



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
02.01.2004 Bulletin 2004/01

(51) Int Cl.7: **B63B 1/02, B63B 1/04**

(21) Application number: **03013410.0**

(22) Date of filing: **20.06.2003**

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HU IE IT LI LU MC NL PT RO SE SI SK TR**
Designated Extension States:
AL LT LV MK

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(30) Priority: **25.06.2002 IT TV20020071**

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(54) **Hull particularly for water buses for inland and lagoon waters**

(57) A hull, particularly usable for water buses for inland waters and lagoon waters, in which the centroid C_B of the immersed volume is spaced from the centroid C_F of the cross-section of the hull taken along the plane

of the calm surface of the water, the centroid C_B being further located forward of the center of the waterplane, the hull having maximum immersions at the bow and maximum beam on waterline in the stern.

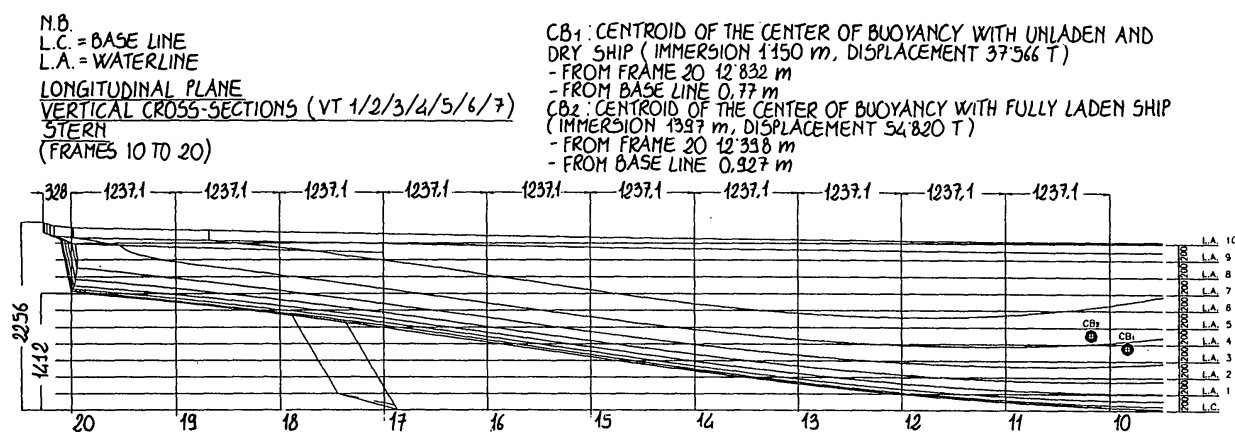


FIG. 2

Description

[0001] The present invention relates to a hull particularly usable for water buses for inland and lagoon waters.

[0002] Currently, the problem of using ferries for urban transport that take into consideration as much as possible the protection of the inland waters of the lagoon, with particular regard for waves, is strongly felt, especially in lagoon cities such as Venice.

[0003] It has in fact been noted that there are considerable environmental impact problems, which substantially consist in the formation of a wide backwash of the propulsion system and therefore of a strong water current generated by the propeller while it accelerates backward, in the presence of high values of emissions at the exhaust, and finally in the generation of waves.

[0004] In relation to the listed problems, it is noted that a boat traveling in particular in shallow water (shallow in relation to the size and speed of the boat) undergoes an increase in drag that is linked to, among other factors, an increase in the energy expended to deform the sea (therefore greater wave generation occurs).

[0005] This rather complex phenomenon in any case entails an increase in drag and often a variation in longitudinal trim, which in turn causes a further deterioration of the performance of the hull.

[0006] Moreover, the most common breakdown of the drag of a hull, considered as a sum of wave generation, viscous pressure and friction, has a percentage weight that is highly variable according to the speed of travel; if it is necessary to also take into account the speed of the water bus, optimizing hull shapes entails assessing the proportions in which the various components involved have an effect, and on the basis of their weight minimizing the causes of drag, especially in the drag system that has the greatest influence (the wave drag, viscous pressure or friction system).

[0007] Considering here only the hydrodynamic aspect (the aspect specific to the architectural design of hulls), it is noted, moreover, that the formation of a wide backwash of the propulsion system and the presence of high values of emissions at the exhaust are tightly linked problems, since they are both dealt with by reducing total drag (which in fact reduces the thrust required and therefore the backwash of the propeller and the power to be delivered and accordingly the exhaust fumes).

[0008] The waves generated by the motion of the hull, however, are tightly linked to the so-called "wave component of drag".

[0009] This is one of the components of total drag, and therefore an attempt to reduce this component is in tune with the solution sought for the above-mentioned problems.

[0010] The distinction that has been made, however, has a reason for its existence: the quest to achieve minimum wave drag without severe compromises can in fact have negative repercussions on other components

of total drag and therefore fail to solve the described problems.

[0011] The aim of the present invention is to solve the above-mentioned problems, eliminating the drawbacks noted above, by providing a hull, particularly usable for water buses for inland and lagoon waters, that allows to minimize the backwash of the propulsion system, to obtain low exhaust emission values, and to achieve maximum containment of wave generation.

[0012] Within this aim, an object of the present invention is to provide a hull that allows to achieve these characteristics together with an optimization of performance for at least two different operating speeds of the water bus, one of which is preferably 40% greater than the other.

[0013] Another object is to provide a hull that allows to minimize the negative effects of the shallow waters in which the water bus moves.

[0014] Another object is to provide a hull that allows to achieve high safety, understood most of all as transverse stability, good maneuverability, linked to operation, and optimum ease of steering.

[0015] Another object is to provide a hull that has low manufacturing and operating costs.

[0016] This aim and these and other objects that will become better apparent hereinafter are achieved by a hull, particularly for water buses for inland waters, characterized in that the centroid C_B of the immersed volume is spaced from the centroid C_F of the cross-section of the hull taken along the plane of the calm surface of the water, the centroid C_B being located forward of the center of the waterplane, the hull having maximum immersions at the bow and maximum beam on waterline in the stern.

[0017] Advantageously, the hull has longitudinal lines, which substantially represent the flow lines of the water, that are highly smooth and therefore nearly straight.

[0018] Further characteristics and advantages of the invention will become better apparent from the following detailed description of a particular but not exclusive embodiment thereof, illustrated by way of non-limitative example in the accompanying drawings, wherein:

Figure 1 is a view of the cross-sections of the hull at the longitudinal plane of the bow;

Figure 2 is a view of the cross-sections of the hull at the longitudinal plane of the stern;

Figure 3 is a view of the waterlines of the hull at the horizontal plane of the bow;

Figure 4 is a view of the waterlines of the hull at the horizontal plane of the stern;

Figure 5 is a view of the body plan in the transverse cross-sections of the hull at the stern and bow;

Figure 6 is a table that represents the body plan of the hull related to the longitudinal vertical cross-sections;

Figure 7 is a chart that plots the data of Figure 6;

Figure 8 is a table that represents the body plan of

the hull related to the half-breadths of the frames;
Figure 9 is a chart that plots the data of Figure 8.

[0019] With reference to the figures, a hull is considered which is used in particular in boats such as water buses for inland and lagoon waters.

[0020] The solution shown has been referred preferably but non-limitatively to the following dimensions, speeds and transport capacities:

- L_{OA} (length overall) ≤ 25.000 m
- B_{MAX} (maximum beam) ≤ 5.00 m

[0021] A speed of interest was also considered:

- $V_1 = 5.94$ kn (11 km/h) speed in canal
- $V_2 = 10$ kn (18.5 km/h) maximum full-load speed
- $V_3 = 10.8$ kn (20 km/h) maximum half-load speed

[0022] V_3 was considered by assuming that it is reached with a margin of 5% of maximum available power

- 250 passengers ± 5
- installable $P_{MAX} = 147$ kW

[0023] On the basis of the above, the present solution was orientated to provide a hull that has the highest L_{WL}/B_{WL} ratio (L_{WL} = length at waterline; B_{WL} beam at waterline) in order to make the hull as elongated as possible and therefore allow it to provide low values of R_W (wave component of total drag).

[0024] Again with the aim of "elongating" the hull as much as possible, the choice was also made to minimize bow rake and stem rake; to summarize, the ratio L_{WL}/L_{OA} was provided as high as possible, since L_{OA} is the maximum allowable longitudinal dimension of the craft.

[0025] Since it is not possible to optimize hull shapes only for the maximum speed, minimization of the consequent negative effects during travel at 10.8 kn was sought; the main one of these effects is the tendency to vary the longitudinal trim due to the considerable growth of the bow wave system; in practice, the stern tends to sink excessively, radically altering the immersed shape of the hull.

[0026] In order to avoid or at least contain this effect, the center of buoyancy C_B and the waterplane center C_F were spaced as much as possible.

[0027] It is noted that C_B is the centroid of the immersed volume and that C_F is the centroid of the cross-section of the hull taken along the plane of the sea surface, obviously when calm.

[0028] The fact of mutually spacing the two centers, particularly C_B toward the bow and C_F toward the stern, tends to shape the hull so as to increase considerably, with the mentioned forced sinking of the stern, the immersed volume of the hull at the stern and thereby the bow-down reaction required to minimize squatting.

[0029] To facilitate the visualization of the above, consider a hull that is very wide at the stern and immerses a large volume per immersion unit (of the stern).

[0030] At the same time, in order to prevent the immersed part of the hull from being too bulky at the stern with respect to the bow, the vertical dimension of the hull is reduced at the stern and increased at the bow.

[0031] This produces the shape according to the present invention, in which the point of maximum immersion is greatly shifted forward and the point of maximum breadth is shifted greatly toward the stern.

[0032] Again with the goal of obtaining hull shapes that are suitable for relatively high speeds, without however compromising performance at the lower speed, the shallowest inclination of the longitudinal cross-sections is provided in the stern region.

[0033] Substantially, the choice has been made to make the water astern of the hull return to its "rest" condition with a motion that is characterized by a strong upper component (to visualize: by contrast, the water can be relocated astern in the rest condition that occurs with a path that has no vertical components but has convergences - on the various horizontal planes - of the right and left fluid streams).

[0034] To obtain the intended effects, adjustments were made not only to the value of the inclination of the longitudinal lines but also to the constancy of said value, in view of the fact that minimizing shape variations entails - assuming the shape as a whole is correct - a reduction of the work applied to the fluid and therefore of drag.

[0035] Another aspect that might be considered as an additional element of the characteristic that can be ascribed to the particular hull that can be produced arises from observing the midship cross-section of any hull (i.e., the transverse cross-section that has the greatest area), which is substantially U-shaped.

[0036] If instead one observes the provided solution in an extreme bow cross-section, it appears to be V-shaped, with lateral segments that are often even convex (where the U has concave sides).

[0037] The conversion of the frames (transverse cross-sections) from the U-shape to the V-shape is one of the critical aspects of the shape of the bow.

[0038] Often, once the required quantity of immersed volume has been determined, the shape variation is provided by forming a so-called "shoulder", i.e., an unwanted shape discontinuity.

[0039] However, since it is believed that it is essential to avoid this circumstance, the immersed volume has been considered as a non-independent variable and an attempt has been made to render the waterlines (horizontal cross-sections) "substantially straight" in the bow region.

[0040] To summarize: by avoiding substantial convexities of the waterlines, the moment of inertia of the bow part of the waterplane has been minimized.

[0041] A prismatic coefficient CP that is a compromise

among those deemed ideal at the lowest and highest speeds was chosen.

[0042] This value was determined experimentally, taking also into account the value of the ratio between the prismatic coefficients of the bow CP_F and of the stern CP_A .

[0043] In particular, in view of a stern shape that is more conditioned (in view of the issues described above), it was preferred to set the stern coefficient to a value that is still deemed good, and various bows with different CP_F values were tested.

[0044] The prismatic coefficient is one of the fineness coefficients of the hull.

[0045] These coefficients define the level of "fullness" of the ends of the hull in relation to its central part.

[0046] Clearly, CP_F and CP_A are understood as the levels of fullness of the bow alone and of the stern alone with respect to the central part of the hull.

[0047] In very approximate terms, one could say that by proceeding in this manner a stern is provided that is slightly unbalanced for the higher required speeds, whereas by testing various bows characterized by different CP_F values and evaluating the overall result (in terms of measured performance), the bow half capable of giving the boat as a whole an excellent behavior at the lower speed was chosen.

[0048] Having chosen, for the cited reasons, the maximum allowable length, it was deemed indispensable to compensate for the difficulties due to the great dimensions by characterizing the hull with great maneuverability.

[0049] Such maneuverability would have been assuredly provided to the hull in any case by the type of propulsion system chosen (for example an azimuthal propulsion system capable of virtually ensuring thrust in every direction), but in order to maximize this characteristic the moment of inertia of the diametrical plane (or centerboard plan) was minimized compatibly with all the other restrictions and conditions.

[0050] Substantially, the "amount" of centerboard at the bow and at the stern was reduced and was concentrated in the central region.

[0051] Two consequences were obtained in this manner:

- a reduction in the yaw resisting moment (the rotation of the boat about a vertical axis) and therefore a faster course variation;
- a placement of the center of rotation very close to the craft center, in order to minimize the body of water affected by the maneuver.

[0052] Two conditions for the possible placement of the centroid C_F of the cross-section of said hull taken along the plane of the calm surface of the water (also known as waterplane center or centroid of the center of flotation) and of the centroid C_B (center of buoyancy) arranged forward of the center of flotation are indicated

in the particular embodiment; therefore, C_{B1} designates the center of buoyancy and C_{F1} designates the centroid of the waterplane when the craft is not loaded and dry (immersion 1.150 m and displacement 37.566 T).

[0053] The reference sign C_{B2} instead designates the center of buoyancy and the reference sign C_{F2} designates the centroid of the center of flotation when the vessel is fully laden (immersion 1.397 m and displacement 54.820 T).

[0054] In the first case, the centroid of the cross-section of said hull taken along the plane of the calm surface of the water (also known as center of the waterplane) C_{F1} is set by the frame 20 at 11.882 m, and said centroid (center of buoyancy) C_{B1} is set by the frame 20 to 12.832 m and by the base line LC to 0.77 m.

[0055] In the second case, the center of buoyancy C_{B2} is placed by the frame 20 at 12.398 m and by the base line LC at 0.927 m, and said centroid of the center of flotation C_{F2} is placed by the frame 20 at 10.972 m.

[0056] It has thus been found that the invention has achieved the intended aim and objects, a hull having been provided which is particularly usable for water buses for inland and lagoon waters and allows simultaneously to minimize the backwash of the propulsion system, to obtain low values of exhaust emissions and to achieve maximum containment of wave generation; further, the hull thus formed allows to achieve these characteristics together with the optimization of performance for at least two different operating speeds of the water bus, one of which is preferably 40% greater than the other.

[0057] The described hull also allows to minimize the negative effects of the shallow waters in which the water bus moves and to achieve high safety, understood most of all as transverse stability, good maneuverability, tied to operation, optimum ease of steering, and low manufacturing and operating costs.

[0058] The invention is of course susceptible of numerous modifications and variations, all of which are within the scope of the appended claims.

[0059] The materials and the dimensions that constitute the individual components of the invention may of course be the most pertinent according to specific requirements. Likewise, the placement of the centroid C_F of the section of said hull taken along the plane of the calm surface of the water (also known as center of the waterplane) and of the centroid C_B (center of buoyancy) varies according to the chosen dimensions, speeds and transport potentials of the hull.

[0060] The various means for performing certain different functions need not certainly coexist only in the illustrated embodiment but can be present per se in many embodiments, including ones that are not illustrated.

[0061] The disclosures in Italian Patent Application No. TV2002A000071 from which this application claims priority are incorporated herein by reference.

[0062] Where technical features mentioned in any

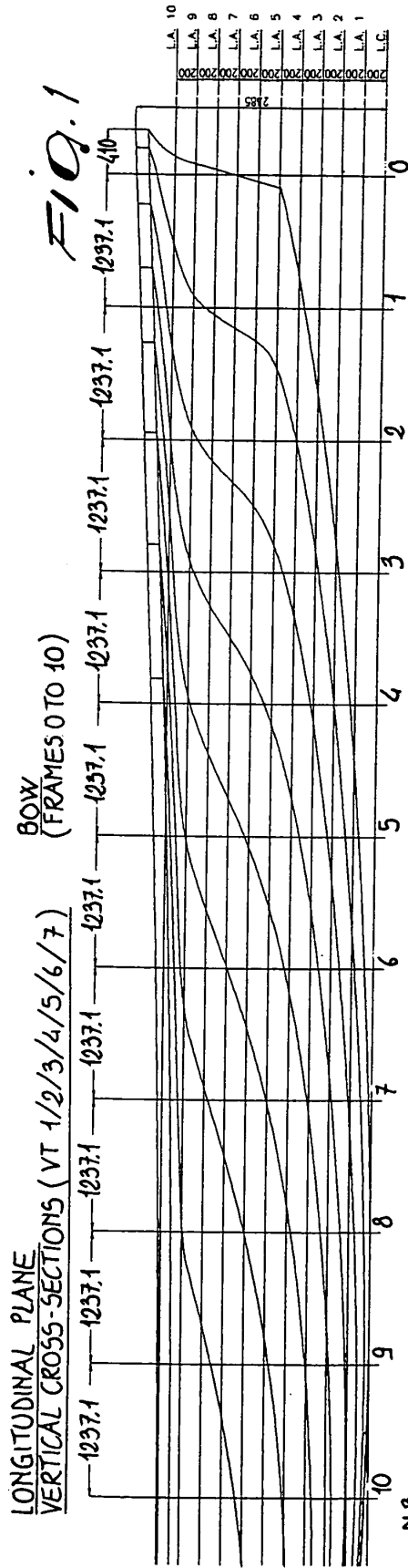
claim are followed by reference signs, those reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly, such reference signs do not have any limiting effect on the interpretation of each element identified by way of example by such reference signs.

Claims

1. A hull, particularly for water buses for inland waters, **characterized in that** the centroid C_B of the immersed volume (or center of buoyancy) is spaced from the centroid C_F of the cross-section of said hull taken along the plane of the calm surface of the water (or center of the waterplane), said centroid C_B being located forward of the center of the waterplane, said hull having maximum immersions at the bow and maximum beam on waterline in the stem. 10
2. The hull according to claim 1, **characterized in that** the longitudinal lines, which substantially represent the water flow lines, are very smooth and are therefore nearly straight in order to minimize the direction changes of the lines of current and therefore minimize shape drag. 15
3. The hull according to claim 1, **characterized in that** the moment of inertia of the diametrical plane (or centerboard plan) has been minimized. 20
4. The hull according to claim 1, **characterized in that** in an extreme bow cross-section, said hull has a substantially V-like shape with some convex lateral segments in order to make the waterlines (i.e., the horizontal cross-sections) in the bow region "substantially rectilinear", so as to avoid substantial convexities of the waterlines, minimizing the moment of inertia of the bow part of the waterplane. 25
5. The hull according to claim 1, **characterized in that** the "quantity" of centerboard at the bow and stem has been reduced and has been concentrated in the central region in order to obtain a reduction in the yaw resisting moment and therefore obtain a quicker course change as well as a placement of the center of rotation very close to the center of the boat, minimizing the body of water affected by the maneuver. 30
6. The hull according to claim 1, **characterized in that** in the condition in which the boat is not loaded and is dry, said centroid of the cross-section of said hull taken along the plane of the calm water surface (also known as center of the waterplane), indicated as C_{F1} , is arranged by the frame 20 at 11.882 m, and said centroid (center of buoyancy), designated as C_{B1} , is arranged by the frame 20 at 12.832 m and 35

by the base line LC at 0.77 m.

7. The hull according to claim 1, **characterized in that** in the condition in which the boat is fully loaded (immersion 1.397 m, displacement 37.566 T), said center of buoyancy, designated as C_{B2} , is arranged by the frame 20 at 12.398 m and by the base line LC to 0.927 m, and said centroid of the waterplane C_{F2} is arranged by the frame 20 at 10.972 m. 40



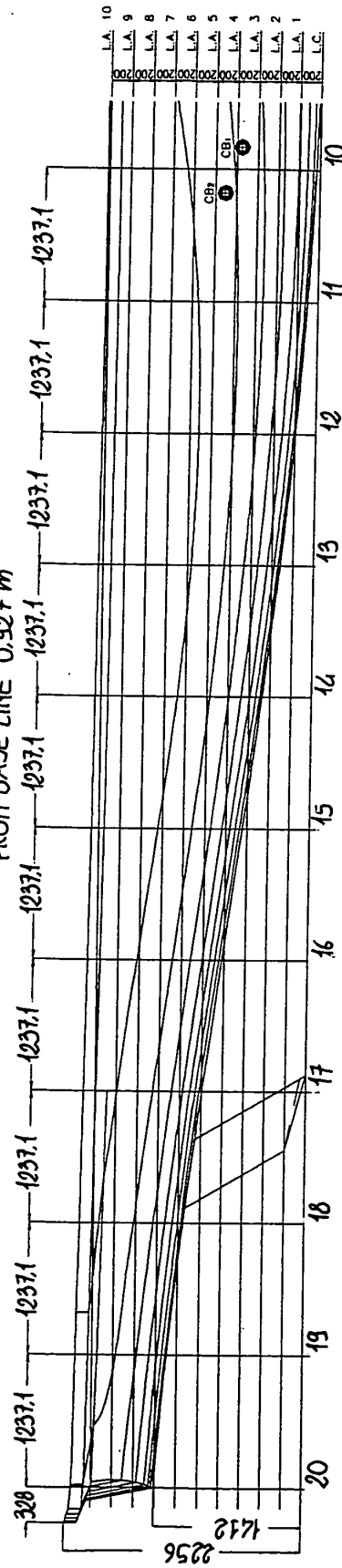
N.B.
L.C. = BASE LINE
L.A. = WATERLINE

LONGITUDINAL PLANE
VERTICAL CROSS-SECTIONS (VT 1/2/3/4/5/6/7)

STERN
(FRAMES 10 TO 20)

CB1 : CENTROID OF THE CENTER OF BUOYANCY WITH UNLADEN AND DRY SHIP (IMMERSION 1'150 m, DISPLACEMENT 37'566 T)
- FROM FRAME 20 12'832 m
- FROM BASE LINE 0,77 m

CB2 : CENTROID OF THE CENTER OF BUOYANCY WITH FULLY LADEN SHIP (IMMERSION 1'397 m, DISPLACEMENT 54'820 T)
- FROM FRAME 20 12'358 m
- FROM BASE LINE 0,927 m



HORIZONTAL PLANE
WATERLINE CROSS-SECTIONS (L.A. 1/2/3/4/5/6/7/8/9/10)
STERN
(FRAMES 10 TO 20)

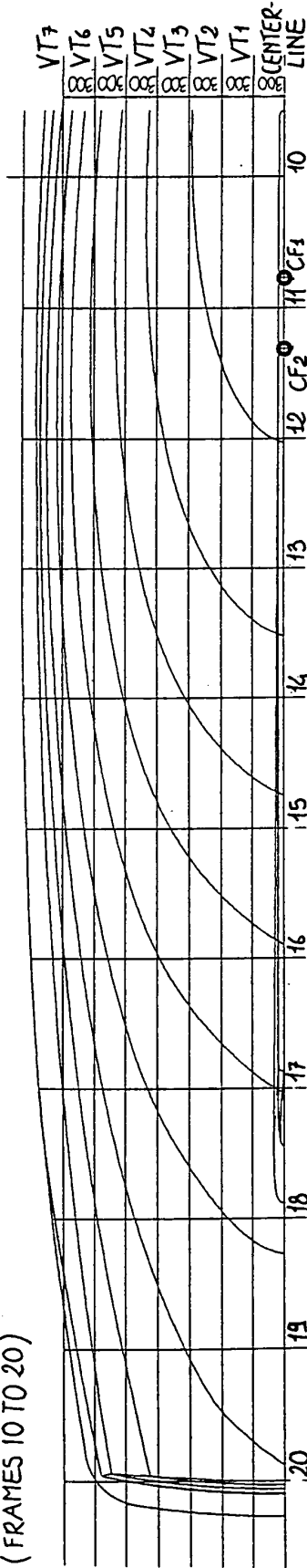


Fig. 3

CF₁: CENTROID OF CENTER OF FLOTATION WITH
UNLADEN AND DRY SHIP (IMMERSION 1150 m,
DISPLACEMENT 37 566 T)
- FROM FRAME 20 11 882 m
CF₂: CENTROID OF CENTER OF FLOTATION WITH FULLY LADEN
SHIP (IMMERSION 1397 m, DISPLACEMENT 54 20 T)
- FROM FRAME 20 10 972 m

HORIZONTAL PLANE
WATERLINE CROSS-SECTIONS (L.A. 1/2/3/4/5/6/7/8/9/10)
BOW

(FRAMES 0 TO 10)

N.B.
VT = VERTICAL

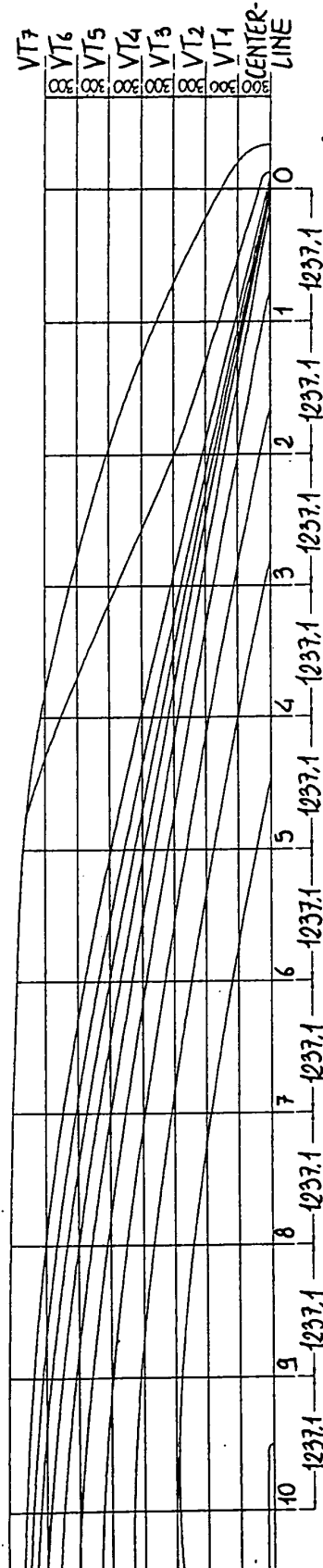
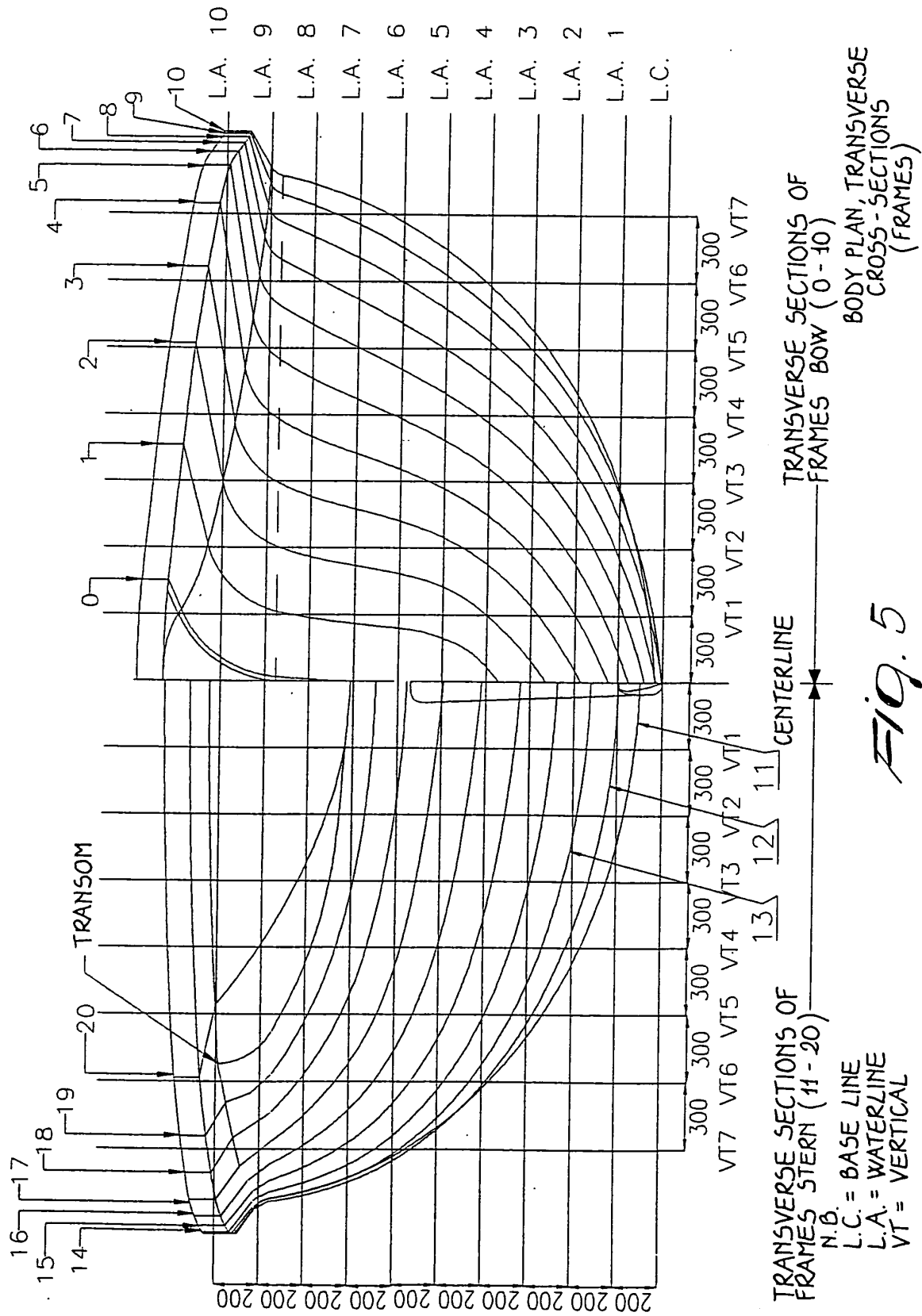


Fig. 4



HEIGHT OF FRAMES WITH REFERENCE TO LONGITUDINAL CROSS-SECTIONS (VERTICAL)								
VERTICAL (n) HEIGHT FROM L.C. FRAME (NUMBER)	CENTERLINE	VT1 mm 300	VT2 mm 600	VT3 mm 900	VT4 mm 1200	VT5 mm 1500	VT6 mm 1800	VT7 mm 2100
	HEIGHT FROM BASE LINE IN mm							
0	1430	2176						
1	743	1689	2061	2142				
2	531	802	1740	2002	2065	2129		
3	370	568	912	1762	1958	2013	2068	
4	246	399	629	1071	1782	1924	1974	2024
5	152	274	449	722	1239	1811	1903	1954
6	81	176	317	519	848	1392	1840	1900
7	31	105	219	378	618	1006	1560	1852
8	3	61	151	281	470	760	1204	1796
9	4	45	116	223	381	612	959	1504
10	36	64	121	211	345	539	821	1267
11	100	120	168	246	363	530	769	1144
12	197	214	257	325	429	576	785	1117
13	323	341	381	444	535	666	856	1168
14	475	496	535	592	674	792	972	1282
15	643	669	707	761	836	947	1122	1445
16	819	848	887	937	1007	1115	1290	1625
17	994	1020	1057	1106	1174	1280	1461	1795
18	1158	1175	1208	1258	1329	1439	1624	1950
19	1300	1313	1343	1391	1465	1584	1776	
20	1412	1437	1512	1637	1812	2008		

Fig. 6

LEGEND: VT = VERTICAL

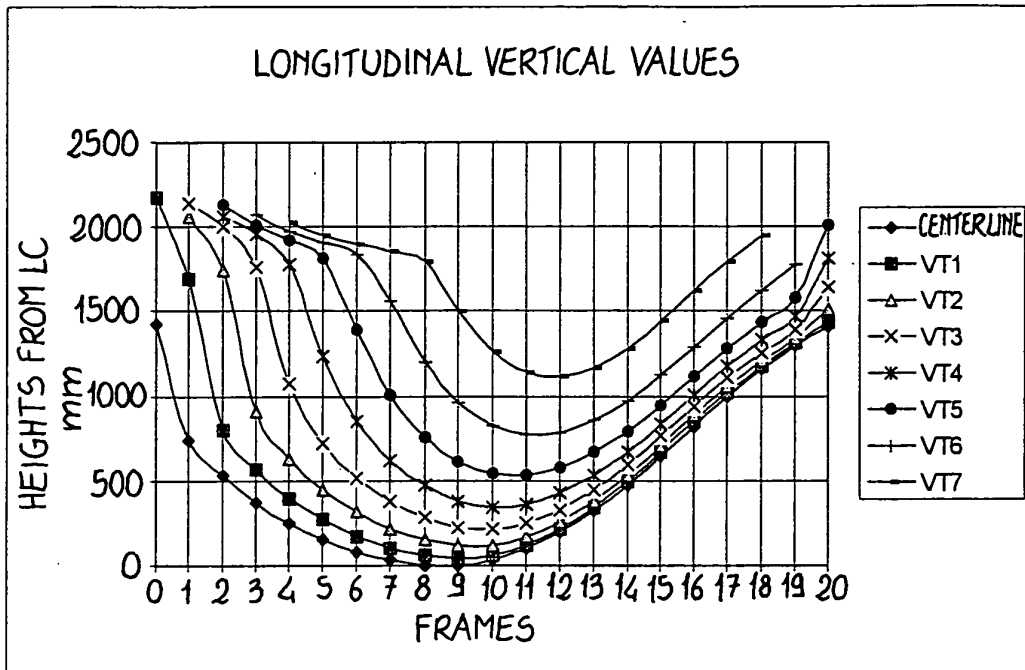


Fig. 7

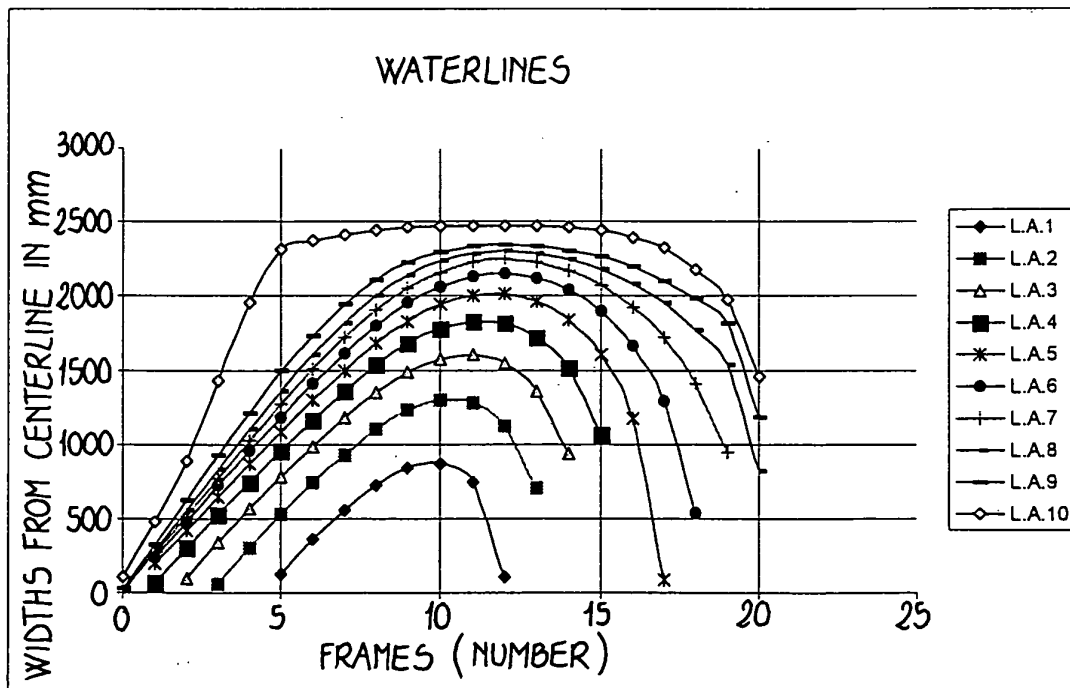


Fig. 9

HALF-BREADTH OF FRAMES WITH REFERENCE TO WATERLINES											
L.A.1 mm 200	L.A.2 mm 400	L.A.3 mm 600	L.A.4 mm 800	L.A.5 mm 1000	L.A.6 mm 1200	L.A.7 mm 1400	L.A.8 mm 1600	L.A.9 mm 1800	L.A.10 mm 2000		
DISTANCES FROM CENTERLINE IN mm											
0							10	26		104	
1				69	194	239	259	285	327	477	
2			96	299	424	483	519	559	626	891	
3		54	338	526	646	721	774	831	924	1429	
4		302	569	747	866	954	1025	1101	1215	1954	
5	130	527	785	960	1085	1183	1270	1363	1498	2316	
6	358	739	990	1166	1297	1405	1504	1605	1732	2378	
7	557	933	1182	1359	1496	1613	1719	1821	1940	2417	
8	727	1102	1351	1533	1676	1798	1905	2000	2106	2442	
9	844	1230	1487	1678	1828	1951	2054	2138	2227	2458	
10	869	1296	1575	1782	1941	2065	2161	2233	2300	2468	
11	738	1276	1600	1832	2004	2132	2224	2287	2336	2474	
12	105	1127	1540	1817	2013	2151	2245	2305	2342	2475	
13		703	1362	1724	1962	2122	2226	2291	2333	2475	
14			934	1517	1836	2040	2168	2250	2309	2467	
15				1068	1607	1895	2071	2182	2263	2439	
16					1173	1666	1925	2084	2195	2396	
17					84	1289	1716	1951	2104	2324	
18						536	1410	1769	1982	2179	
19							946	1531	1822	1972	
20								824	1182	1454	

LEGEND: L.A. = WATERLINE L.C. = BASE LINE

Fig. 8



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 03 01 3410

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.7)
X	"IN SEARCH OF LOW WASH HULL FORMS" SHIP AND BOAT INTERNATIONAL, ROYAL INSTITUTION OF NAVAL ARCHITECTS, LONDON, GB, no. 2, 1 March 1991 (1991-03-01), pages 8-11, XP000176972 ISSN: 0037-3834 * page 1, right-hand column, line 20 - line 22; figures PAGE,3 *	1-7	B63B1/02 B63B1/04
X	US 5 711 239 A (RAMDE ROAR ROLLAND) 27 January 1998 (1998-01-27) * column 4, line 41 - line 47; figure 1 *	1-7	
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The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
THE HAGUE		17 September 2003	DE SENA HERNAND..., 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			

EPO FORM 1503 03/92 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 03 01 3410

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17-09-2003

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