repellant action and the floating body is rotated about its longitudinal axis.

Figure 16 is a side elevation corresponding to Figure 1, in which however the water supporting body has vertical attached pieces.

To the hull B of the board shown in Figures 1 to 3 is attached a water supporting surface w. This supporting surface is of such a shape that each surface element, the element $t.\Delta b$ for example, is at a greater distance from the bows of the boat that its adjoining neighbouring element when it lies lower than its neighbouring element. When the boat is in motion and if the position of the surface of the water be represented by the line $m—m$, the supporting surface elements which are in the water produce hydrodynamic buoyancy forces of which let A be the resultant. If the hull of the boat has been lifted higher out of the water, the surface of the water will be situated in the position $n—n$, and the resultant of the hydrodynamic buoyancy forces will be moved rearwards to approximately A'.

If the position of the centre of gravity of the boat be denoted by S, the boat, taking into account only the forces of gravity and buoyancy, will be in equilibrium when the surface of the water is in the position represented by $m—m$, as it has been assumed that for this position the resulting buoyancy force occupies the position denoted by A.

If now the speed of the boat increases, the water supporting surface rises by a certain amount out of the water, while the resulting hydrodynamic buoyancy force moves slightly to the rear behind the centre of gravity S and consequently produces a moment which lowers the bows of the water craft and therefore reduces the angle of incidence of the supporting surface. In this way a reduction of the angle of incidence is always produced automatically without assistance means of any kind when the speed increases and this reduction of the angle of incidence is of such a nature that the buoyancy remains the same and the position *m—m* for the surface of the water is retained. In this case the bows would be forced slightly too much downwards by the moment which arises and consequently the angle of adjustment of the water supporting surface would be too small; with the result that a larger supporting surface would be needed and therefore the supporting surface would sink lower in the water than is represented by the line *m—m*. In consequence however the resulting buoyancy force would be shifted to the right from the centre of gravity S in Figure 1 or in other words would produce a moment which lifts the bows and thereby again increases the angle of incidence to an amount which corresponds to the speed and the position of the surface of the water.

As will be seen from what has been said and from Figures 1 and 2, the height of the hull of the boat above the surface of the water depends on the position of the centre of gravity S. If S be shifted away from the bows to the stern, that is to say rearwards, the hull of the boat will lift itself higher above the surface of the water and will do so even when the speed remains constant, and certainly with an increase in the angle of incidence that is to the inclination of the boat to the horizontal. If on the other hand the speed of the boat remains constant and the centre of gravity be shifted nearer to the bows, the supporting surface will sink lower in the water and the angle of incidence of the water supporting surface will be simultaneously reduced. As the so-called sliding number, that is to say the ratio of resistance to upward thrust depends primarily on the angle of incidence, the centre of gravity can be adjusted by suitably shifting it to that angle of incidence for which the sliding number is most favorable, that is the smallest.

Even a single water supporting surface as shown in Figure 1 ensures longitudinal stability, that is to say stability against rotation about the transverse axis passing through the centre of gravity S. In such case if when a boat is in motion and the speed is constant the bows of the hull of the boat were brought by an external force into slightly downwardly depressed position, the angle of incidence would simultaneously have been reduced. This however would cause the upward thrust to be lessened and the water supporting surface would in consequence sink lower still into the water. In the water supporting surface according to the present invention however the shifting of the resultant buoyancy force towards the bows that is to say towards the right of the centre of gravity S in Figure 1 is connected necessarily with a drop in the water of the supporting surface and consequently the production of a moment which tends to lift the bows again and this lasts until the boat has again acquired its position of equilibrium. The assumption that the boat when in motion is out of its position of equilibrium by an external force in a counter-clockwise direction about its transverse axis leads by an analogous consideration likewise to the discovery that even a single water supporting surface according to this invention guarantees stability.

In order to obtain the necessary stability against rotation about the longitudinal axis passing through the centre of gravity any one of the well known transversely stable water supporting surfaces or arrangements of water supporting surface may be taken as a pattern. In this respect Figure 3 shows merely an example.

Figures 4 to 6 show a different constructional form of the water supporting surface according to this invention in which certainly as regards the height of the single floating body above the surface of the water only a limited transverse stability exists. When such floating bodies are used in pairs alongside each other great transverse stability can be obtained.

In Figures 7 to 9 is shown a further constructional form which is specially characterised by the fact that, notwithstanding transverse stability, the immersed part of the water supporting surface need only be very small when the hull of the boat is lifted high. The solution shown in Figure 9 for obtaining transverse stability consists of an inversion of a well known form of water supporting surface.

For reasons of strength it may be necessary to use one or more struts, or in Figure 3 for example the keel might be carried down to the lower part of the water supporting surface *w* instead of the strut *s* shown there.

In order to still further increase the effect of the water supporting surface according to the present invention in respect of longitudinal stability, and of the automatic adjustment of the angle of incidence when the speed varies, it may be advantageous to use so-called constant pressure centre profiles for the water supporting surface that is to say symmetrical profiles. This effect can be increased still further beyond this by giving to the lower part of the water supporting surface according to this invention which always remains in the water, an arrow-like disposition with a buoyancy number which decreases outwards. Such a form of water supporting surface according to the present invention is shown in Figures 10 to 12. In these figures the decrease in the buoyancy number outwards for the lower part *b* of the water supporting surface according to this invention which in this case is constructed horizontally, is obtained by making the angle of incidence decrease outwards while yet using the same supporting surface profile, that is to say in Figures 11 and 12 the angle of incidence is greater at the points C than at the points D. In Figures 10 to 12 *s* denotes a strut which in many cases may be necessary for reasons of strength. It may also be necessary to construct the upwardly directed parts of the water supporting surface of the present invention in such a way that the size of the surface or of the angle of incidence or even of both increases upwards.

Figure 13 shows an arrangement of several (two in this case) water supporting surfaces w_1 and w_2 according to the present invention in which one surface lies in front of and the other one behind the centre of gravity S. The arrangement shown in Figure 13 according to which for the working speed of the boat the distance of the two supporting surfaces w_1 and w_2 from the centre of gravity S is the same namely d_1 and d_2 respectively is only intended to be an example of the different arrangements which are possible. The distances of the water supporting surfaces from the centre of gravity do not need by any means to be the same. In like manner the supporting surfaces according to this invention which are attached to the hull of the boat may also themselves be different from each other both in size and also in shape and in respect of the angle of incidence. In the water supporting surface according to the present invention all parts thereof need not necessarily be so constructed that their surface elements are the more distant from the bows the lower they are placed but only the parts of the supporting surfaces which cut through the surface of the water at the working speeds. In particular this need not necessarily be the case in the upper parts of the water supporting surfaces as is shown by way of example in Figure 16. Instead of vertical parts w' other connecting pieces suitable to the purpose may be used.

The front view of the water supporting surfaces shown in Figure 13 may for example be similar to the one shown in Figure 3. In large boats stiffening struts s are generally used, which in this case can again be either wholly or partially replaced by taking the keel of the hull down to the central part of the water supporting surface in a manner suitable to the purpose.

In Figure 13 therefore a special example is shown according to which d_1 is equal to d_2 and therefore also A_1 equal to A_2, while in addition to this the sum of A_1 and A_2 is equal to the weight of the whole boat. As forces which arise only the forces of gravity and buoyancy have been taken into consideration as hitherto, while the forces of resistance and thrust have not been considered, so as to make the investigation of the stability and the automatic adjustment of the angle of incidence simpler. In order to justify this the assumption may be made for example that the thrust is equal and opposite to the resistance and that the direction of thrust coincides with the line of resistance. If the speed of the boat gradually increases, the hull of the boat will be lifted higher out of the water with the result that d_2 will be greater but d_1 smaller at the same time. A resulting moment is therefore set up which depresses the bows of the boat slightly, whereby the angle of incidence of both water supporting surfaces is reduced, which is just what is desired, owing to the increase in the speed. By this inclination of the boat however the front water supporting surface dips more deeply into the water than the rear water supporting surface does, so that consequently the effective surface of w_1 will be greater than that of w_2. In the assumed increase in the speed such a height and inclination of the boat then automatically sets in that the moment of the buoyancy force produced by the front greater supporting surface multiplied by the front smaller lever arm, is opposite and equal to the moment produced by the rear smaller supporting surface, multiplied by the rear larger lever arm. For an assumed decrease in the speed it can be shown by a similar consideration that in this case also an automatic adjustment (but now with an increase in the angle of incidence) results.

When a number of water supporting surfaces are used of which Figure 15 shows an example, the shifting of the centre of gravity is not of the same importance as regards the height of the hull of the boat above the surface of the water as it is when only one water supporting surface according to this invention is used, see Figure 1. In many cases and in particular when there are many passengers in the boat who want to move about in it, this circumstance may be of advantage. For example if the centre of gravity S in Figure 13 moves slightly towards the stern, the front lever arm d_1 will become greater and the rear lever arm s_2 smaller. This produces a resulting moment which lifts the bows. The result of this is however that the front water supporting surface w_1 is lifted further out of the water than the rear water supporting surface w_2 so that the front effective surface of w_1 is smaller than the effective surface of w_2. Moreover such a height and inclination of the boat set is again in this case also that the smaller buoyancy force (smaller because produced by the smaller effective surface w_1) multiplied by the larger lever arm d_1 is opposite and equal to the product of the greater buoyancy force produced by the greater effective surface w_2 and the smaller lever arm d_2. A similar consideration also permits the centre of gravity S being shifted towards the bows of the boat.

Figure 14 shows a floating body with a water supporting surface w according to the present invention and also with a water supporting body q (known per se). The supporting surface q is situated entirely below the surface of the water and is attached by the strut r, which may also be utilised simultaneously as a steering rudder, to the floating body B. The important feature of the supporting surface q is that its effective surface remains of the same size when the height of the floating body above the surface of the water changes, in contradistinction to the supporting surface w according to the present invention. In Figure 14 is shown the special case in which for the working speed the resulting buoyancy force A_1 of the water supporting surface w according to this invention lies close behind the centre of gravity S of the boat. For reasons of equilibrium it is necessary therefore that the buoyancy force produced by the water supporting surface q shall be negative, that is to say A_2 must be repellant. It is not necessary however for this arrangement to be chosen. In some cases it is advantageous to so select the angle of incidence that a positive upthrust is produced. In such case the water supporting surface w according to this invention must be arranged nearer to the bows of the boat. The special advantage which results from the cooperation of the two different kinds of water supporting surfaces w and q, lies in the great longitudinal stability which is obtainable and also in the automatic adjustment of the angle of incidence within a very wide range of different speeds, combined with the possibility of enabling negative buoyancy forces to be also obtained with the water supporting surface q:

If it be assumed for example that the speed of the floating body shown in Figure 14 becomes smaller, the two water supporting surfaces w and q sink lower in the water. Now although it is true that the effective surface of w becomes somewhat greater, the comparatively great decrease of the lever arm d_1 (which is small per se) nevertheless preponderates in the effect produced so that the moment of the buoyancy force A_1, multiplied by the lever arm d_1 (the percentage of which has become greatly curtailed) becomes smaller than the moment of the buoyancy force A_2, multiplied by the lever arm d_2 which remains of the same size. The moment which results from those two moments therefore effects an automatic adjustment of the floating body, that is to say an increase in the angle of incidence in accordance with the reduction in the speed. A similar consideration can be carried out for the assumption of an increase in the speed.

In the case also in which the supporting surface *w* as well as the supporting surface *q* produce positive buoyancy forces, it can easily be shown by a similar consideration that an automatic adjustment of the angle of incidence always takes place when the speed changes. In this case the centre of gravity lies between the lines of action of the two buoyancy forces A_1 and A_2.

On some occasions it may be of advantage to so arrange the water supporting surface according to the present invention that at moderate speeds positive buoyancy values are produced by the supporting surface *q* and that as the speed increases, that is to say the angle of incidence decreases, these buoyancy values then decrease to zero, and finally become negative again as the speed increases still further.

If the water supporting surface *q* produces a negative buoyancy at the stern of the floating body, that is to say a repellant action, this circumstance may be of special advantage for the initiation of a curve and for keeping the floating body in the curve. If the floating body is to describe a curve to starboard it will in general lay itself in the curve that is to say to starboard, so as to be able to absorb the centrifugal force exerted on the floating body. For this position of the floating body a section along the line X—X looking in the direction from stern to bows of Figure 14 is shown in Figure 15. The repellant force A_2 is inserted in Figure 15 and shifted in its line of action up to the longitudinal axis E through the centre of gravity of the boat. If the force A_2 be divided into two components at right angles to each other, one component being directed at right angles to the surface of the water, the result will be that the other component tends to force the stern towards the larboard side and thus acts in the right way like a steering rudder so to speak or assists the already existing steering rudder in its action. Although this horizontal component will not be very great in most cases, the moment which is produced may nevertheless be considerable, as the lever arm d_2 can be made correspondingly great.

To enable the floating body to be drawn up on land or for other reasons it may be desirable to attach the water supporting surface *w* and also the water supporting surface *q* to the floating body in such a way that they can be rotated about certain axes P_1 and P_2 respectively. In this case it is advantageous to so construct the strut *s* of the water supporting surface *w* that the front and rear edges of the strut form substantially arcs of circles with the axis P_1 as the centre. This makes it possible to do with as small an opening in the keel of the floating body as possible when the supporting surface according to the present invention is swung upwards.

In these circumstances it is found to be particularly favorable to place the lowermost part of the water supporting surface according to the present invention rearwards from the point of rotation so that the strut can be constructed in the manner described and at the same time stands nearly vertical so that it can effectively transmit buoyancy forces to the floating body.

Instead of the water supporting surface *q* being placed behind the water supporting surface *w* as shown in Figure 14, the supporting surface *q* can, taking the well known condition for longitudinal stability into consideration, be also placed in front of the supporting surface *w* approximately in the vicinity of the bow.

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