United States Patent [19]

Oberle

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[45] **Feb. 4, 1975**

[54] **HANG GLIDER**

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[52] **U.S. Cl.** **244/16**

[51] **Int. Cl.** **B64c 31/02**

[58] **Field of Search** ..... 244/4, 13, 16, 123, 124, 244/126, 133, 138, 145; 46/74 R, 76 R, 46/77-81; 272/1 C; 273/105.3

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[57] **ABSTRACT**

A hang glider which relies upon ground effect forces in order to dynamically support a person suspended therefrom.

11 Claims, 10 Drawing Figures

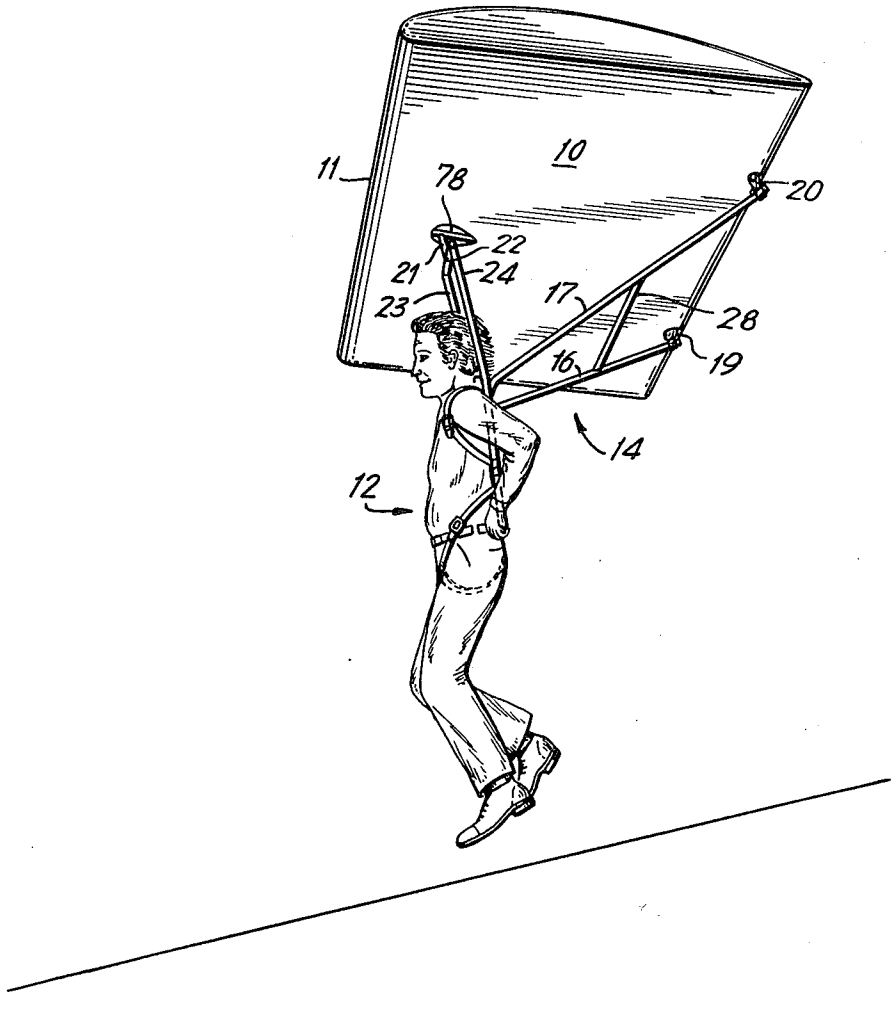


FIG. 1
PRIOR ART

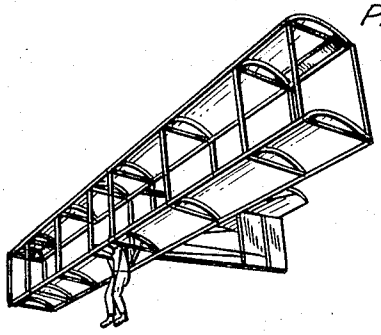
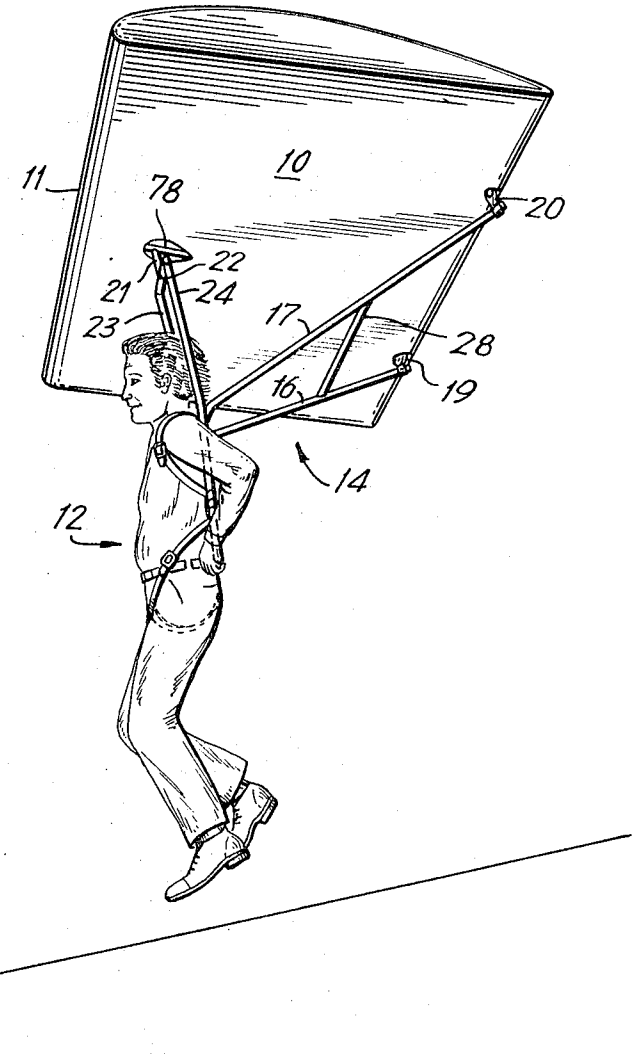


FIG. 2



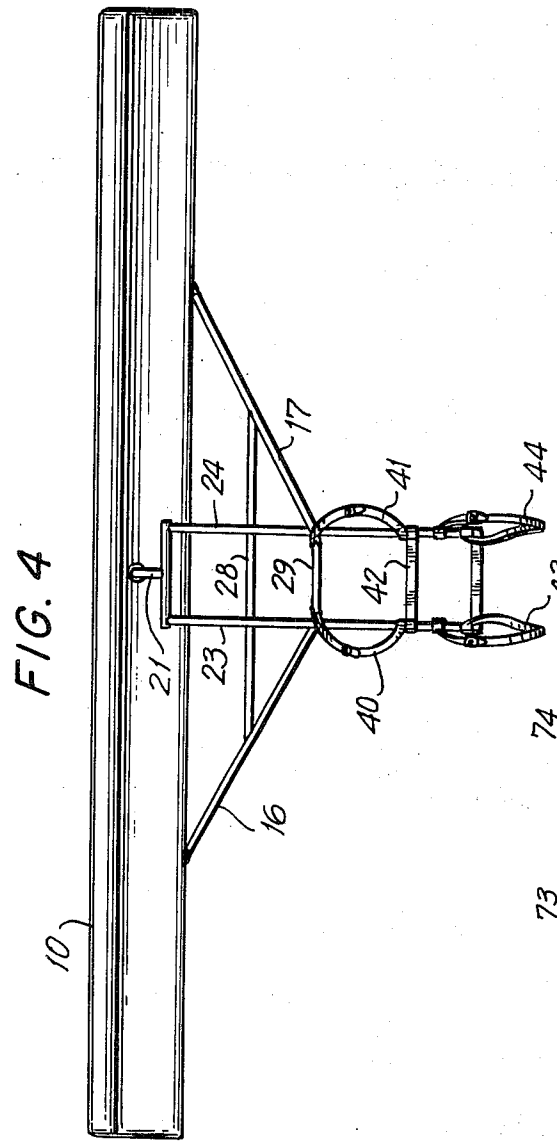


FIG. 4

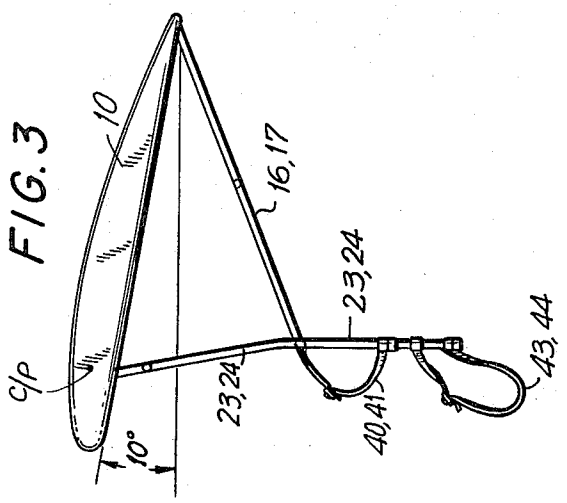


FIG. 3

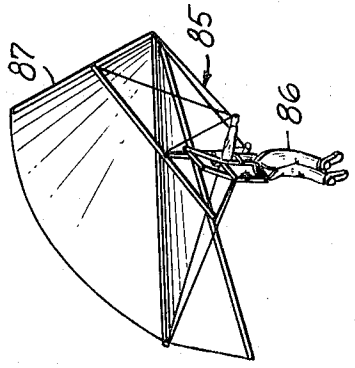


FIG. 6

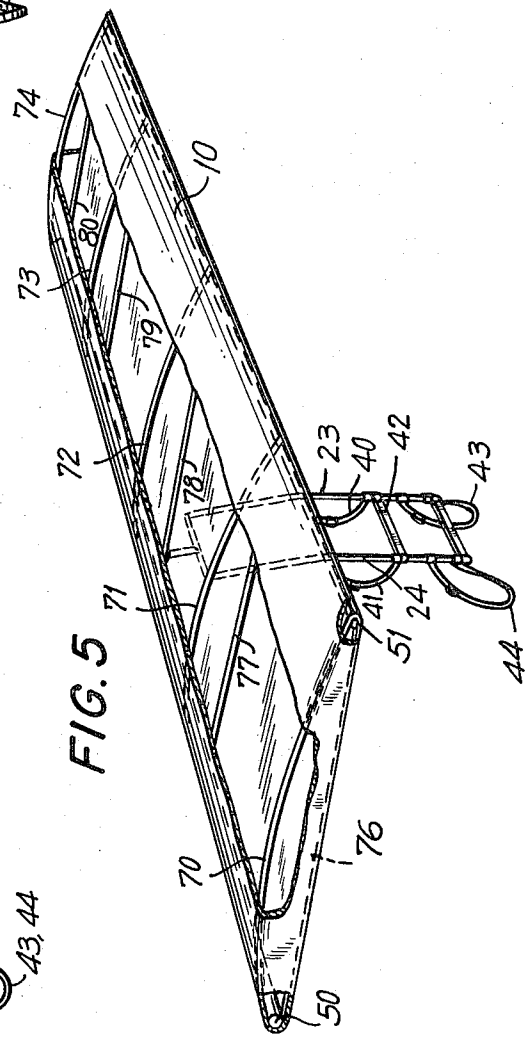


FIG. 5

FIG. 7

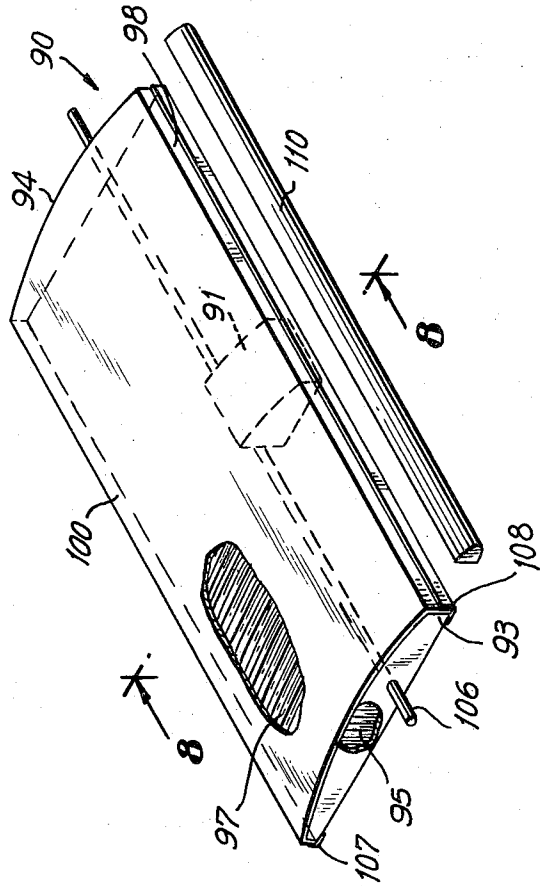

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FIG. 8

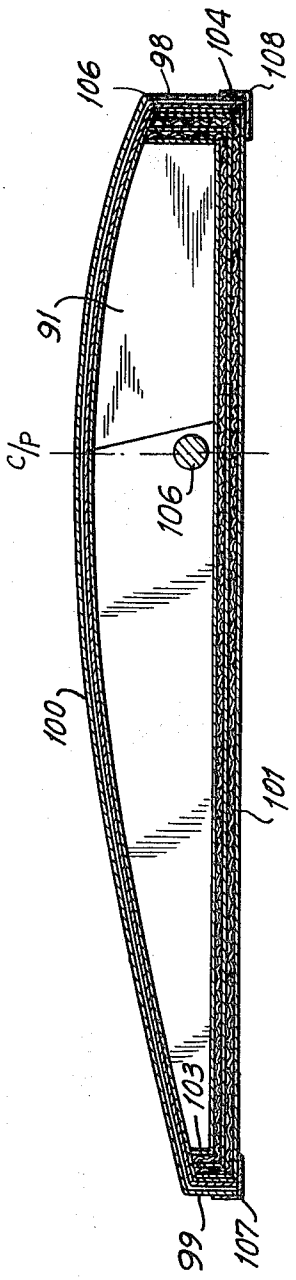

106
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C/P
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FIG. 10

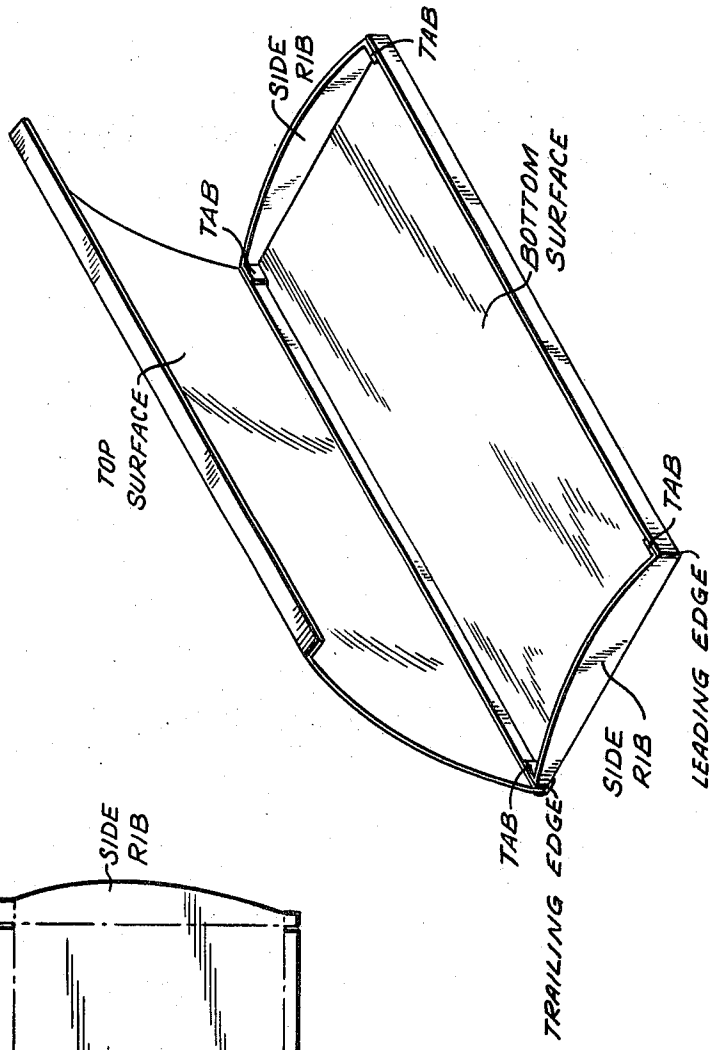
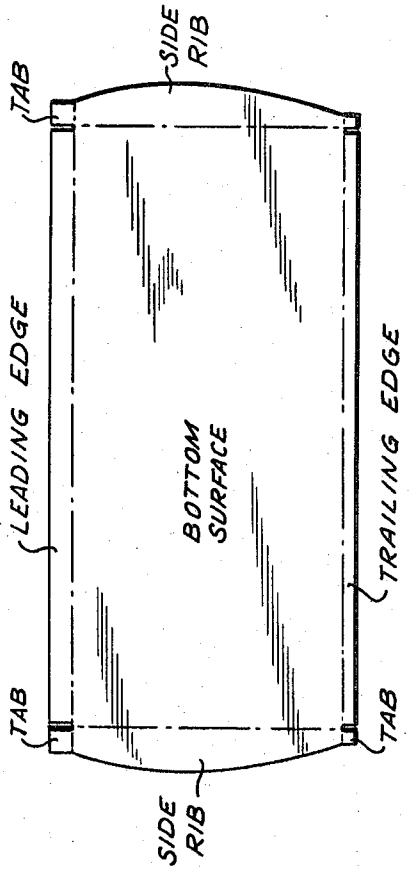

SIDE RIB
TAB
TAB
BOTTOM SURFACE
TOP SURFACE
TAB
SIDE RIB
LEADING EDGE
TAB
TRAILING EDGE

FIG. 9


TAB
SIDE RIB
LEADING EDGE
BOTTOM SURFACE
TRAILING EDGE
TAB
TAB
SIDE RIB

HANG GLIDER

BACKGROUND OF THE INVENTION

The word glider generally calls to mind an airplane-like structure but without self-contained means for providing a thrust, e.g. an engine. Such a glider generally includes the major components associated with an airplane, e.g., a fuselage carrying the pilot with a cockpit, wings, a tail assembly connected to the fuselage and a landing gear.

Although gliders of the type heretofore described (hereinafter called airplane gliders) are relatively well-known, there exists another type of glider which is not as well-known, viz., the so-called hang glider. A hang glider is essentially a wing with the pilot suspended therefrom. Generally, hang gliders do not include a fuselage or any form of landing gear. In their most elaborate form, they comprise one or more wings with a tail surface connected thereto. In order to maintain a clear distinction between airplane gliders and hang gliders, it is to be understood that, as used herein, the phase hang glider shall mean a flying device which includes a wing but does not include either a fuselage or means for providing a thrust and is adapted to be launched by a pilot suspended therefrom. Additionally, in order to clearly differentiate between hang gliders and devices which employ a reaction force to support a person, e.g., kites, the word wing will be understood to mean a surface which provides a predominantly upper surface aerodynamic lift.

In addition to the structural differences between an airplane glider and a hang glider, there are a number of differences between the manner in which each of these devices is generally used. For example, airplane gliders are launched by towing, e.g. an airplane glider may be towed to an altitude of several thousand feet by an airplane and then released. In contradistinction, hang gliders are launched by the pilot rather than by a tow rope connected to another vehicle. More particularly, hang gliders are typically launched by the pilot running down a hill while supporting or carrying the device. When the pilot runs at a speed sufficient for the wing to produce a lift equal to the weight of the hang glider and the pilot, the pilot may then rest upon the hang glider or a support attached thereto and lift his legs from the ground. Typically, hang gliders will take off (allow the pilot to lift his feet from the ground) at air speeds in the range of 15 to 20 mph. Since a speed of 20 mph is approximately equal to running 100 yards in 10 seconds, it will be appreciated that a hang glider pilot will generally prefer to run downhill into a slight wind, e.g., 5 to 10 mph, in order to achieve an air speed of 15 to 20 mph. The desire of hang pilots to launch themselves into a head wind in order to avoid running fast is a factor which is important to remember in order to appreciate the significant features of my invention.

Referring to the drawings, FIG. 1 shows a hang glider illustrative of the type known to the prior art. As may be noted, the hang glider of FIG. 1 has a bi-wing configuration with aileron control surfaces associated with the upper wing. Additionally, a tail assembly is connected to the wing structure by horizontally extending members.

While hang gliders of the type shown in FIG. 1 unquestionably work, it might be said that they work too well. That is to say, a hang glider of the type shown in

FIG. 1 and, so far as I know, all prior art hang gliders, have been so designed, constructed and arranged as to allow the attainment of substantial altitude. More specifically, all prior art hang gliders have been designed and constructed so as to provide a significant lifting area. Thus, prior art hang gliders employ wings having a substantial span. Additionally, as is evident from considering the construction shown in FIG. 1, the prior art has so assiduously endeavored to maximize the lifting area as to resort to a bi-wing construction. As a specific example, a commercially available hang glider of the type shown in FIG. 1 has a wing span of 28 feet and a total wing area of 225 square feet.

As a consequence of the design approach and construction used by the prior art with respect to hang gliders, all such prior art hang gliders have possessed a significant number of disadvantages. For example, because of their sheer size, some of the prior art hang gliders, particularly the more efficient ones, are quite heavy. For example, a commercial hang glider of the type shown in FIG. 1 weighs approximately 100 pounds. Since hang gliders are self-launched, i.e. launched by running down an incline until the lift-off velocity is achieved, such a substantial weight causes great difficulty in running, tires the pilot and generally precludes the use thereof by children and most women. Additionally, because of the substantial wing span, and to relieve the burden of carrying the full load of the hang glider, a hang glider pilot generally requires two or three persons to stabilize the wing tips and the tail and generally assist in carrying the device, while he is running down hill. Another significant disadvantage associated with prior art hang gliders relates to the control thereof during flight. Because of the exceedingly large wing span and the substantial weight associated with prior art hang gliders, significant forces must be exerted during flight to achieve control, i.e. to cause the wing thereof to pitch or roll. Many prior art hang gliders are not provided with control surfaces. When using such hang gliders, the pilot maintains control by shifting his weight and thereby endeavoring to exert control forces upon the wing from which he is suspended. However, because of the large wing span and substantial weight associated with prior art hang gliders, it may be difficult to produce even small control actions especially roll or yaw. In recognition of this problem, the prior art resorted to the use of control surfaces, e.g. the ailerons, rudder, etc. shown in FIG. 1. While this increase in sophistication did provide the pilot with greater control, the cost of the resulting hang glider was increased considerably as was the complexity of operation.

Although the disadvantages enumerated above are significant, the major and most significant disadvantage associated with prior art hang gliders resides in the fact that such devices can achieve a substantial altitude. In other words, as previously stated, all prior art hang gliders of which I am aware employ lifting surfaces of a substantial area, and thus, all such prior art hang gliders operated with low wing loading. As a result, if one launched himself in a prior art hang glider by running down a relatively shallow hill and into a moderate wind, the relative air speed would be sufficient for the glider to attain substantial altitutes. As a result, the use of hang gliders has heretofore been attended by a substantial danger. Indeed, a leading magazine recently char-

acterized the use of hang gliders as "dangerous, even lethal." *Soaring*, January, 1972.

As distinguished from the prior art, a hang glider embodying my invention is almost intrinsically safe and does not suffer from the disadvantages associated with prior art hang gliders and heretofore enumerated. More specifically, a hang glider constructed in accordance with my invention is small, light and easy to control. Additionally, and most importantly, a hang glider constructed in accordance with my invention will allow flights of a significant duration but will essentially preclude the achievement of any substantial altitude, e.g. any altitude greater than approximately 12 feet. Thus, it will be appreciated that a hang glider embodying my invention will be attractive for use by anyone wishing to enjoy the feeling of flight while not incurring a substantial risk of bodily harm.

The capabilities of my invention, as summarized above, viz. permitting flights of a considerable duration while nevertheless substantially precluding the attainment of a significant altitude, point out the distinguishing feature of my invention vis-a-vis the prior art. Thus, unlike existing prior art hang gliders, a hang glider embodying my invention will not, short of jumping or flying off a cliff, permit one to attain an altitude which is significantly greater than three times the chord of the wing. Additionally, unlike hang gliders suggested by some of the prior art literature, my invention allows flights of a considerable duration. The prior art literature which considered a hang glider having some parameters similar to my invention concluded that only flights of short duration were possible. *Low and Slow*, copyright 1971, page 37. Additionally, the literature concluded that take off speeds of greater than **30**mph were required. In comparison, my invention requires a take off speed of only, approximately, 18 to 20 mph and allows flights of long duration.

SUMMARY OF INVENTION

A hang glider constructed in accordance with my invention is specifically designed to insure that the aerodynamic lift generated by the associated wing is generally innsufficient to support a person suspended therefrom. However, when the wing is operated close to the ground, e.g. at an altitude less than **12** feet, the wing is subjected to ground effect type forces which, in combination with the aerodynamic lift of the wing, are sufficient to dynamically support a person suspended from the wing. A hang glider embodying my invention would employ a wing which had an aspect ratio in the range of from 1.0 to 4.0 and 1.0 to 3.0 was so dimensioned so as to insure that a high wing loading would be attained when a person was dynamically suspended therefrom. More specifically, a wing useful in the practice of my invention would preferably have a wing loading in the range of 2.5 to 5.5 pounds per square foot and an aspect ratio in the range of from 1.0 to 3.5. Considering the fact that such a wing would support a person, my invention would employ a wing having an area in the range of approximately 12 to 100 square feet.

Preferably, means are provided for suspending a person from the wing in substantially vertical alignment with the center of pressure of the wing. Preferably, the suspension means employed will be such that the entire person of the pilot is suspended below the wing and the pilot's torso is maintained in a fixed position with respect to the wing surface. In any event, the suspension means is so constructed as to insure that the distance between the ground and the undersurface of the wing is not greater than approximately twice the average chord when the device is mounted on a person and the person is standing on the ground.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a prior art apparatus.

FIG. **2** is a perspective view of one embodiment of my invention.

FIG. **3** is a side view of the embodiment shown in FIG. **2.**

FIG. **4** is a front view of the embodiment of my invention shown in FIG. **1.**

FIG. **5** is a perspective view of the embodiment of FIG. **2** with portions thereof broken away to show the interior thereof.

FIG. **6** is a perspective view of another embodiment of my invention.

FIG. **7** is a perspective view of a preferred embodiment of a hang glider wing with portions broken away.

FIG. **8** is a section taken along the section line **8—8** of FIG. **7.**

FIG. **9** is a plan view of a blank from which a portion of the wing shown in FIG. **7** may be formed.

FIG. **10** is a perspective, assembly drawing.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **2,** there is shown in perspective, one embodiment of a hang glider constructed in accordance with my invention. More particularly, the embodiment shown in FIG. **2** employs a generally rectangular fixed wing **10** which has a continuous leading edge **11.** As shown in FIG. **2,** the pilot **12** is suspended below the wing **10** by a structure or suspension means generally indicated as **14.** The suspension means **14,** which is preferably fabricated of tubular aluminum, may be attached to the trailing edge spar as at **19** and **20.** Near the leading edge, a support member **21** is attached to the underpart of the center rib **78.** At the other end, the member **21** is attached to a transverse support member **22** which has two downwardly depending members **23, 24** attached thereto. The members **23** and **24** extend downwardly with the members **16** and **17** attached thereto at, approximately, a point above the mid-point of the members **23, 24.** In order to insure a degree of rigidity, cross members **28** and **29** (see FIG. **4**) may be employed to join members **16, 17** and **23, 24** respectively.

As may be noted by references to FIG. **3,** the plane formed by the lower part of the parallel members **23, 24** is located rearwardly of the center of pressure of the wing **10.** More generally, the suspension means **14,** which may assume a variety of configurations, is preferably so constructed and attached to the wing **10** as to insure that a pilot mounted on or suspended from the suspension means **14** is maintained in susbstantially vertical alignment with the center of pressure of the wing **10.**

With further regard to the suspension means **14,** I prefer, in general, to employ a suspension means which insures that two constrains are satisfied, viz. that the pilot is suspended below the wing and the suspension means is so constructed and arranged as to insure that the torso of the pilot is maintained in a fixed position with respect to the wing **10.** It is desirable to satisfy

these constraints for a number of reasons. For example, if the pilot's torso is fixedly attached to the frame and the wing is above the head of the pilot when he is on the ground, the pilot then has his hands free to maintain his balance when he is running or, alternatively, to grasp the members **23, 24.** Additionally, by maintaining the torso of the pilot in fixed relation to the frame **14,** a degree of stability is obtained since the major portion of the pilot's weight is then maintained in vertical alignment with the center of pressure of the wing **10.** In order to achieve such a fixed relation between the frame **14** and the pilot, I prefer to use a harness which engages the pilot about his shoulders, waist and thighs. Thus, referring to FIG. **4,** it will be seen that a number of harness straps are shown. More particularly, in this embodiment, I provide shoulder straps **40, 41,** a waist strap **42** and straps **43, 44** through which the pilot would place his legs.

Returning to a consideration of FIG. **3,** it may be noted that when the plane defined by the lower portion of the members **23, 24** is in a vertical position, the wing **10** is disposed at a positive angle of attack. Through experimentation, I have found that a preferable angle of attack is in the range of 8 to 12 degrees depending upon the particular wing which is employed. A generally optimum angle of attack is approximately 10 degrees. In general, it is desirable to provide a positive angle of attack in order to insure that, as the pilot runs down a hill, the wing **10** generates a lifting force on the upper surface thereof.

With specific regard to the structure of the wing **10,** a light, inexpensive and aerodynamically acceptable wing may be fabricated using aluminum tubing and polyethylene sheet material. Thus, referring to FIG. **5,** there is shown an exemplary wing having a leading edge spar **50** and a trailing edge spar **51.** The leading edge spar and the trailing edge spar may be fabricated from, respectively, two inch diameter and one and a half inch diameter aluminum tubing having a wall thickness of 0.035 inches. The upper surface of the wing is defined by members **70–74** inclusive and may advantageously be constructed from half inch diameter aluminum tubing having a wall thickness of 0.035 inches. The lower surface of the wing is defined by members **76–80** inclusive which are associated with the members **76–80** respectively to form ribs. The members **76–80** may be constructed from one inch diameter aluminum tubing having a wall thickness of 0.035 inches.

I have found that a material satisfactory for covering the structure shown in FIG. **5** is four mil polyethylene film. One longitudinal edge of a polyethylene sheet may be adhesively secured to the trailing edge spar **51** and the sheet thereafter wrapped about the wing. Thereafter, the second longitudinal edge of the polyethylene sheet may be heat sealed to the first longitudinal edge at the trailing edge of the wing. A sufficient amount of material is supplied to provide an overlap at both ends of the wing whereat the transverse edges of the polyethylene may be sealed to each other.

Having described the gross or overall construction of one embodiment of my invention, the aerodynamically significant factors which distinguish my invention from hang gliders of the prior art will now be described.

As previously indicated, a typical wing used in a prior art hang glider would have a wing span which was substantially greater than 15 feet and a surface area substantially greater than 100 square feet, e.g. 220 square feet. In contradistinction, my hang glider employs a wing which has a relatively small wing span and a vertically small surface area. Additionally, the particular wing employed is approximately sized for a particular range of pilot weight. Thus, by using a wing with a small surface area and approximately sizing the wing for a particular range of pilot weight, a high wing loading may be obtained as opposed to the prior art wherein all prior art hang gliders employed wings which were specifically designed for a low wing loading, e.g. one pound per square foot or less. For example, the preferable range of wing loading associated with a hang glider constructed according to my invention is in the range of 2.5 to 5.5 pounds per square foot. A particularly desirable wing loading is approximately 3.5 pounds per square foot.

In conjunction with a heavily loaded wing, I employ an airfoil or wing cross section which provides a high lift characteristic wherein it will be understood that the term lift characteristic, as used herein, means lift force per unit area. An example of such an airfoil or wing cross section is the Gottengen 436 airfoil.

As a result of using, in a hang glider, a wing having an airfoil and wing loading as heretofore described, such a wing may have an aerodynamic lift, under commonly encountered conditions of hang glider use, which is slightly insufficient to support the weight of a pilot for which the wing was designed. Although, at first, such a design criterion may be seem to be useless and of no purpose, a useful structure does, in fact, result because of the presence of forces which have found to act on hang gliders when operated relatively close to the ground. While the nature and origin of all of these forces are not understood it is believed that at least a significant component of these forces is the so-called ground effect force. Although the nature of ground effect forces is not clearly understood, such forces are known to be encounterable and the manifestations thereof are well known. Thus, some of the manifestations of ground effect forces will be described although the theory which explains the existence of such forces is in doubt.

Ground effect forces are manifested as an apparent increase in lift which is encountered when an airfoil is moving through the air in relatively proximity to the ground. Generally, ground effect forces are viewed as being significant when an airfoil is moving above the ground at a distance of up to, approximately, 1.5 to 2.0 times the chord of the airfoil. Within this range, ground effect forces will increase as the airfoil gets closer to the ground. However, when the airfoil is above the ground by a distance somewhat greater than 2.0 times the chord, the ground effect forces diminish exponentially. A manifestation of ground effect forces which may be easily observed occurs when an airplane is landing. Thus, one watching a plane land may observe that the plane's altitude will continuously decrease until the wheels are close to the ground. However, at this time, one may also observe a decided tendancy for the airplane to seemingly "float" or continue along the runway maintaing a constant altitude slightly above the ground surface. The floating action thus observed is a manifestation of ground effect forces.

A significant attribute of ground effect forces is that an apparent increase in lift is produced without a corresponding increase in induced drag. That is to say, if a wing is moving through the air, the shape of the wing

and the relative velocity between the wing and the air creates an area of low pressure on top of the wing. Thus, lift is produced and, in general, the lift thus produced will increase as the relative velocity between the wing and air increases. However, comcomitant with the production of lift, there is also produced a drag force which increases as the lift increases. Such a drag force is called induced drag. Thus, an increase in aerodynamic lift is accompanied by an increase in induced drag. However, theoretically the apparent increase in lift caused by ground effect forces is not attended by an increase in induced drag.

As indicated above, when a hang glider embodying my invention is operated close to the ground, e.g. at an altitude of less than three chord lengths, forces act upwardly on the undersurface of the wing and the most significant component of these forces is the ground effect force. However, the present theories for predicting ground effect forces do not account for the total force which I have encountered. Thus, to at least some extent, the forces exerted under the conditions described cannot be accounted for by present theory. For the purposes of this application, all of such upward forces will hereinafter be referred to as net ground effect forces.

Having thus set forth a brief summary of the manifestations of ground effect forces, the thrust of my invention may now be fully appreciated. Thus, my invention resides in providing a hang glider which includes a wing wherein the aerodynamic lift produced by the wing under commonly encountered hang glider circumstances is insufficient to dynamically support the pilot. However, when the wing is operated within a region wherein net ground effect forces are present, e.g. when a wing is operated at distance from the ground which is less than approximately three times the chord of the wing, the net upward force provided by the combination of the aerodynamic lift of the wing and the ground effect forces is sufficient to dynamically support the pilot. However, if the pilot should intentionally or unintentionally attain or endeavor to attain a substantially greater altitude, only a transient increase in altitude will occur, absent an exceptionally high airspeed, because, as soon as a hang glider constructed in accordance with my invention leaves the ground effect region, (i.e. the region wherein net ground effect forces are operative) the resulting aerodynamic lift is insufficient to dynamically support the pilot and the pilot and the hang glider will return to a region wherein net ground effect forces are operative. As such, it will be appreciated that in accordance with my invention there is provided a hang glider which is essentially intrinsically safe because, under commonly encountered hang glider conditions, a hang glider which embodies my invention will essentially track or follow the hill under the pilot and will not attain an altitude significantly greater than approximately two to three times the chord of the wing. In this context, it should be noted that commonly encountered hang glider conditions do not contemplate the situation wherein one using my invention would jump off a cliff. Rather, a hang gliders are, as hereinbefore indicated, generally used by running down a hill. Thus, the slope of the hill essentially defines a maximum glide angle, i.e. if a hang glider pilot established a glide angle which was greater than the slope of the hill, a crash would result. Thus, the pilot will insure that his glide angle is not greater than the slope of the hill. The maintainence of such a maximum glide angle would, of course, be obvious to the pilot since the specter of a crash would be apparent if the glide angle exceeded the slope of the hill. However, what may not be apparent to the pilot and what is of even greater significance to this safety is the minimum glide angle. That is to say, with all prior art hang gliders of which I am aware, flight could be maintained at a rather shallow minimum angle and, thus, one could quickly achieve a significant altitude above a rather shallow hill. However, a hang glider constructed in accordance with my invention would prevent such an occurrence because, when the hang glider reached an altitude which was significantly greater than approximately twice the chord of the wing, ground effect forces would be substantialy reduced and the hang glider and pilot would return to the ground effect region in the absence of exceptionally high airspeeds. Of course, should one jump off a cliff (which does not constitute a condition of normal hang glider usage) with a hang glider constructed in accordance with my invention, a degree of flight could be maintained by following a larger glide angle than if the glider was being operated close to the ground.

As hereinbefore indicated, a hang glider constructed according to my invention is characterized by the fact that under normal hang glider usage conditions, such a hang glider will be able to dynamically support a person only in the presence of ground effect forces. I achieve this characteristic of my invention by approximately sizing the wing for the weight of the pilot and employing a wing having an aspect ratio within a particular range. Of course, it will be appreciated that there are almost an infinite number of combinations of airfoils, wing shapes and wing areas which will provide the desired result of an aerodynamic lift which is slightly less than the weight of the pilot and the hang glider. In general, however, I prefer to use a fixed wing which has a continuous leading edge, i.e. there is no break or discontinuity in either the covering of the leading edge of the wing or the leading edge spar. A discontinuity in the leading edge is preferably avoided since any such discontinuity will materially reduce the total lift of the wing.

A specific example of a wing-hang glider combination embodying my invention is the wing shown in FIG. 3 and the hang glider of FIG. 4. Using a wing of the type shown in FIG. 3, i.e. a rectangular, fixed wing having a continuous leading edge and a Gottengen 436 airfoil, I have found that the following wing sizes provide the desired aerodymanic characteristics.

Ex.No.	Pilot wt.-lbs.	Wing span-ft.	Chord-feet	Wing area	Wing loading lbs/square ft.
1	50–100	8	2.5	20	2.5 – 5.0
2	100–150	10	3.3	33	3.03– 4.55
3	150–200	12	4.16	50	2.98– 3.96

Of course, it will be appreciated that the above dimensions and parameters are presented by way of example. Thus, a person who weighed slightly more than 100 lbs. could use a hang glider which had a wing of the type described in Example 1. As such, there is obviously a degree of overlap between the above, illustrative examples. However, although a degree of overlap is possible and thus the wing loading may vary some-

what, the characteristics of a hang glider which embodies my invention would generally not allow a substantial deviation from the range of pilot weight for which the device was designed. For example, if a pilot weighing 160 pounds were to attempt to use a hang glider having a wing of the type described in Example No. 1, under normal conditions of hang glider usage the aerodynamic lift would be so insufficient that even in combination with ground effect forces, the hang glider could not support the pilot in sustained flight. Alternatively, if a 90 pound pilot were to attempt to use a hang glider having wing of the type described in Example 3, the weight of the glider and the strength of the pilot, as well as the weight of the pilot, would generally be insufficient to maintain control to a degree that would permit a take-off. Thus, it will be seen that although a relatively small overlap is possible, the nature of my invention is such that a substantial deviation is generally not possible. Thus, once again, it will be seen that a hang glider embodying my invention, is, to a significant degree, intrinsically safe.

Some of the characteristics indicated in the above table are significant. For example, a hang glider constructed in accordance with the instant invention will have a wing loading in the range of approximately 2.0 to 6.25 lb./ft.^{2} and, preferably in the range of 2.5 to 5.5. With respect to the area of a wing used in a hang glider embodying my invention, the wing area will be in the range of, approximately, 15 to 100 square feet, and, preferably, within the range of 20 to 75 square feet. Of course, the wing loading and wing area characteristics just recited relate to a wing of the type shown in FIG. 2, i.e. a fixed wing having a straight, continuous leading edge.

With further regard to the characteristics of a wing used in combination with my invention, it should be recalled that the chord of the wing is significant in that ground effect forces diminish significantly when a wing is operated at a distance above the ground which is greater than approximately three times the chord of the wing and the preferable operating range is within two chord lengths of the ground. In recognition of this fact, it will be apparent that a hang glider constructed in accordance with my invention will employ a wing having a chord of at least, approximately, two and one-half feet. In other words, one must insure that the chord of the wing is sufficient so that when the wing is at an altitude at which the ground effect is beginning to diminish, the altitude will be greater than the length of the pilot's body which extends below the bottom of the wing. By way of example, marginal or generally unsatisfactory performance would usually result if a pilot who is six feet tall attempted to use a hang glider of the type used in FIG. 2, but which had a chord of 2.5 feet. The marginal performance would result from the fact that ground effect forces with such a wing would commence to rapidly diminish when the wing was operated at an altitude significantly greater than 5.0 feet (twice the chord). Thus, if a pilot six feet tall had such a hang glider mounted one foot above his head, the wing would be in or above the marginal ground effect region and thus would endeavor to return to that region since the aerodynamic lift outside of the ground effect region would be less than the weight of the pilot, in accordance with my invention. As such, the pilot would continuously return to the ground after take off.

The condition of quickly and continuously returning to the ground, i.e. long distance jumping, was thought by the prior art to be the only use for hang gliders having a small wing, e.g. the article in the publication *Low & Slow* concluded that any flight with such a hang glider would be quite short. The prior art did not perceive the possibility of extended flights with such a hang glider because the presence and effect of net ground effect forces was not considered. As such, the prior art attached no unusual significance to the chord of the wing or the aspect ratio, i.e. the prior art considered the wing chord and the aspect ratio only in terms of the resulting Reynolds number and the efficiency of the wing. Thus, the prior art concluded that if one used a low aspect ratio, any resulting gain would, at best, only offset the resulting losses to some degree. Of course, consistent with this conclusion, the prior art never conceived the thought of relating the chord of the wing to the height of the pilot.

In contrast to the teachings of the prior art, my invention attaches critical significance to the wing chord and the aspect ratio and contrary to the prior art, the criticality which reflects my invention is opposed to the teaching of the prior art. Thus, the prior art teaches that a high aspect ratio is generally desirable so that tip losses are minimized and wing efficiency is improved. Indeed, even the *Miller* publication considers an aspect ratio of 4.0 as a minimum. In contrast, my invention employs a wing having an aspect ratio in the range of approximately 1.0 to 3.75 and preferably in the range of 1.0 to 3.5. An aspect ratio within these limits is critical for the following reasons. First, an aspect ratio within these ranges, together with the area requirements recited above, substantially insures that when the wing is mounted above the pilot and the pilot is on the ground, the wing will be within at least three chord lengths from the ground. Second, because of the low aspect ratio, which I employ, the wing will be unusually inefficient outside of the ground effect region and therefore the possibility of attaining a substantial altitude is even further diminished. Stated otherwise, such a wing will have an acceptable lift to drag ratio within the ground effect region but a poor lift to drag ratio outside the ground effect region as opposed to prior art wings which have high aspect ratios and which, in turn, have a high lift to drag ratio outside of the ground effect region. A wing of the type which I employ has an acceptable lift to drag ratio within the ground effect region because the net ground effect forces provide an increase in lift without a corresponding increase in induced drag. Third, aspect ratios within the aforesaid ranges result in improved controlability of the hang glider. Fourth, the stability of the hang glider, which includes such a wing, is improved because of the improved weight to span ratio. Fifth, as pointed out in some detail hereinafter, aspect ratios in the aforesaid ranges are structurally desirable because of the concomitant reduction in the bending moment.

With still further regard to the wing portion of a hang glider embodying my invention, in addition to employing a fixed wing having a straight, continuous leading edge and a high lift, low speed airfoil, I found it desirable to use a wing which has a flat under surface. In general, such a combination provides a high coefficient of lift.

In the embodiment of my invention shown in FIG. 2, it may be observed that the pilot 12 is suspended below

the wing **10** by means of the supports **14.** In genearal, such an arrangement has been found to be particularly desirable. The desirability of this arrangement arises for a number of reasons. For example, with a rigid mounting system **14** and the associated harness, the torso of the pilot remains fixed with respect to the center of pressure of the wing and, thus, the stability of the hang glider is promoted. Additionally, when the pilot is on the ground, his visability and maneuverability are improved if the wing is fixedly mounted above his head. However, it will be appreciated that, if desired, arrangement could be made for a portion of the pilot's body to extend through the wing. Obviously, with this arrangement, appropriate carrying and suspension means would be provided. However, if this approach were resorted to, the continuity of the leading edge of the wing would preferably not be disturbed.

Although it is desirable that the torso of the pilot is fixedly maintained with respect to the wing, It is possible that the pilot may suspend himself below the wing by placing his arms through the support members, e.g. placing his arms over the intersection the members **16,23** and **17,24.**

The embodiment of my invention shown in FIG. **2,** illustrates a number of operational advantages which my invention possesses as compared to prior art hang gliders. For example, the size of the associated wing is significantly smaller than all of the prior art hang gliders of which I am aware. Thus, the entire hang glider may be easily transported, e.g. in the back of a stationwagon. To facilitate such transit, suspension system **14** may be removably mounted on the wing or foldably mounted. For example, the connections **21, 17** and **20** may advantageously be pivotal connections and the points at which the member **17** and **20** connect with the downwardly depending members **23** and **24** may conveniently be pinned.

Another advantage which occurs as a result of the construction which I employ relates to the controlability of the hang glider. Thus, a hang glider constructed in accordance with my invention is relatively small as compared to prior art hang gliders and, therefore, control thereof is substantially improved. Experiments conducted with a hang glider of the type shown in FIG. **2** have established that adequate control may be maintained by the pilot appropriately displacing his legs and thus exerting a moment on the wing. Indeed, sufficient control may be obtained as to obviate the need for control surfaces. Thus, in the preferred embodiment of my invention, control surfaces are not employed.

Still another advantage of my invention is the fact that because of the construction which I employ in order to achieve the desired aerodynamic characteristics, the resulting structure is relatively light. Thus, a hang glider embodying my invention may easily be carried by the pilot without any assistance as compared to prior art hang gliders where two or even three people are often required to assist the pilot during take off and preparation therefore.

Referring to FIG. **7,** there is shown a wing construction which I prefer to employ and which may be generally useful with many hang gliders. In the construction of FIG. **7,** the entire wing **90** is constructed of corrugated paperboard except for an interior former **91** which may be an expanded foam. (Surprisingly, I have found that such a construction provides more than adequate strength while obviously being low in cost and light in weight). The ribs **93, 94** are preferably double wall corrugated paperboard having vertically disposed corrugations as shown at **95.** As best shown in FIG. **8,** the upper and lower surfaces of the wing (the major surfaces) are corrugated paperboard. More particularly, I have found that the upper surface of the wing is preferably single wall corrugated paperboard while the lower surface is double wall corrugated paperboard. Additionally, I have found that a superior construction results if two additional constraints are satisfied, namely that the corrugations of the paperboard on the upper surface **100** are disposed transversely (i.e. substantially parallel to the chord of the wing) and the corrugations of the corrugated paperboard on the lower surface **101** of the wing are longitudinally disposed (i.e. substantially perpendicular to the chord). I have found that it is desirable to satisfy these conditions for the following reasons. First, if the corrugations of the top surface of the wing are transversely disposed, as shown at **97** in FIG. **7,** a smoother surface is attained and maintained than if the corrugations were longitudinally oriented. With respect to the bottom surface, it is preferable to employ longitudinally oriented corrugations since superior bending strength will result. Similarly, I have found that it is preferable to employ double wall board for the bottom surface and end ribs of the wing so as to improve the bending strength of the wing as well as torsional strength.

It may be noted that the wing of FIGS. **7** and **8** has essentially flat leading and trailing edges, **98** and **99,** respectively. Tests conducted upon the occasion of this invention suggest that if corrugated paperboard is used to fabricate a wing, a substantial increase in strength and rigidity results if flat leading and trailing edges are utilized. Presumably, such increased strength and rigidity arises because of the box like nature of the wing, i.e. because the four sides of the wing are flat and vertical.

A wing of the type shown in FIGS. **7** and **8** may advantageously be constructed from three pieces, viz. a lower sheet, an upper sheet and a nose rib. For example, a sheet of double wall corrugated paperboard may be cut, scored and notched as shown in FIG. **9.** Thereafter, the blank of FIG. **9** may be folded and combined with an appropriately sized top sheet of single wall board, all as shown in FIG. **10.** As shown in FIGS. **7** and **8,** a nose rib **91** is fixed positioned within the wing adjacent the leading edge and at the midpoint of the span. The nose rib **91** should extend rearwardly at least to the center of pressure of the wing as shown in FIG. **8.** Of course, depending upon the size of the wing, additional ribs may be employed. Preferably, however, the nose rib and other ribs are corrugated paperboard so that the entire wing is corrugated paperboard having end ribs and leading and trailing edges which are integral with the bottom surface.

Any convenient means may be employed to secure together the edge portions of the wing, for example, gluing, stapling or taping. One especially convenient means I found is so-called double stick tape interposed between the edges. Similarly, to provide a smoother contour and to further unify the wing, I have found it desirable to tape the lower corners of the edges, for example as shown in FIG. **8** at **107** and **108.** Additionally, the contour of the wing may be improved, if desired, by affixing to the leading edge of the wing a fairing strip **110** as shown in FIG. **7.** The strip **110** may be made of any convenient material, e.g. expanded foam.

A corrugated paperboard wing of the type described above is particularly useful in combination with a hang glider which embodies my invention because of the low aspect ratio which my invention employs. Thus, by employing a low aspect ratio and a relatively small wing area, unduly large bending moments are avoided and the above described corrugated paperboard construction provides more than adequate strength. Additionally, it will be obvious that such a construction is both low in cost and light in weight. For example, a wing or wing section of the type shown in FIGS. **7** and **8** and having a span of five feet and a chord of four feet will weigh about five pounds, will have a material cost of only about a dollar, yet will support a pilot weighing over 200 pounds.

Another advantage which accrues from the construction of a wing of this type is the freedom to employ modular construction. Thus, a wing of the type shown in FIG. **7** may be provided with a tubular spar located at the center of pressure as shown in FIGS. **7** and **8.** In this manner, two such wings may be joined together or additions made to each end of a wing. The desirability of such modular constructions is particularly apparent when a wing of this construction is used as a component of a hang glider embodying my invention. For example, a wing having a span of six feet and a chord of 3.33 feet would correspond, in area and wing loading, to the wing of Example 1 above and would have an aspect ratio of 1.8. If a pilot weighing 150 pounds desired to use a hang glider having such a wing and if a wing construction was employed which permitted modular assembly, a wing section having a span of two feet and a chord of 3.3 could be added to each end of the wing, resulting in a wing of the type described in Example 2. To facilitate the addition of wing segments, the spar **106** may extend beyond the ribs **92, 94** (FIG. **7**) so as to be appropriately received within the added wing segments.

It may be noted that all of the examples of my invention, heretofore described have related to a hang glider of the general type shown in FIG. **2,** i.e. a hang glider which employs a fixed wing. Although the use of a fixed wing is preferred in the practice of my invention, it is also possible to employ a so-called flexible wing, for example Rogallo wing. Referring to FIG. **6,** a flexible wing of the Rogallo type is shown. In the embodiment of FIG. **6** the pilot **86** is suspended below the Rogallo wing **87** by an appropriate suspension apparatus, generally indicated as **55** and known to those skilled in the art to which this invention pertains. In general the wing **87** as shown in FIG. **6** would be designed to provide the basic aerodynamic characteristics previously described and characteristic of my invention, viz. an aerodynamic lift which sufficient to dynamically support a person generally only in the presence of ground effect forces.

Although there have been recited hereinbefore a number of embodiments of my invention, it will be appreciated that such descriptions are presented by way of example and not by way of limitation. Thus, variations thereof may be perceived by those skilled in this art without departing from the scope of my invention as defined in the claims appended hereto.

I claim:

1. A hang glider which comprises:

a. a wing having a continuous leading edge and an area and lift characteristic which is sufficient to dynamically support a person generally only when said wing is less than approximately three chord lengths from the ground, said wing having an aspect ratio in the range of 1.0 to 4.0, an area in the range of 15 to 100 square feet and a loading in the range of 2.0 to 6.25 pounds per square feet when said wing is dynamically supporting a person; and

b. means for mounting said wing on a person such that the person is in generally vertical alignment with the center of pressure of said wing and said wing is not more than approximately two chord lengths from the ground when the person is standing on the ground.

2. The hang glider of claim **1** wherein the area of said wing is within the range of 20 to 75 square feet.

3. The hang glider of claim **2** wherein at least one of the major surfaces of said wing is corrugated paperboard.

4. The hang glider of claim **1** wherein said wing loading is within the range of 2.5 to 5.5 pounds per square feet.

5. The hang glider of claim **4** wherein at least one of the major surfaces of said wing is corrugated paperboard.

6. The wing of claim **5** wherein said major surface is the top surface.

7. The wing of claim **6** wherein the corrugations of said paperboard are transversely disposed.

8. The wing of claim **7** wherein said paperboard is single wall corrugated paperboard.

9. The wing of claim **5** wherein said major surface is the bottom surface of said wing.

10. The wing of claim **9** wherein the corrugations of said paperboard are longitudinally disposed.

11. The wing of claim **10** wherein said corrugated paperboard is double wall corrugated paperboard.

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