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(54) **Hybrid high performance water vessels**

(57) A special arrangement and structures of the upper hull, lower-hull and foil means for a displacement-hydrodynamic hybrid water vessel and its operation methods are disclosed. The water vessel consists an upper hull(H1) disposed at stern end section, a slender lower-hull(H2) disposed at bow end section of the water vessel, and a set of mainfoils means(9) disposed beneath said upper hull(H1). At high speed, the water resistance can be reduced by inclining the hull longitudinally such that the upper hull(H1) being raised from the water surface by using the hydrodynamic-lifting-force. When operating in a shallow water, the draught can be reduced by inclining the hull longitudinally to the opposite direction such that the lower-hull(H2) being raised closer to the water surface.

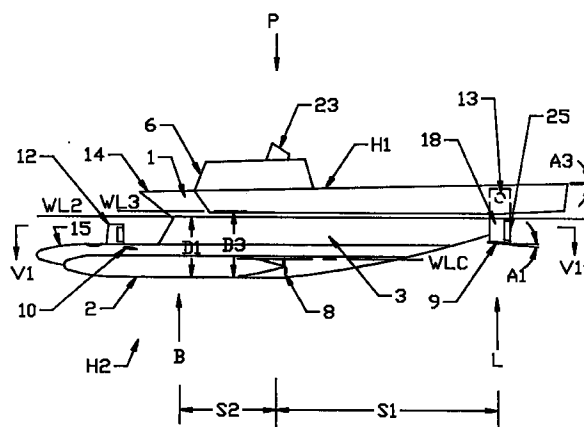


FIG 1

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Description

This invention relates to special arrangements and means of displacement-hydrodynamic hybrid water vessels.

5 BACKGROUND OF THE INVENTION

It is well known in naval architecture that the tonnage of a hydrofoil type craft is limited currently to about 400 tons, because the weight increase of a hydrofoil craft is much faster than the lifting force of the foils when the dimensions of the vessel are increased. In fact the tonnage increases cubically with its dimensions while the lifting force of the hydro-
10 foil increases squarely with its dimensions.

For decades, marine engineers in US, Germany and Japan have developed a new hull form called HYSWAS (Hydrofoil Small Waterplane Area Ship). One of the recent new developments is the Japanese TSL-F (Techno-Superliner, Foil Supported) program. The HYSWAS combines elements of conventional hydrofoils and (demi-)SWATH ships. It is proved to have the advantages of long-range at high-speed capability, excellent seakeeping, and sizing flexibility. But it also has a big disadvantage, that is its wings (or foils) and sub-hull are always buried deeply into water. Obviously,
15 it has a deep draught, therefore it needs a deep port for loading and unloading. Its operation and maintenance costs are high.

The water vessels of this invention not only have the same advantages as a current HYSWAS, but also reduce substantial draught, therefore, its operation and maintenance costs are much lower. Furthermore, the vessels of this inven-
20 tion are much easier to control in terms of pitching stability.

From basic trigonometry (see Fig 15 and 16), a horizontal bar BR with length $2LN$, to be inclined in a longitudinal direction against the center of gravity GC with an angle A , the vertical displacements at both ends are $V=LN*\sin A$. When the LN is large, a small amount of inclined angle A may generate a some good amount of V . Let's apply this phe-
25 nomenon to a ship by embedding a bulb (or sub-hull 2, refer to FIG 16 and FIG 1) at one end, and widening the other end to become upper hull. Propeller 8 and foils 9 are adapted at suitable places. The "inclined bar" becomes a hybrid hydrofoil craft with varied characteristics. FIG 16 shows that V is the upper hull's "flying" height, and $-V$ is the depth of the sub-hull diving. It should be noted that when the angle A approaches to zero, V and $-V$ disappeared; implying that the draught of this craft will be much reduced when the hull (or bar) inclined toward to the other direction.

Therefore, the other objects of this invention are: to disclose the unique "Hull Inclination Methods" (by using said
30 "Inclined Bar Phenomenon") for high speed ship operation; and to disclose new ship structures and means to apply said "Hull Inclination Methods", for improving operational performances.

SUMMARY OF THE INVENTION

Referring to FIG 16, the basic structure of water vessel of present invention consists of: an upper hull H1 placed at stern end section of said water vessel; a set of mainfoils means 9 disposed beneath said upper hull, for providing dynamic lifting force at high speed; a slender body (BR 3) placed at bow and mid sections of said water vessel for pro-
35 viding flotation to said water vessel.

For a large ship, a streamlined, generally torpedo shaped sub-hull 2 is disposed beneath the bottom portion of said
40 slender body, for providing additional flotation to said vessel. Referring to FIG 1, let us call the slender body 3 and sub-hull 2 together as lower hull H2. When running at high speed, the center of hydrodynamic forces (L) of the mainfoils means 9, and the center of buoyancy (B) of said lower-hull H2 is offset substantially along the longitudinal axis of the vessel. The mainfoils means provide substantial rolling and pitching control, and partial lifting support. The remaining lifting is contributed by the buoyancy of said lower-hull.

The first embodiment of present invention is basically the combinations of a submarine and a hydrofoil craft with the mainfoils mounted at stern end.

The second embodiment is for a small craft using a tiltable stern drive unit. This embodiment has a slender lower-hull.

The third embodiment is a combination of a submarine and hydrofoil craft with the propeller means located at bow
50 section. Two different designs are provided for bow propeller protection.

BRIEF DESCRIPTION OF THE DRAWINGS

All drawings provided here in this literature are somewhat schematic and wherein the like reference characters like
55 parts in all views and drawings:

FIG 1 through 7 are views of the first preferred embodiment.

FIG 1 is a side elevational view of the first preferred embodiment of this invention while the vessel is at high cruising speed.

FIG 2 is the V1-V1' section view of FIG 1.

FIG 3 is the top view of FIG 1. This drawing shows the portion above the water line only.

FIG 4 is the stern view of FIG 1.

FIG 5 is the bow view of FIG 1.

FIG 6 is a side elevational view of the vessel when the vessel is cruising at low speed.

FIG 7 is a side elevational view of the vessel while the vessel is resting on a harbor with all foils retracted.

FIG 8 is a side elevational view of the second embodiment, while the vessel is at high cruising speed.

FIG 9 is the top view of FIG 8.

FIG 10-14 are views of the third preferred embodiment.

FIG 10 is a side elevational view of the third preferred embodiment of this invention when the vessel is at high cruising speed.

FIG 11 is a side elevational view of the vessel when the vessel is moving backward at low speed.

FIG 12 is a side elevational view of another alternate design of the third embodiment.

FIG 13 is the partial bow elevational view of FIG 12.

FIG 14 is the top elevational view of FIG 12 with the foils 10 vertically retracted.

FIG 15 and FIG 16 are the drawings showing the "Inclined Bar Phenomenon".

DETAILED DESCRIPTIONS OF THE PREFERRED EMBODIMENTS

Referring to FIG 1 to FIG 7, the first preferred embodiment of this invention basically is a hydrofoil craft (upper hull H1) with a central body 1 that rides and is fixed on the stern top of a submarine (two stages hull, sub-hull 2 and 15), and said two crafts are connected by a slender body 3. On the upper hull, two stabilizers 4 and wing like wide decks 5 (in FIG 3) are disposed to both the port and starboard sides of the central body 1. A pair of retractable mainfoils 9 installed at the stern end of the central body 1. A pair of auxiliary foils 10, which are not absolutely necessary but in most cases they help for pitching and rolling control, are installed to the both sides of said sub-hull. Two main propellers 8, which generate pushing forces at high speed, are installed at the aft end of said sub-hull 2, and is located approximately at the midship of the whole system. Besides a stern rudder 25, a fore rudder 12 is adapted for improving yawing control and maneuverability.

A funnel 23 is adapted on the top of pilot-house 6. The sub-door 17 can be opened when docking (in FIG 7). FIG 2 shows the section view by the water line down to the sub-hull 2. It has a fish or airplane like body for minimizing water resistance. The longitudinal cross section of the slender body 3, shown with hatched lines in FIG 2, has a knife-like edges for minimizing the crucial wave resistance. FIG 3 shows the top view of the vessel above water line WL2. The wide stern section is designed for low speed stability, and the wave-piercing sharp bow visor 14 is designed for high speed capability.

In stern view shown in FIG 4, the mainfoils 9 have a long span for generating substantial lifting force and providing primary rolling control at high speed. Shown in FIG 5 is a bow view of FIG 1. The V bottom 19 of the central body 1 and the bottom of stabilizers 40 are designed as dynamic planes for high speed operation and for an easy takeoff. FIG 7 shown in low speed, a pair of retractable, rotatable (steerable) auxiliary propellers 20 are lowered into water for pushing ahead, pulling back or making turns.

One of an important and useful new feature of present invention is that: since the center of lifting forces of the mainfoils and the center of buoyancy of the lower-hull is offset substantially along the longitudinal axis of the whole vessel system, it will create moment to incline the present vessel forward or backward. This nature makes present water vessels so versatile and flexible that it can accommodate many different situations: from docking in a shallow harbor, to cruising at high speed in an open sea.

In FIG 1, when the vessel is cruising at high speed, the deck inclines slightly forward with an angle A3. The sub-hull 2 is buried deeply into water to improve propellant efficiency and to minimize wave making resistance. When the hydrodynamic center line of the sub-hull WLC is parallel with the water line WL2, it has the minimum water resistance. The upper hull H1 is foil borne. The forces for lifting the upper hull H1 up from the water surface are provided by: the lifting forces of the mainfoils 9, and the net buoyancy of the lower-hull.

Refer to FIG 1 and 6, when the speed of the vessel slows down slightly from FIG 1's condition, the lifting force L of the mainfoils 9 reduced. The stern portion of upper hull, and stabilizers 4 will be lowered and the angle of attack A2 (in FIG 6) of the mainfoils increased automatically. In turn, extra lift will be generated by the larger angle of attack A2, and compensating the reduced lifting force causing by the lost speed; therefore encouraging and keeping the upper hull H1 "flying". When the speed is slowed down further, the stern portion will finally touch down and stay on water surface as shown in FIG 6.

At taking off, the process is reverse. The larger angle of attack A2 of the mainfoils shown in Fig 6 creates more resistance (implying that it needs more power when taking off), but it also generates more lifting force. As speed increased, the lifting force L (shown in FIG 1) of the mainfoils increases; in turn it will raise the stern section of the upper hull H1 (including stabilizers 4) higher, and create a moment S1 times L to press the sub-hull 2 down. Then by adjusting

the angle of attack of the auxiliary foils 10, or by pumping out some ballast water from the sub-hull, or doing both, a lifting force B can be created to raise up the bow section. When the vessel reaching a suitable high speed, these two forces can raise the whole upper hull H1 up and hold above the water surface; and a flying equilibrium condition can be obtained. That is:

Horizontal forces: Water and air resistance forces = propellent force (not shown)
 Vertical forces : Gross weight of water vessel "P" = buoyancy of lower-hull "B" + lifting forces of mainfoils "L" (shown in FIG 1)
 Moments: "L" times "S1" = "B" times "S2" (shown in FIG 1) (In above, it is assumed that the moments created by air, water resistance and propellent forces are small and negligible.)

The ratio of foil lift and lower-hull buoyancy (L)/(B) can be expressed as (S2)/(S1) (shown in FIG 1). Its value depends on the application and size of a water vessel. The large vessel like the first embodiment shown in FIG 1, which may be a liquid cargo tanker, the buoyancy portion can be larger than 80%. For a small vessel such as a speed boat, the buoyancy portion can be less than 25%. For a mini-vessel such as a toy, the buoyancy portion can be less than 10%. In general, the larger the size or weight, the larger will be the buoyancy portion.

One of the advantages of the present embodiment is that: once the vessel reaching a constant design speed, the "flying" condition is pretty much inherently stable. If the upper hull was lowered, the angle of attack A1 (in FIG 1) automatically increased; in turn, the lifting forces of the mainfoils 9 are automatically increased to lift the upper hull up. At the front section, if the sub-hull was lowered, the increased emerged volume in the bow slender body 3 and bow central body 1 will generate extra buoyancy to lift it up, even though without the help of auxiliary foils 10. This character is more apparent for a ship having a long slender body that provides substantial buoyancy like the ship shown in FIG 8. This property makes this water vessel very easy to control the pitching movements. Therefore the principles and means of this invention can be utilized to a very small and simple water vessel such as water ski boards or toys.

WL3 and D3 shown in FIG 1 are the water level and the maximum draught when the present vessel is at low speed or at rest in a deep water. The D3 possibly is also the draught of the same size of current HYSWAS needed at low speed. Utilizing said "Hull Inclination Method", by inclining the hull backward longitudinally (with an angle A5 as shown in FIG 7), the vessels of present invention have a unique "draught reducing capability" not found in any type of current HYSWAS and hydrofoil crafts. When operating in a shallow water, the draught of present water vessels can be reduced by pumping out ballast water (not shown) closer to the bow end, and raising up the deepest portion of the vessel system, which is at the bottom of said sub-hull 2. The minimum draught D2 (shown in FIG 7) as at docking, is roughly 70% of the draught D1 as at high cruising speed, and is roughly 60% of the maximum draught D3 as at rest or at low speed in deep water. Therefore the operation and maintenance costs of present vessel systems will be much less than the conventional fixed hydrofoils and the current HYSWAS.

The present embodiment has one more advantage. That is the mainfoils 9, auxiliary foils 10, and fore rudder 12 can be retracted or raised up from the water surface to avoid hitting the sea bed when docking. These features also reduce the operation and maintenance costs.

The second preferred embodiment, shown in FIG 8 and FIG 9, is a smaller craft. The slender body 3 provides substantial buoyancy to said craft. The sub-hull and auxiliary fore foil are eliminated. This craft uses a tiltable stern drive unit 81 and two pairs of retractable type mainfoils 9. The propeller and mainfoils can be tilted and retracted up for beaching or launching.

FIG 10 through FIG 14 show the third preferred embodiment of present invention. The ship structure and the operational methods of this embodiment are similar to the first embodiment; except that the main propellent means 7 is reversible type and located at the bow end of the sub-hull and a backward steering means (including side thruster means 21) is adapted.

There are two advantages of mounting propellers to the bow end of a ship. First, there is no disturbing flow at the front of a ship. Second, when flying, as shown in FIG 10, the vessel is inclined slightly forward, so that the bow end is at the deepest position of entire system. By mounting propeller at this place will minimize the "cavitation" phenomena at the low pressure side of blades of a propeller, and increase the propellent efficiency thereof.

In order to avoid a serious damage to the fore propeller 7, the ship of this design should go backward when operating in a shallow water or harbor. A backward steering systems including a backward pilot-house 6' (shown in FIG 10 and FIG 11) is adapted. In FIG 11, by reversing the angle of attack of the propeller 7 (or turning propeller the other way), the vessel is moving backward (arrow BW showing the direction) with strut 18 retracted horizontally. The propeller 7 is well protected by moving backward. The side thruster 21 at the bow end is for making turns. The dotted lines 18' shown the strut was retracted vertically for docking. The line WLO indicates the water line for shallow water operations.

FIG 12 to FIG 14 illustrate another alternate design for providing fully protection to the fore propellent means. Shown in FIG 12, a fore propellent means 7 is mounted on the top structure of the sub-hull 2, and the fore end of said sub-hull is extended over the front of the propellent means 7. In this design, the machinery such as motor, power transmission or impeller means (in case of using water jet) will be embedded into the fore end section of the sub-hull 2. An

extra strong structure means 31 is disposed at the end and bottom portions around the fore end of said sub-hull, for providing protection to said machinery means and fore propellent means. The auxiliary foils 10 are located by the sides of propeller 7. They can be rotated up vertically (shown in FIG 13) to protect propeller 7 being damaged by floating debris. The backward steering system is not an absolutely necessary for this design, since the flaps 36 (shown in FIG 14) can be turned to the same direction for manipulating said water vessel.

Furthermore, by emptying the ballast tanks close to the propeller end, said water vessel will incline, and raise the propeller 7 above the water line WLO (in FIG 12). This special feature provides a convenient access to the propellent and foil means for repairs or routine maintenance.

Other special features of this design are that the mainfoils 91 are the fixed and rugged type structures. The ship can be beached or launched without the delicate tilting or retracting means.

It should be noted that the propellers such as 8, 20 (in FIG 7, first embodiment) and 7 (in FIG 10 and FIG 12, third embodiments) can be substituted by any other types of propellent means (such as water jet, magnetohydrodynamic system or wind-sail-system etc.) whenever they are available and adaptable.

Claims

1. A water vessel comprising:

an upper hull having a wide stern section, said wide stern section providing substantial buoyancy to said water vessel when said water vessel is at low speed and at rest on the water surface;

a single, slender, lower-hull disposed at a lower elevation than said upper hull for providing flotation to said water vessel, said lower-hull's center of buoyancy being disposed forward to said water vessel's center of gravity; and

at least a pair of mainfoils means disposed at a lower elevation than said upper hull and at a longitudinal position aft of the center of gravity of said water vessel, said mainfoils means being the primary support for said water vessel aft of said center of gravity when said water vessel is moving over the water at a suitable high speed, said mainfoils means' center of hydrodynamic-lifting-force having a substantial distance to said lower-hull's center of buoyancy.

2. The water vessel of claim 1 wherein along the high-speed-waterline of said lower-hull having a narrow width at the lateral cross sections for reducing the water resistance.

3. The water vessel of claim 2 wherein said lower-hull includes a streamlined, generally torpedo shaped, buoyant sub-hull disposed beneath the bottom portion of said lower-hull for providing additional space and flotation to said lower-hull.

4. The water vessel of any one of claim 1 to 3 which further comprises at least a pair of auxiliary hydrofoil means placed close to the fore end section of said lower-hull for at least providing substantial pitching control to said water vessel.

5. The water vessel of claim 4 which further comprises:

reversible fore propellent means for generating both forward and backward propellent forces to said water vessel, said reversible fore propellent means being located close to the fore end of said sub-hull;

hydrofoil retracting means adapted to said mainfoils means for retracting said mainfoils means; and

a backward steering means which includes a means for generating sideward forces to steer and turn said water vessel when said water vessel is operating in a backward direction.

6. The water vessel of claim 4 which further comprises:

strong bow structure means disposed at the end and bottom portions around the fore end of said sub-hull; and fore propellent means located after and on the top of said strong bow structure means, said fore propellent means being protected by said strong bow structure means when said water vessel is going forward.

7. The water vessel of claim 6 which further comprises:

a pair of vertically rotatable auxiliary hydrofoil means located by both sides of said fore propellent means, said auxiliary hydrofoils means providing further protection to said fore propellent means when said auxiliary hydrofoil means are rotated and stayed upward.

8. The water vessel of any one of claim 1 to 7 which further comprises:

at least a pair of stabilizer means disposed to both the port and starboard sides of said upper hull, said stabilizer means providing rolling stability when said water vessel is at low speed or at rest on the water surface.

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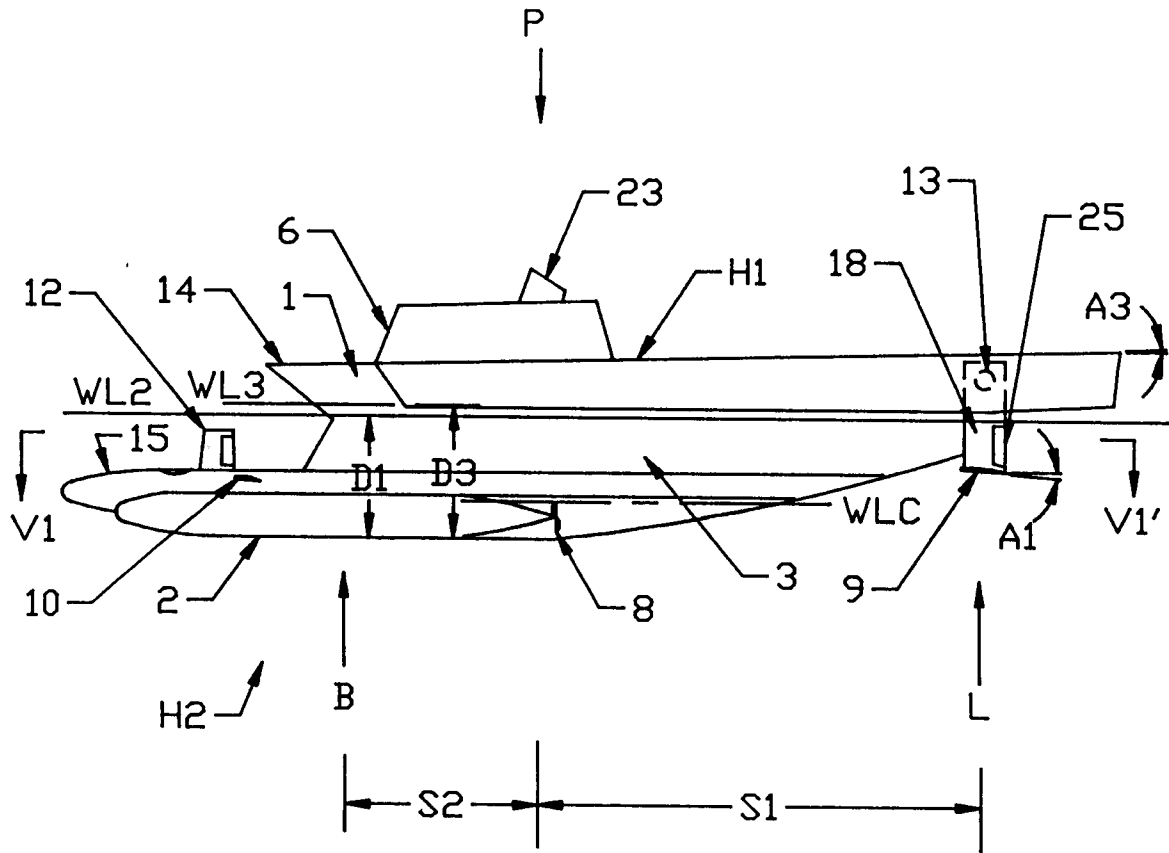


FIG 1

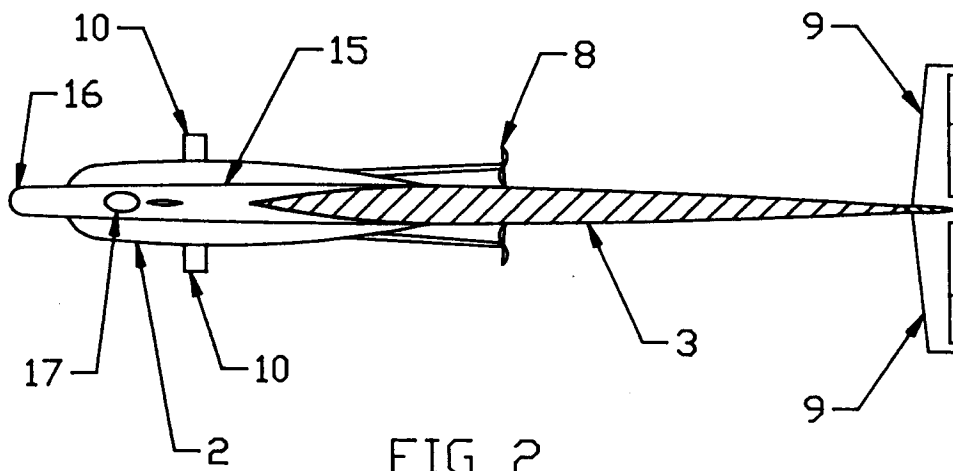


FIG 2

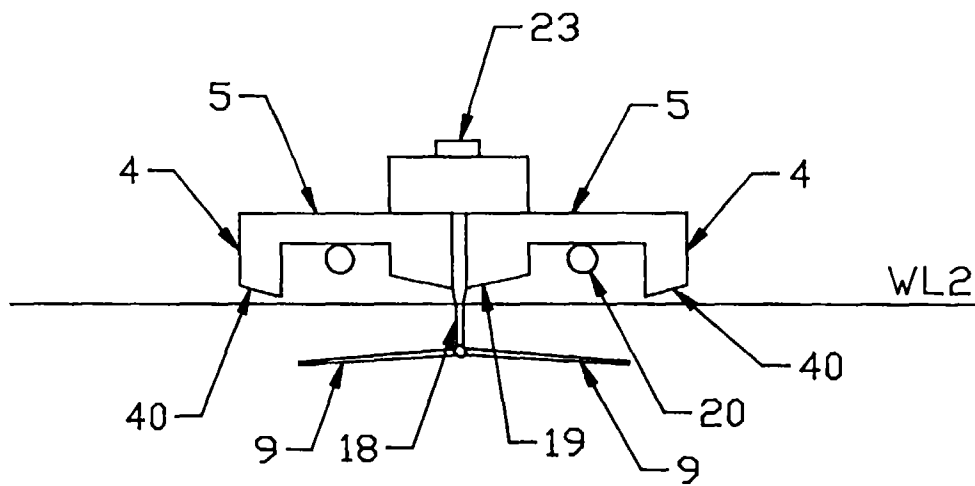
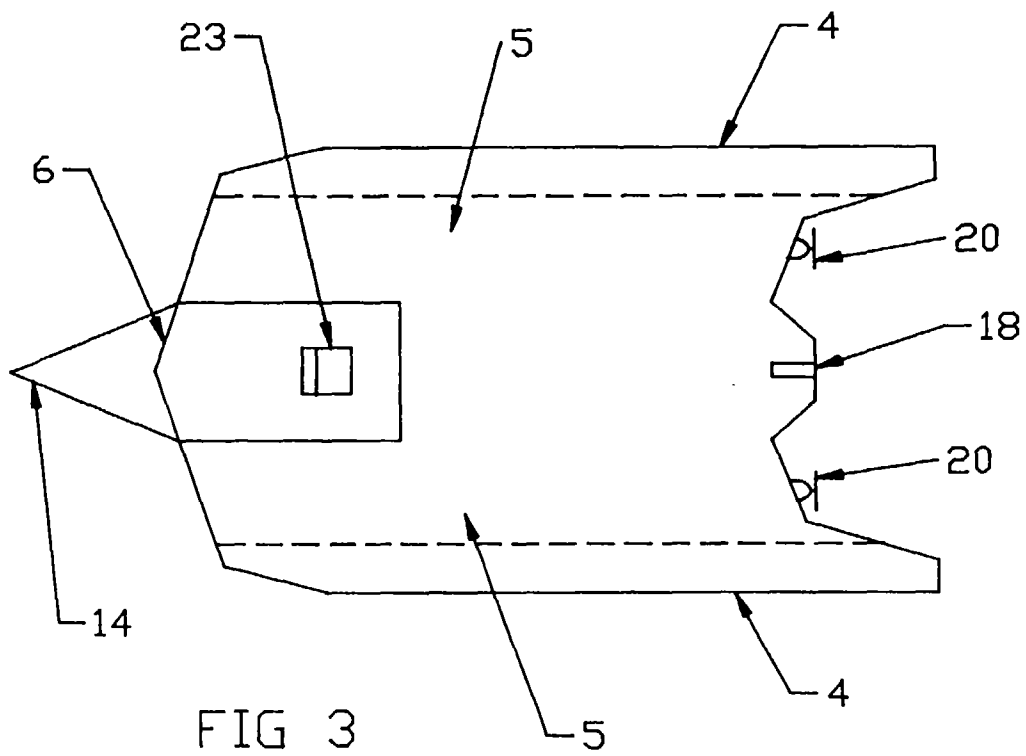


FIG 4

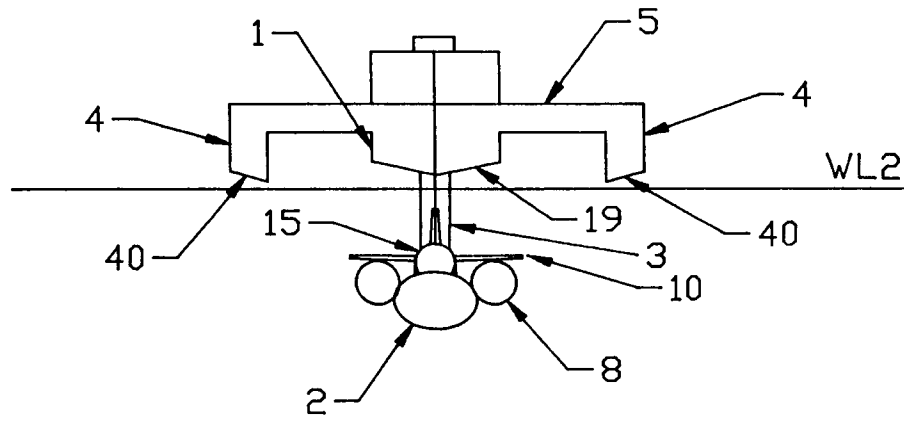


FIG 5

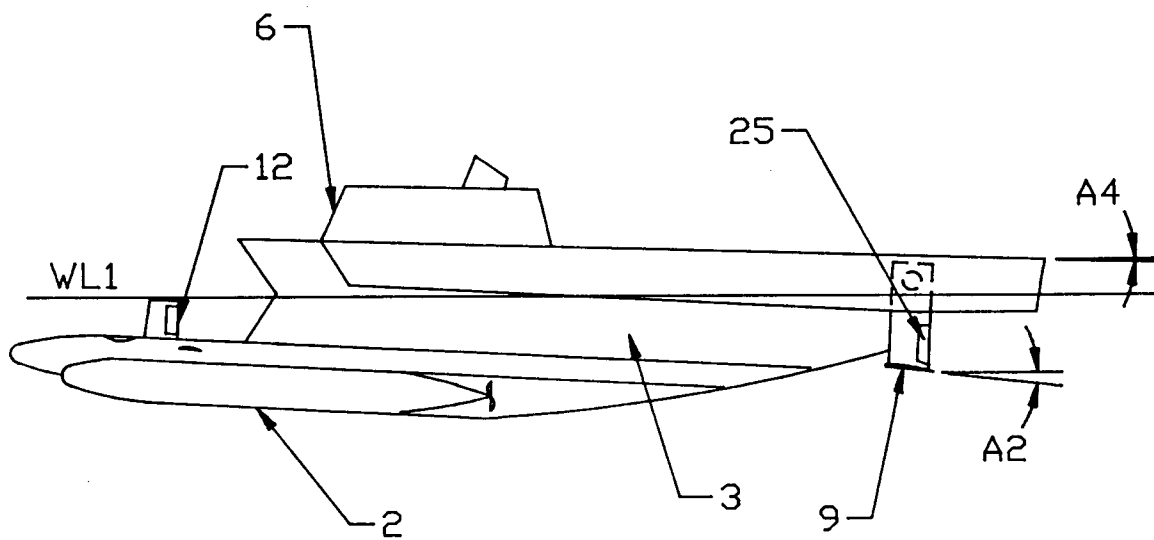


FIG 6

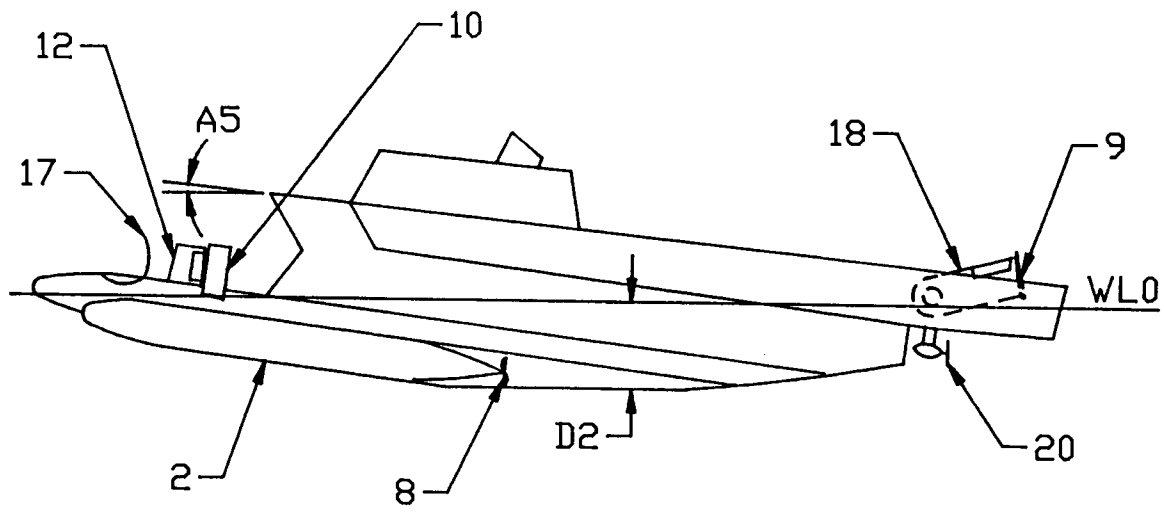


FIG 7

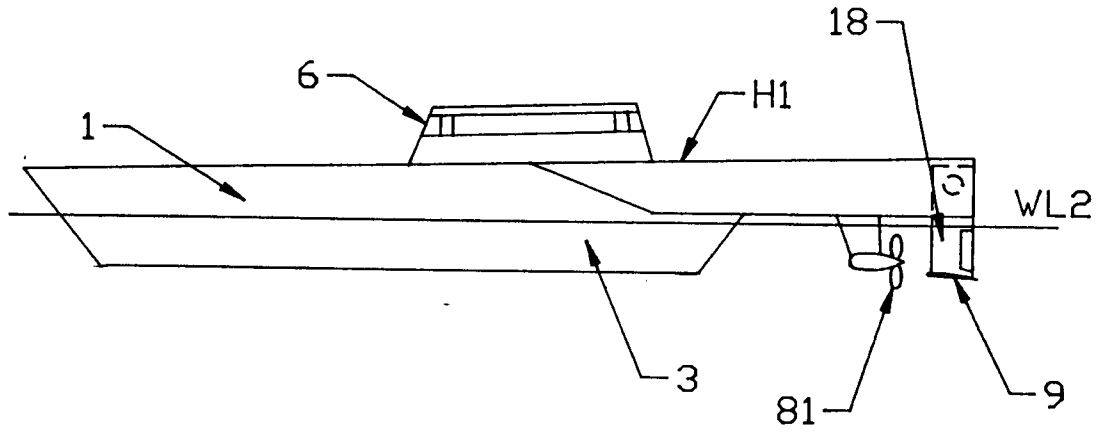


FIG 8

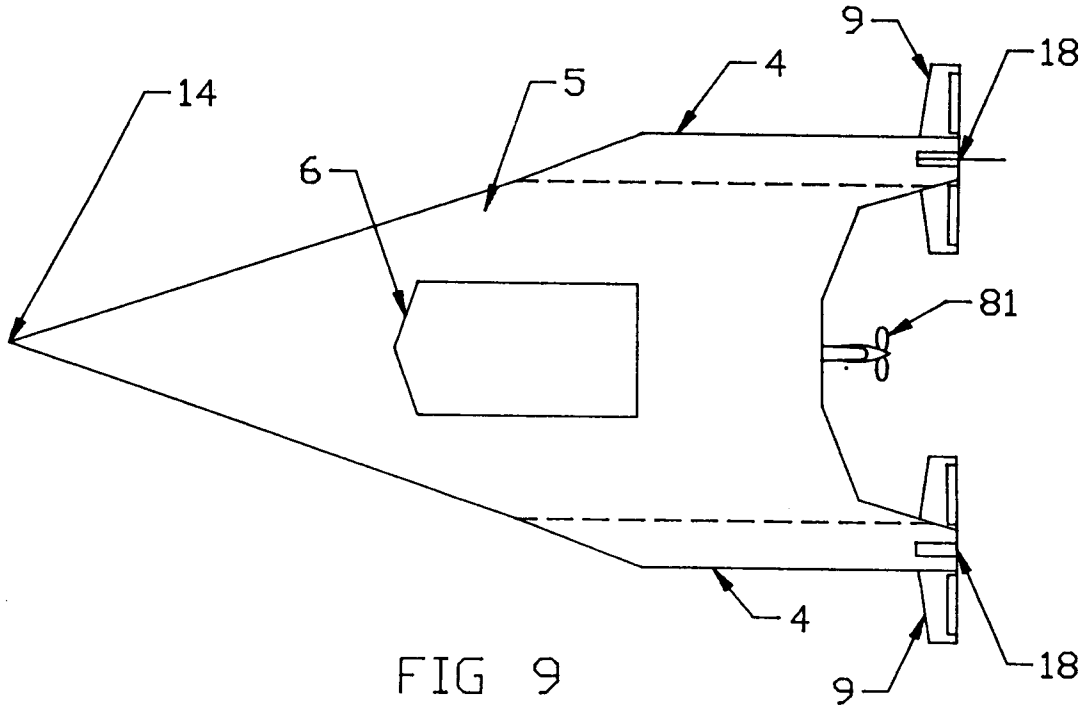
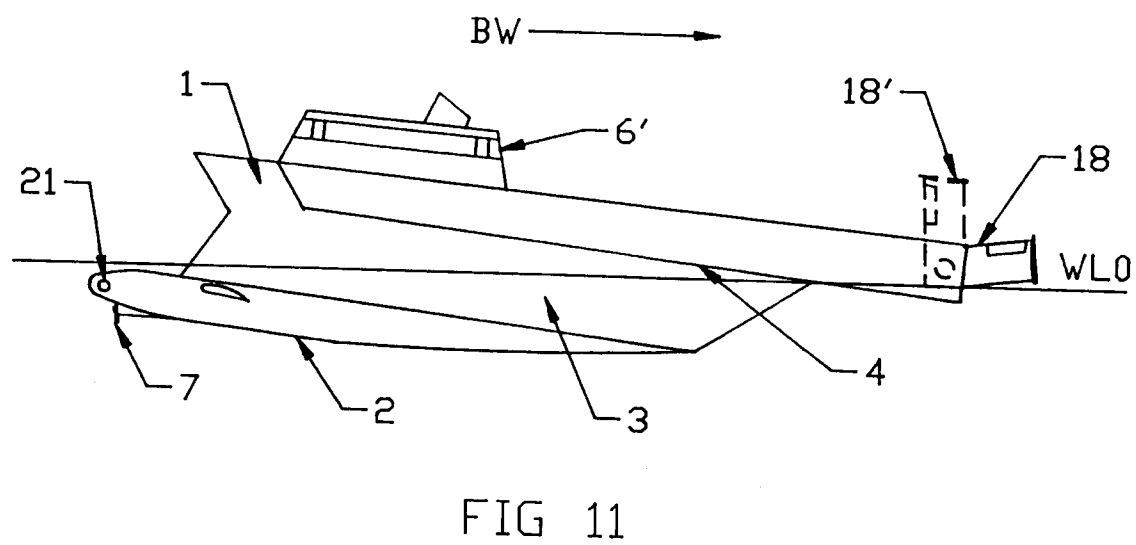
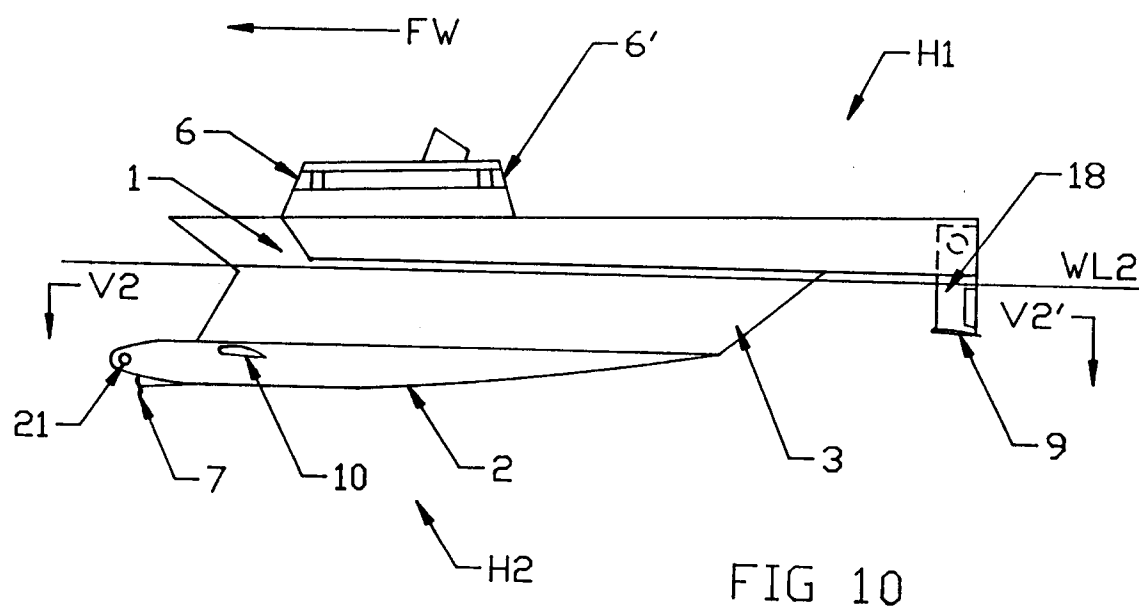


FIG 9



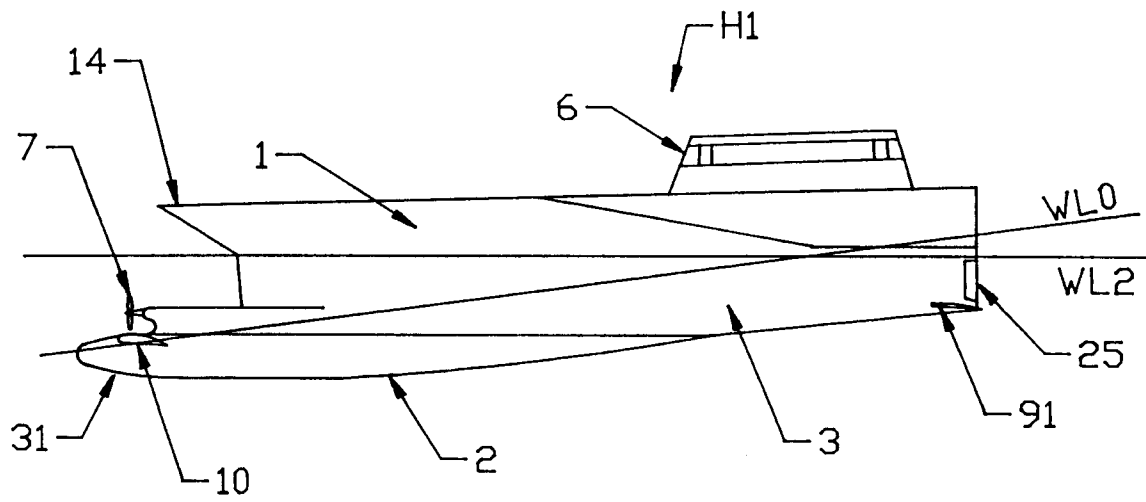


FIG 12

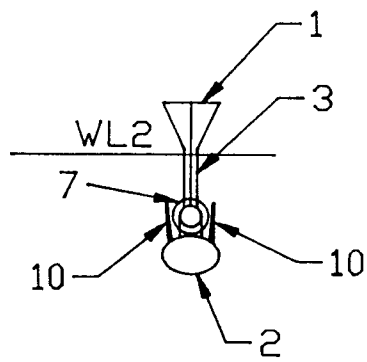


FIG 13

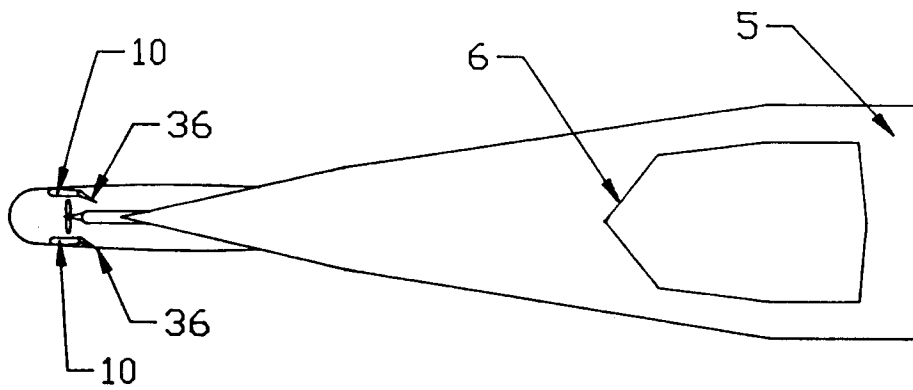


FIG 14

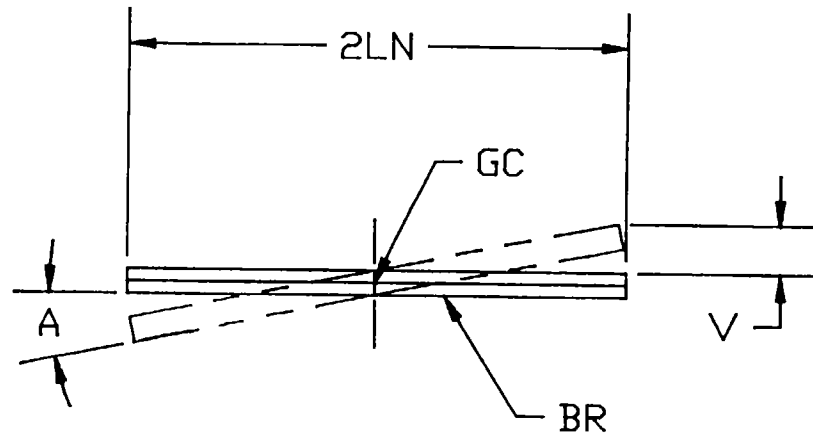


FIG 15

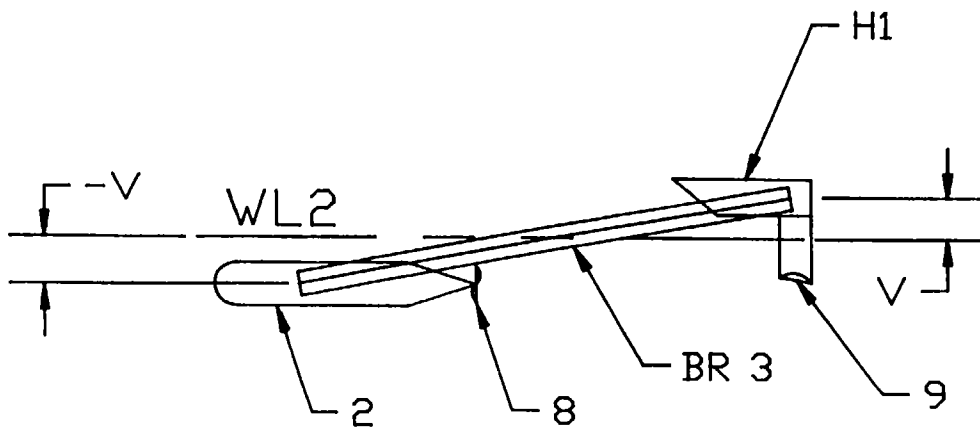


FIG 16



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 30 2222

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US-A-2 139 303 (GRUNBERG)	1-4	B63B1/00
Y	* page 1, line 20 - page 2, line 39; figures 1,5 *	5-7	B63B1/24

X	GB-A-752 639 (INTERNATIONAL AQUAVION S.A) * page 1, line 48 - page 2, line 25; figures 1,2 *	1,8	

X	US-A-3 227 123 (VOIGT) * figures 1,5,6 *	1-3	

Y	US-A-3 800 727 (STARK) * abstract; figure 1 *	5,7	

Y	FR-A-1 272 180 (LEGAT) * the whole document *	6,7	

A	NAVY TECHNICAL DISCLOSURE BULLETIN, vol. 3, no. 8, August 1978, NAVY OCEAN SYSTEMS CENTER, SAN DIEGO, CA, US, pages 1-5, XP002016887 LANG ET HIGDON: "Single-hulled semi-submerged soarcraft with three struts" * the whole document *	1-8	

The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 25 October 1996	Examiner DE SENA, A
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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