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(54) **Sailboat mast construction.**

(57) Disclosed herein is a sailboat mast (10) primarily intended for racing which is constructed of three or more vertical columns (12, 14, 16), two of which (12, 14) can be tubular and the other (16) of which is solid. The columns are arranged in a triangular or diamond pattern and connected by cross braces. The diameter of the tubing columns and the diameter of the solid column are selected to maximize the strength and moment of inertia so that the weight can be lessened. The solid column (16) supports a sail track (32) and is arranged so that a portion of the column is aligned with one of the forward tubes so that it is in the windshadow (33) of one of the forward members at the normal up-wind tacking angle of the boat. This reduces overall drag on the mast system. In addition, the hollow forward tubes are used as conduits for the mainsail halyard and the jumper wires for adjusting or tuning the shape of the mast. If three columns are employed they are arranged in a triangular pattern with two forward columns forming a leg at right angles with the keel and the aft column on the keel line.

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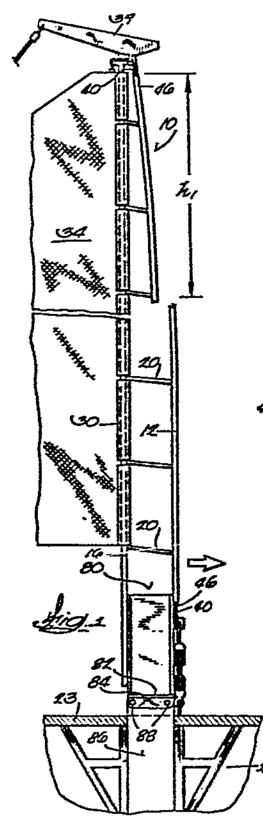
39
40
46
10
h_1
34
20
30
12
20
16
80
46
40
82
84
13
88
86
24

Fig. 1

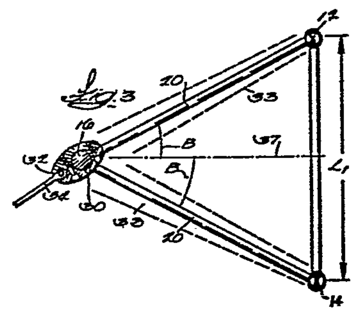
12
20
33
16
B
37
L_1
32
34
30
33
20
14

Fig. 3

Sailboat Mast Construction

Sailboat masts modify speed and pointing ability of a sailboat in numerous ways. The drag of the mast through the air creates a negative force when the apparent wind is forward of the beam. Also, the mast is a projection in the airstream and spoils the air flow over a portion of the sail directly behind the mast. The turbulence is roughly proportional to drag, as a large part of the drag is caused by turbulence to leeward. When a jib sail is used, the mast becomes an obstruction in the airstream flowing through the slot between the two masts. Thus the windage of a mast is the primary consideration of most builders. Other factors relating to the mast and hull speed involve considerations of weight. Ideally the mast should have a small diameter and low center of gravity. The weight of the mast produces a relatively high inertia that must be overcome when the boat pitches over waves. When a boat heels over, the mast weight increases the heel, requiring more keel weight or less sail area. Within certain limits, the less weight you need to keep the boat upright in the water, the faster you can go. Drag also increases heeling moment. Accordingly, it is desirable to minimize drag through the air with any mast and reduce the weight of the mast, both of which will improve air flow on the sail and provide increased boat speed. Mast stiffness is also a consideration. Most sails are designed for masts that bend and, accordingly, a stiff mast will not produce an optimum mainsail for light winds. Various mast control systems are employed to "tune" the mast. It is also desirable to be able to bend the mast while sailing to maximize speed. Various mast configurations are employed in racing. The oval shaped mast with the long axis coincident with the longitudinal axis of the boat hull is quite popular for racing. Although the coefficient of drag for the oval shape is relatively low and less than a round mast having a comparable cross-sectional area, the coefficient increases with change in wind direction to port or starboard whereas the coefficient of drag of a round mast stays essentially the same.

According to the present invention there is provided a mast construction for a sailboat comprising at least two forward columns and an aft column, said aft column including means for supporting a sail and means connecting said columns characterised in that the two forward columns are aligned so that at least a portion of length of the aft column supporting the sail is in the shadow of one of the two forward columns when the boat is substantially on its normal tacking angle to port and at least a portion of the length of the aft column is in the windshadow of the other of the two forward columns when the boat is substantially on its normal tacking angle to starboard.

The invention provides a lightweight three column mast in which low windage, low weight and controllable flexibility provide increased hull speed for racing. The mast vertical members are aligned in a triangular pattern with respect to each other to position the aft sail supporting column in the windshadow of one of the forward columns when a boat is substantially on its normal tacking angle as close as possible to the apparent wind to port and of another member when it is on its normal angle tacking to starboard. More specifically, the forward vertical columns are desirably tubular and form a leg of a triangle which is at right angles with the keel or longitudinal center line, and the rearward or aft member of the three column mast is desirably solid and positioned on the boat center line. The angle B between a triangle leg connecting the forward column with the sail column and the center line is selected for the particular hull involved to provide this result. The spacing of the members is selected to provide the desired angle so that the combined compressive stress is reduced to minimize the weight of the structure required to handle the stresses and bending moments to thus obtain the advantages of a lightweight mast.

The reduced drag afforded by the three column mast improves the jib entry angle so that the boat can point higher into the wind without losing speed. Reducing the weight of the mast also enables carrying more sail, which is helpful in light to medium air.

Further objects, advantages and features of the invention will become apparent from the disclosure.

Embodiments of the invention will now be described by way of example, reference being made to the accompanying drawings, in which:-

Fig. 1 is a side elevational view of a mast in accordance with the invention, with the bow of the boat being to the right of the figure as viewed,

Fig. 2 is a reduced perspective view of a sailboat employing the mast of the invention,

Fig. 3 is an enlarged sectional view along line 3--3 of Fig. 2,

Fig. 4 is an enlarged view of a mast spacer spreader,

Fig. 5 is a view of the cable tightening apparatus shown in Fig. 1,

Fig. 6 is a side elevational view of a modified embodiment of a mast,

Fig. 7 is a sectional view along line 7--7 of Fig. 6,

Fig. 8 is a view along line 8--8 of Fig. 6,

Fig. 9 is a sectional view of a further modified embodiment of a mast,

Fig. 10 is an enlarged plan view in partial section of a modified embodiment of a spacer and sail track assembly,

Fig. 11 is a fragmentary side elevational view of the spacer and sail track assembly shown in Fig. 10,

Fig. 12 is an enlarged sectional view of a modified embodiment of a mast spacer,

Fig. 13 is a perspective view of a further modified embodiment of a mast spacer, and

Fig. 14 is a perspective view of a further modified embodiment of a mast spacer.

Although the disclosure hereof is detailed and exact to enable those skilled in the art to practice the invention, the physical embodiments herein disclosed merely exemplify the invention which may be embodied in other specific structure. The scope of the invention is defined in the claims appended hereto.

In the drawings the mast 10 comprises a forward pair of spaced columns in the form of tubes 12 and 14 and a rear or aft column 16 of solid stock which, as subsequently described, supports the sail. The columns 12, 14 and 16 are interconnected by spacers 20. In Figs. 1 and 3 the spacers can be in the form of tubes or rods which are welded between the columns. The mast 10 can be supported by an assembly 86 recessed in the deck 23 in the boat hull 24. The column 16 is provided with a vertical array of pivotally supported guide members 30 which are clamped to the column 16 in between the spacers 20 and provide a vertical track 32 for the main sail 34.

Design of the three column mast consists of sizing the two forward tubes 12 and 14 with adequate spacing L_1 to provide the required moment of inertia I to handle the bending and compressive stresses involved. The moment of inertia of the mast in a sideways direction to port or starboard must be maintained in a certain proportion to the fore and aft inertias. A ratio of 1 to 2 or 1 to 2.5 is appropriate, or an I of 2 towards port or starboard and an I of 4.3 in fore and aft direction.

Using a 7/8 inch outside diameter for the forward tubes or column 12 and 14 and having a 0.065 inch wall thickness and area = 0.165 sq. in. provides sideways

$$I = 2\ A\ d^2 = 2.0.\ d = \sqrt{\frac{2}{2 \times .115}} = 2.46 \text{ inches}$$

from the beam longitudinal center line and total distance L_1 (Fig. 2) on both sides of the beam of where .875 is double the radius of the tubes = 2.46 + 2.46 + .875 = 5.8 inches.

To calculate the fore and aft distance or fore and aft column spacing we have

$$I \text{ fore and aft (fa)} = A, d^2, + A_2\ d_2 = 4.3$$

$$\frac{d_1}{d_2} = \frac{A_2}{A_1} = \frac{.55}{.33}$$

$$I = .33\ \frac{.55}{.33} d_2{}^2 + 5.5\ (d_2)^2 = 4.3$$

$$d_2^2 = \frac{4.3}{1.46} + d_2 = 1.72$$

$$d_1 = 1.72 \times \frac{.55}{.33} = 2.86$$

Length = 1.72 + 2.86 + .875 = 5.455 inches

If the areas are divided equally

fore and aft $I = 4.3 = .44\ d^2 + .44\ d^2$

$$d^2 = \frac{4.3}{2 \times .44} = \sqrt{4.87}$$

$$d = 2.21$$

Length (fa) = 2.21 + 2.21 + .875 = 5.3 inches.

The angles B (Fig. 3) formed by triangular legs connecting the column 16 with the columns 12 and 14 and the hull centerline 37 should desirably approximate the direction of apparent wind for the particular boat at the typical tacking angle to place the column 16 and sail track members 30 in the windshadows 33 of the forward columns 12 and 14 to reduce drag and improve airflow. The angle B can be controlled by changing the proportions of column area from the forward tubes to the sail supporting column.

Since bending stresses are calculated by $S = \frac{MC}{I}$ where C is the distance from the neutral fiber to the outer fiber, making the sail column 16 solid, with thus more than twice the cross-sectional area of the forward tubes, reduces the compressive stress in the sail supporting column 16 by moving the neutral axis and reducing C. Since bending the mast creates tensile stress in the forward tubes and compressive stress in the sail tube, proper distribution of the tube sizes can reduce the mast stresses and allow more overall mast weight reduction, which reduces heeling moment. Hence, using a solid column for column 16 is desirable to reduce the weight of the mast. Alternatively, the increased strength required for column 16 can be obtained by appropriate selection of materials or using a column with a greater wall thickness or area. For instance, the rear column 16 can be aluminium and the forward columns steel.

A major part of the compressive load in the mast is caused by the halyards. These loads can be placed in the forward columns 12 and 14, thus opposing the tensile load from bending and reducing the compressive load in the sail tube.

The upper section of the mast h_1 can be tapered as shown in Fig. 1 to enable controlled bending or tuning, as is well known in the art. Jumper wires 40 connected to the top piece 39 of the mast can be employed. Each jumper wire 40 can be contained in one of the tubes 12, 14 and exit at tube ends 46. Tension can be put on the wires 40 with a block and tackle 52 or a winch which is connected to a connector 53.

The lower end of the columns can be connected to three upstanding plates 80 which are welded to the columns and also to a base plate 82 which is secured to two spaced hinge plates 84. The hinge plates 84 are pinned to a mast supporting assembly 86 by pins 88. If one of the pins is removed, the mast can be pivoted about the other pin to aid in stepping the mast.

Fig. 4 shows a combination spacer-spreader plate 90 which is notched to receive the columns and is welded to the columns. The spreader plates can be provided with tips 92 which are hinged at 94 to the main body of the spacer-spreader plates. The spreader tips 94 are connected to the mast side stays 96 in conventional fashion.

The spacers 20 can be of adjustable length to shape the mast for appropriate spacing at different vertical sections of the mast to adjust the windshadow on the sail supporting column. The apparent wind acting on the mast varies at different heights of the mast because of increase in wind speed at higher elevations and because of the presence of a jib.

It is not necessary that the rear column 16 be completely in the windshadow of one of the forward columns. If, for instance, only the upper one-quarter of column 16 or the portion of column 16 above the jib stay is in the wind-shadow when the boat is at a desirable tacking angle, some benefits of reduced drag can be obtained.

Figs. 6, 7 and 8 show a mast with a reduced triangular cross-sectional area along the section of Fig. 8 compared with the Fig. 7 cross-section. To accomplish the change in shape the spacers connecting the vertical columns can be in the form of turnbuckles 62.

Fig. 9 shows a modified embodiment in which a forward column 70 is added to provide a diamond shape. This configuration has certain advantages from the standpoint of strength at the expense of increased weight.

Fig. 10 shows a modified embodiment of a spacer 110 which comprises a solid plate which is welded or otherwise connected to the columns. Fig. 10 also discloses means forming a sail track comprising a lightweight shell 120 wrapped around column 16 and riveted to ears 122 by rivets 124. The ears 122 are connected to an arcuate member 126 which provides a sail track 128. A friction bearing 130 formed from a longitudinal section of plastic tubing or pipe is riveted by rivets 132 to the shell. The ends 134 bear against the column 16 and provide a bearing surface with frictional restraint which enables the sail and assembly to pivot about the column 16. If shell 120 is made from plastic, the bearing 130 may not be required. The shell 120 is notched to interfit with the spacers. The plate 110 is desirably inclined at an angle A with the horizontal plane 140 so that drag is reduced when the boat is heeling. Similarly, the spacers illustrated in Fig. 1 are at an angle. The angle A can vary with the particular boat, but angles of 4^{o} to 8^{o} are generally appropriate.

Fig. 12 shows a modified embodiment of the mast in which the forward tubes 150 and 152 are oval and the mast supporting column 154 is similarly oval in cross-section and desirably formed from an extrusion with an integrally formed sail track 156.

Fig. 13 shows a spacer 170 which can be formed from one piece or, as disclosed, formed from upper and lower shell halves 172, 174. The shell halves 172, 174 are joined by a weldment along the split line 176. The halves 172, 174 are desirably shaped to provide a vertical oriented elongated oval end 180 which is welded to a sleeve 182. The sleeve 182 is welded, riveted or otherwise secured to column 16. The forward ends 184 of the shells form a thin fin with upturned corners 186 to give a vertical thickness for joining to the sleeves 188 which can be welded, glued or riveted or fastened by any combination thereof to the forward columns 12, 14. The gaps 190 between the shells can be filled with a weldment. The sleeves can be half sleeves or full sleeves. If the spacer material is weld-able to the mast columns, the intermediate sleeve portions may not be required.

The shape of spacer 170 provides minimum drag and adds vertical beam strength at end 182. With bending of the mast in use, spacers 170 will tend to keep points on the various columns at the same distance and orientation and control strength and flexibility. The spacer 170 is desirably formed from stainless steel. Alternatively, the spacer can be constructed as shown in Fig. 14 in which the spacer 190 has a horizontally oriented tear drop air foil shape with the thick end connected to the forward columns and providing vertical beam strength to maintain the column orientation.

Claims

1. A mast construction for a sailboat comprising at least two forward columns and an aft column, said aft column including means for supporting a sail and means connecting said columns characterised in that the two forward columns are aligned so that at least a portion of length of the aft column supporting the sail is in the shadow of one of the two forward columns when the boat is substantially on its normal tacking angle to port and at least a portion of the length of the aft column is in the windshadow of the other of the two forward columns when the boat is substantially on its normal tacking angle to starboard.

2. A mast construction according to claim 1 characterised in that the two forward columns are connected by struts to the aft column and the cross-sectional area of the aft column is greater than the cross-sectional area of the two forward columns, the spacing between the columns being such as to reduce the combined compressive stress and reduce the overall weight of the mast.

3. A mast constructed according to claim 1 characterised in that the two forward columns are connected by struts to the aft column and the aft column is made of a different material from the two forward columns to provide increased strength of the aft column to reduce compressive stress.

4. A mast construction according to claim 1, 2 or 3 characterised in that the two forward columns and the aft column are disposed at the corners of a triangle with connecting legs, the leg connecting the two forward columns being generally perpendicular to the center line of the boat and the respective legs connecting the aft column to each of the two forward columns each making an angle with the center line of the boat substantially equal to the normal tacking angle for the boat close to the wind.

5. A mast construction according to any one of the preceding claims characterised in that the means connecting the columns includes spacer means at least some of which are adjustable to adjust the size of the triangular cross-section formed by the columns to adjust the windshadow on the aft column and minimize wind drag.

6. A mast construction according to any one of the preceding claims characterised in that the means connecting the columns includes turnbuckles connected between the columns to adjust the spacing therebetween.

7. A mast construction according to any one of the preceding claims characterised in that the means for connecting the columns includes a spacer plate having notches to partially receive the columns.

8. A mast construction according to claim 7 characterised in that the spacer plate has extrusions to form a spreader for the mast.

9. A mast construction according to any one of claims 1 to 4 characterised in that the means connecting the columns comprises two opposed shell portions forming an elongated vertically oriented oval end and a fin-shaped forward edge with the oval end connected to the aft column and the forward edge connected to the forward columns.

10. A mast construction according to claim 9 characterised in that the oval end and the forward edge are provided with sleeve portions connected to the columns.

11. A mast construction according to any one of claims 1 to 4 characterised in that the means connecting the columns comprises a horizontally oriented tear drop air foil shaped spacer with the thick end connected to the forward columns and the thin end connected to the aft column.

12. A mast construction according to any one of the preceding claims characterised in that the means for supporting the sail includes a track provided on the aft column.

13. A mast construction according to claim 12 characterised in that the track is formed integrally with the aft column.

14. A mast construction according to any one of claims 1 to 11 characterised in that the means for supporting the sail includes a shell wrapped around the aft column, a tubular track member connected to the ends of the shell and a bearing member inside the shell engaged with the aft column.

15. A mast construction according to claim 14 characterised in that the bearing member comprises a longitudinal section of a non-metallic tube connected to the shell and having longitudinal edges bearing against the aft column.

16. A mast construction according to any one of the preceding claims characterised in that the forward columns are oval tubes and the aft column is an oval extrusion.

17. A mast construction according to any one of claims 1 to 15 characterised in that the forward columns are hollow with jumper wires extending through the forward columns and connected adjacent to the top of the mast, the jumper wires being connected at their lower ends to means operable to apply tension to the wires to bend the mast assembly.

18. A mast construction according to any one of the preceding claims characterised in that an additional mast column is located forwardly of the two forward columns and arranged with respect to the other columns to form a diamond shaped pattern with connecting means provided to retain the columns in such pattern.

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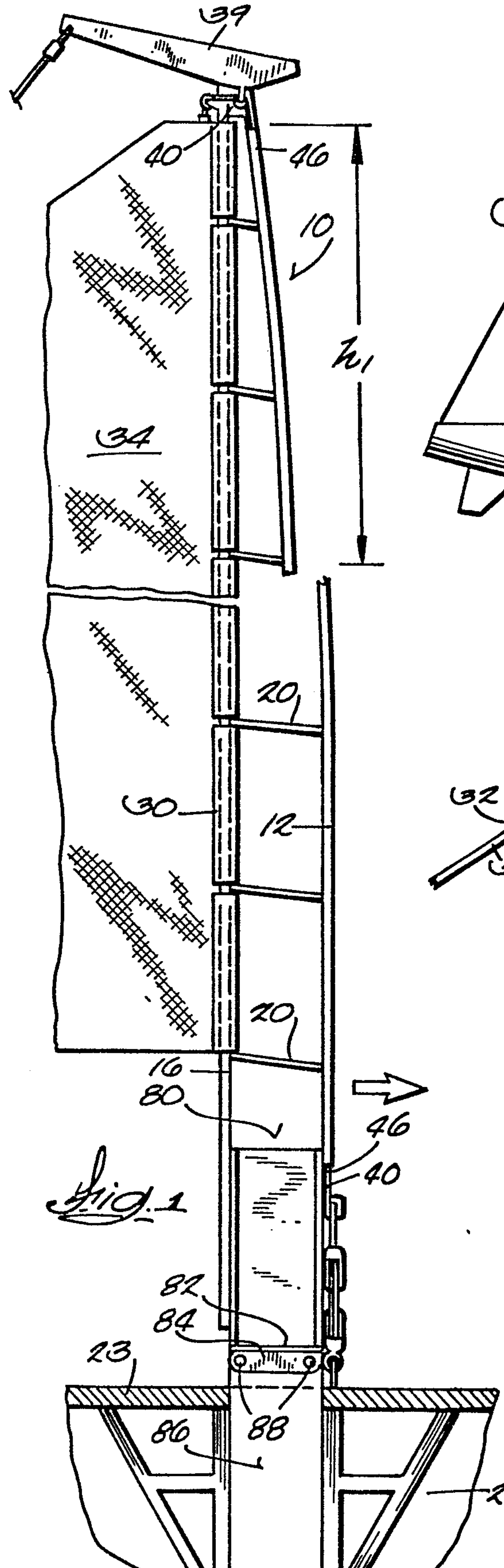

Fig. 1

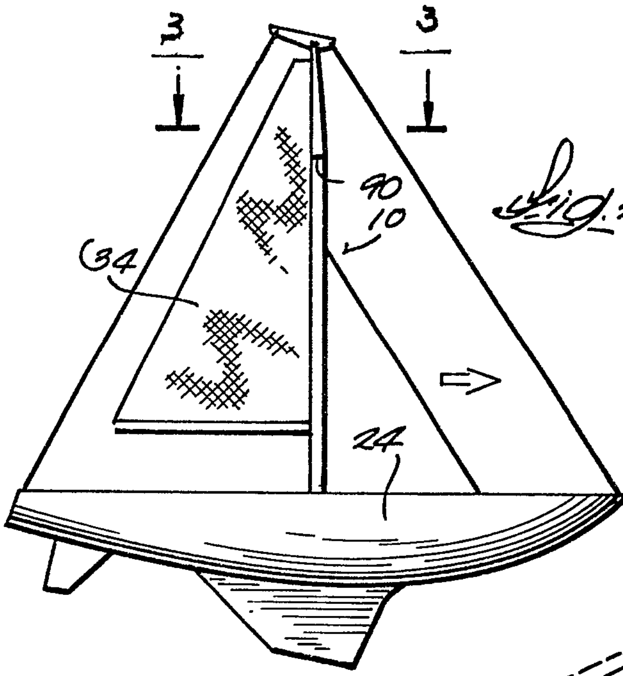

Fig. 2

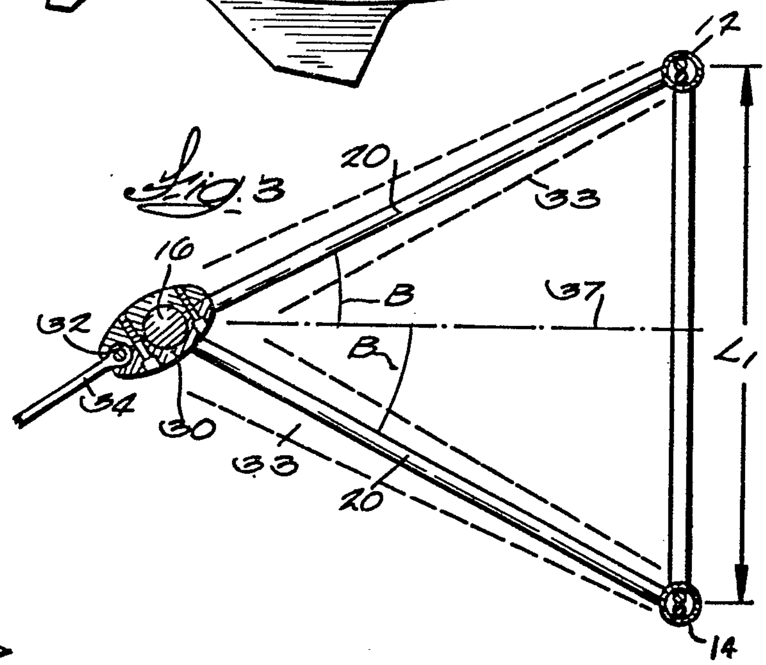

Fig. 3

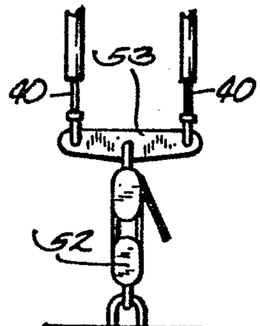

Fig. 5

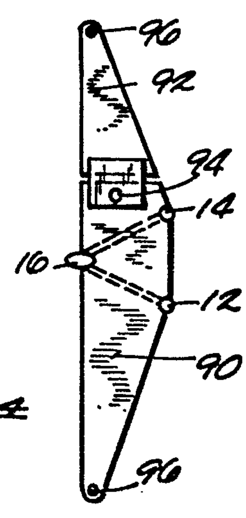

Fig. 4

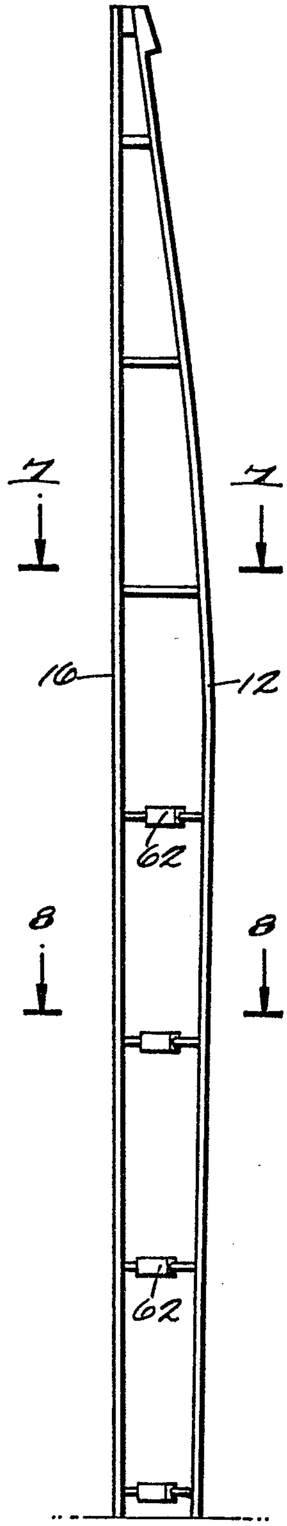

Fig. 6

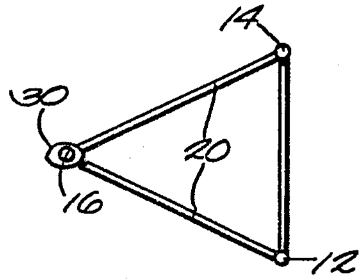

Fig. 7

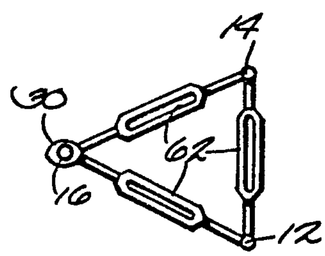

Fig. 8

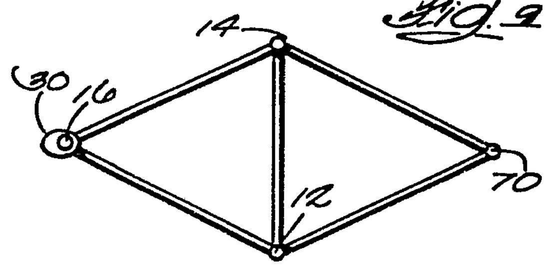

Fig. 9

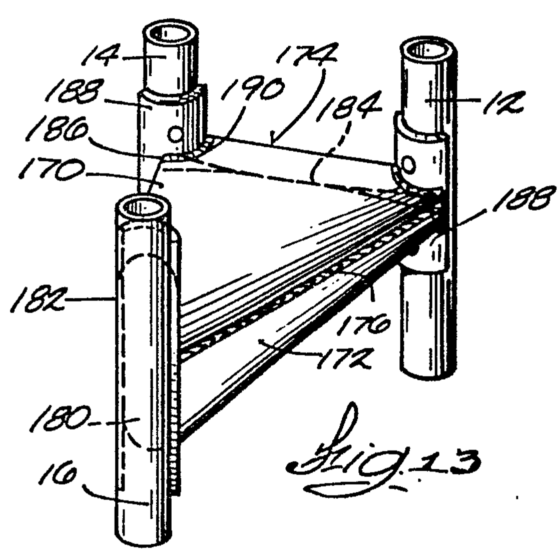

Fig. 13

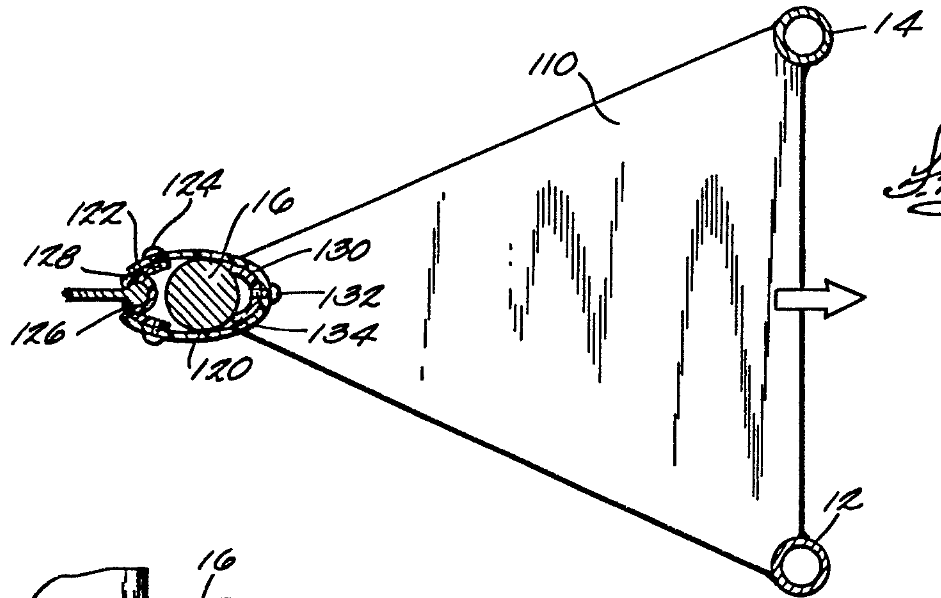

Fig. 10

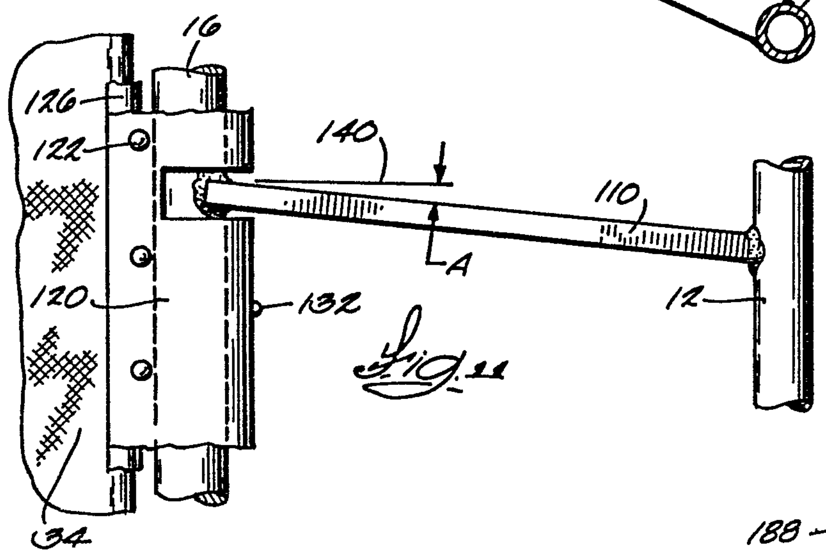

Fig. 11

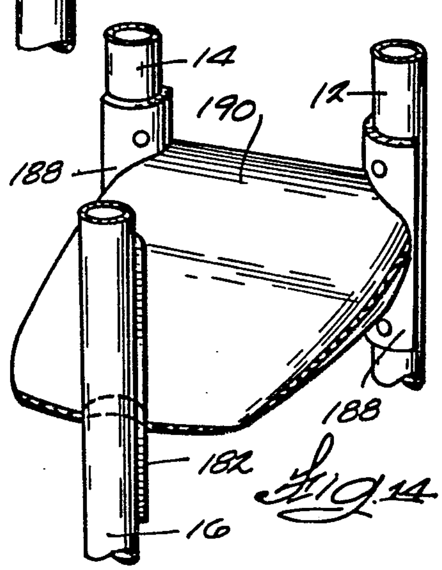

Fig. 14

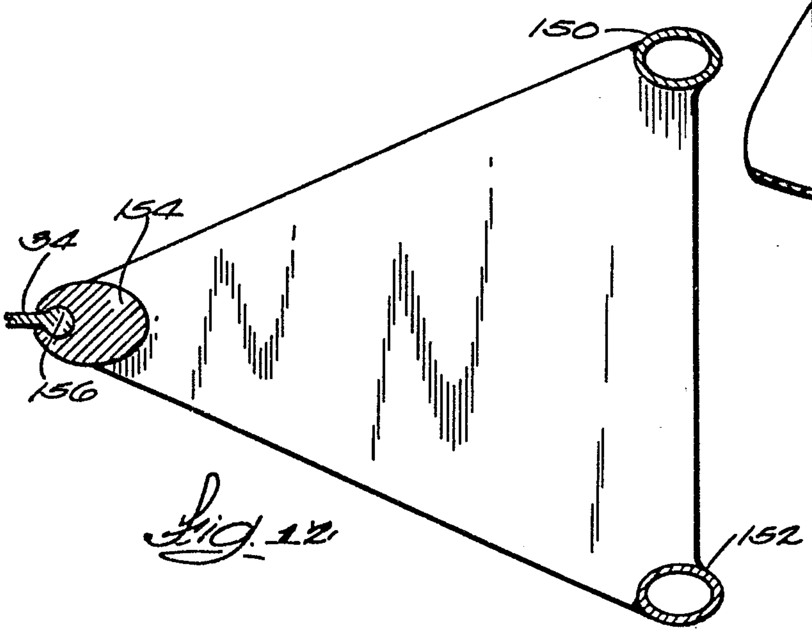

Fig. 12

European Patent Office

EUROPEAN SEARCH REPORT

0069576
Application number
EP 82 30 3522.5

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
A	RUDDER, No. 5, Mai 1973 New York "More Jury Rig", page 103, column 1 * full text and figures * --	1-3, 17	B 63 B 15/00 E 04 H 12/08
A	US - A - 3 085 539 (W. PROLSS) * fig. 1 * --	1-3	
A	GB - A - 2 037 686 (NOBUHIRO OHNO) * page 1, lines 82 to 94; fig. 9, 10 * --	1,7, 12	TECHNICAL FIELDS SEARCHED (Int.Cl. 3)
A	US - A - 3 724 412 (BLECKER) * column 5, line 40 to column 6, line 48; fig. 8, 9 * --	1,7, 12	B 63 B 15/00 E 04 H 12/00
A	DE - U - 1 900 501 (R. LILIENTHAL) * page 1, paragraph 3 to page 2, paragraph 5; fig. A * --	14	
A	DE - A - 1 559 199 (KGL. LUFTFARTSSTYRELSEN) * page 5, paragraph 3 * & US - A - 3 447 276 ----	18	

CATEGORY OF CITED DOCUMENTS

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D: document cited in the application
L: document cited for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	01-09-1982	PAETZEL

EPO Form 1503.1 06.78