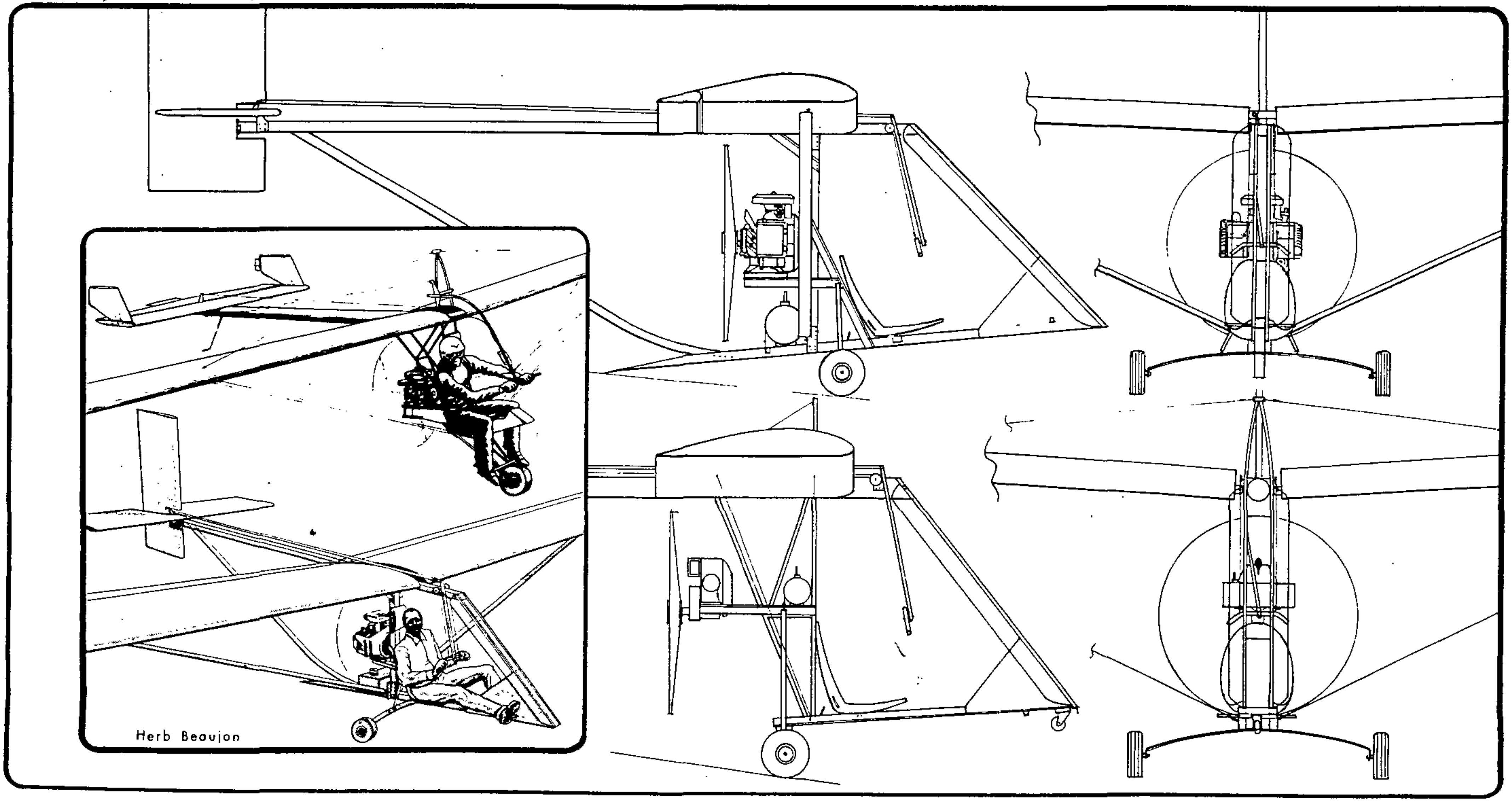
How to build ULTRALIGHTS



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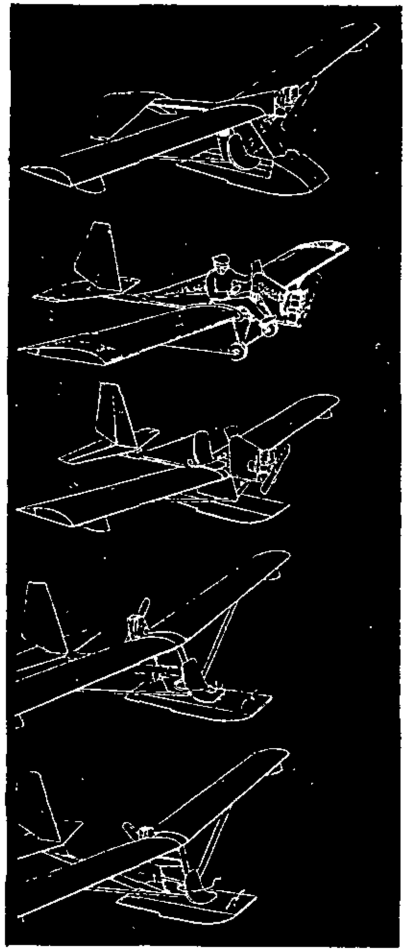


THE EMERGING ULTRALIGHT AIRPLANE

Somewhere between the downhill hang glider and the expensive homebuilt airplane lies an area that may well provide the answer to our emotional and economic flying needs. We are referring to the ultralight airplane.

Ideally, we can achieve a true sense of flight only by growing and utilizing our own set of natural wings. Hang gliding, especially with rogallos, almost fulfills that sensation. Unfortunately, a rogallo takes you nowhere but down. To go down, you must first go up. This physically exhausting procedure of climbing up a tall hill in return for a short moment of flight, eventually discourages many hang gliding enthusiasts. Where thence, oh J. L. Seagull?

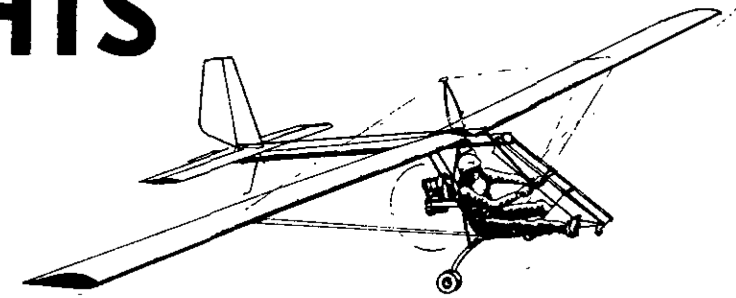
Only a few of us have the patience, relative affluence, and personality to spend several thousand dollars and hours creating a winged encasement containing a panoramic view of an instrument panel. Shoehorned and buckled in the cockpit of such an expensive homebuilt aircraft, the sensation of flight is only a slight improvement over that of watching a TV flight movie in your rocking chair with a fan blowing in your face.

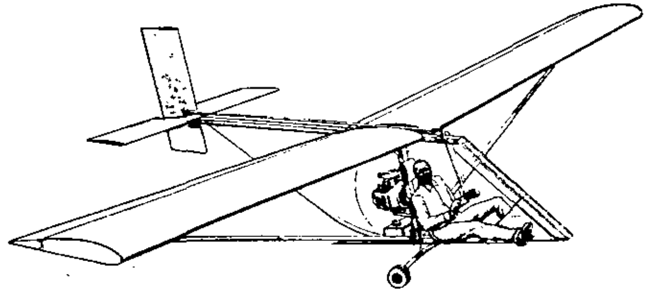
Obviously, the price of gasoline had little to do with the recent surge of interest in ultralight airplanes. Emotional factors play a major part. The closest thing to true flight can be experienced with a rogallo. This simple machine is, however, very limited where endurance, distance, and direction are concerned. A standard aircraft conveys almost no physical sense of flight to the pilot. It does get you up, down, here, and there. The ultralight airplane combines the best features found in both hang gliders and conventional aircraft. Mobility, together with a strong flight sensation, are preserved.

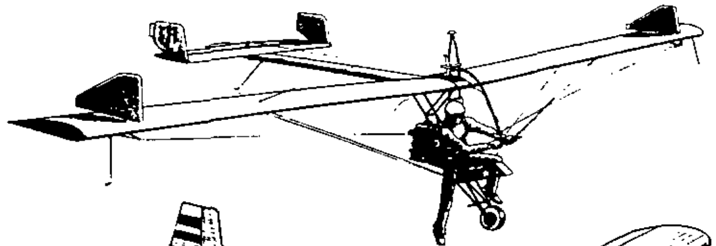
Low construction time and cost add significantly to the popularity of the ultralight airplane. Construction time for an ultralight averages between three and nine months. Total construction cost will run from $400.00 to $1200.00. A typical standard homebuilt airplane may take as long as four years to build at a cost of about $4000.00. Aye, there's the rub...patience and money. Few of us have it.

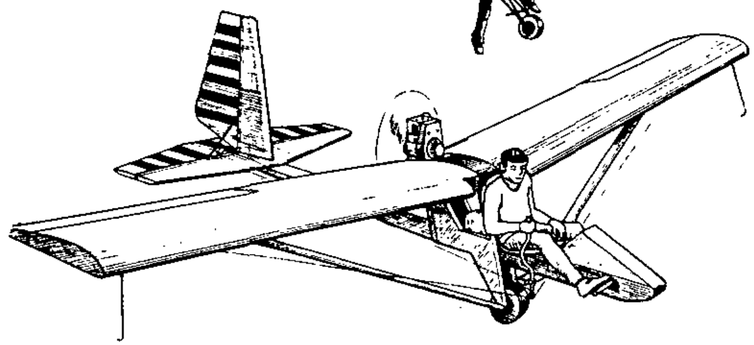
WHY THIS BOOK IS DIFFERENT

The best way to accumulate information for your own design, is to study plans of other designers. This form of fact scavenging is common in the business. Since your design must be stress analyzed, books in this area must be purchased. You may also need books on prop design, engines, fittings, etc. By the time you have all your information, you also have a sizable library which has depleted your budget.









BJ AIRCRAFT
10 B N.W.
Ardmore, Okla. 73401

A WORD ABOUT FOAM........

Take a piece of 1/8 inch thick plywood, 10 inches wide, and 4 feet long. Set one end on the ground and press down on the other end. About 25 pounds of pressure will bend and break the plywood strip. Now, epoxy glue this same size plywood strip to a foam block 3 inches thick, 10 inches wide, and 4 feet long. After the epoxy glue has hardened, compress the plywood strip as before. You cannot break it. It will easily support two men.

To the other side of the foam block, epoxy glue another similar plywood strip. After the epoxy has hardened, place the foam sandwich across a cement block. Place two men on either side of the seesaw. The foam sandwich will barely bend.

The above illustrations cover the basic principle used in foam aircraft construction. Foam is never used as a load bearing structural member, but rather as a stiffener for load carrying surfaces which would otherwise buckle, or as a shear body between two load carrying surfaces.

Foam has excellent shear and good compression characteristics. Tension is never considered in calculations.

Here are some of the most popular foams.....

BLUE STYROFOAM or EXTRUDED FOAM (Poly-Styrene). Most highly recommended for ultralight aircraft. Weighs 2.2 lbs. per cubic foot. Dissolves slowly in fuel, solvents, contact cement, and polyester resins. Compressive strength: 40 lbs./sq. in. Does not dissolve in epoxy. Easily cut with hot wire. Does not give off poison gasses when heated.

TAN or GREEN URETHANE (Polyurethane). The tan variety is most commonly used. Weighs 2 lbs. per cubic foot. Resistant to gasoline, solvents, most glues, epoxy, and polyester resins. Compressive strength: 20-25 lbs./sq. in. Do not hot wire cut,-gives off poison gas. Often used where fuel is present.

PVC (Polyvinyl Chloride). Hard to find. No longer made in U.S.A. Very expensive, but very good. Used in sailplane construction. Resistant to most chemicals.

ACRYLIC FOAM. Extremely strong and expensive. Made in Germany. For the rich who can afford high performance sailplanes.

WHITE STYROFOAM (Expanded Poly-Styrene). The worst of the lot. Looks like a bunch of foam balls squashed together. Weighs only 1 lb. per cu. ft. Virtually disappears in the presence of heat or gasoline. Has been used in aircraft in solid form, but only as a stiffener with no shear involved. Deteriorates in sunlight. Must be painted a very light color. Used in making molds.

Not all types of foam are practical for aircraft use. White styrofoam is used in cups, picnic coolers, packing boxes, etc. Its use in aircraft construction is reserved for the experts. Placed in solid form between wing or tail spars, it acts as a mild stiffener where all load bearing members are in contact with each other. Unlike the better foams, white styrofoam is considered to have no shear capabilities. For long lasting results, the finished aircraft must be painted a highly reflective color (white is best) to keep ultra violet rays from disintigrating the foam. Gasoline trickling down a pinhole in the dynel/epoxy covering will create a big empty hole where the white styrofoam once was. As a medium for creating molds, it has few equals. Carve it into the desired shape, then coat with dynel/epoxy. After the epoxy has set, wash out the white styrofoam with gasoline, leaving a perfect shell.

Blue styrofoam is best all around - price and strength wise. It must be used with epoxy. Polyester resins will slowly dissolve it.

Second best - in the same category - is tan urethane. Green urethane is seldom used. Urethane foam can be covered with either epoxy or polyester resin. It is more resistant to most chemicals than blue styrofoam, but has only half the shear and compressive strength . Its use should be restricted to areas where fuel spillage could occur.

Always wear a mask whenever sanding foam. An energetic sander can create a real 'snowstorm'.

EPOXY AND POLYESTER RESINS.........

Because there are so many different types of epoxies on the market, we shall cover only the general characteristics.

A typical epoxy kit will contain a large can of resin and a small can of hardener. Resin and hardener are thoroughly mixed in ratios varying from three to six parts resin for each part hardener. Since the hardener is a curing agent, it enters into the reaction and becomes part of the final solid. A quart of resin mixed with ¼ quart of hardener will give 1¼ quarts of cured resin. Most epoxies have a working life of 20 minutes to 2 hours. The complete cure takes about 24 hours.

Viscosity of the epoxy resin will vary from syrupy to pasty. The less viscious variety is used for applying dynel, dacron, or fibercloth to foam. the thicker epoxies are best for creating strong bonds between smaller contact areas.

Epoxy shrinks very little, and can thus be used to bond slick surfaces of hard materials (glass, metal). Epoxy will stick to polyester, but polyester will not hold well to epoxy. Polyester shrinks and pulls away from hard, smooth surfaced materials.

Epoxy is expensive - about twice as much as polyester

Polyester resins come with a hardener (catalyst) which does not become part of the final cured product. One gallon of polyester resin requires about two ounces of hardener.

There are two types of polyester resins commonly used in aircraft construction.

Bonding polyester resin hardens with a tacky surface, permitting additional layers to be applied without sanding.

Surfacing polyester resin hardens with a dry, hard surface. Before additional layers can be applied, it must be thoroughly sanded.

As with epoxy resin, polyester resin is used with fibercloth, dynel, dacron, or just about any kind of loosely woven material. Maximum strength is reached with fiberglass cloth.

Although polyester weighs less and costs less than epoxy, there are some penalties involved. Polyester resin shrinks as it hardens. It will break away from any material that will not 'give', such as metal and glass. If not properly applied, polyester resin can cause deformation in flexible materials. It may only be used on certain foams (urethane, for example). Never use it on styrofoam.

EPOXY RESINS, FOAMS, AND FIBERGLASS CLOTHS AVAILABLE FROM:

AIRCRAFT SPRUCE AND SPECIALTY COMPANY
BOX 424, FULLERTON, CALIFORNIA 92632

EPOXIES

RA epoxy kits: RAEF Fast Cure (3 to 6 hours)
RAES Slow Cure (10 to 16 hours)
Five Minute Epoxy

FIBERGLASS CLOTH

Rutan fiberglass cloth (unidirectional & bidirectional)

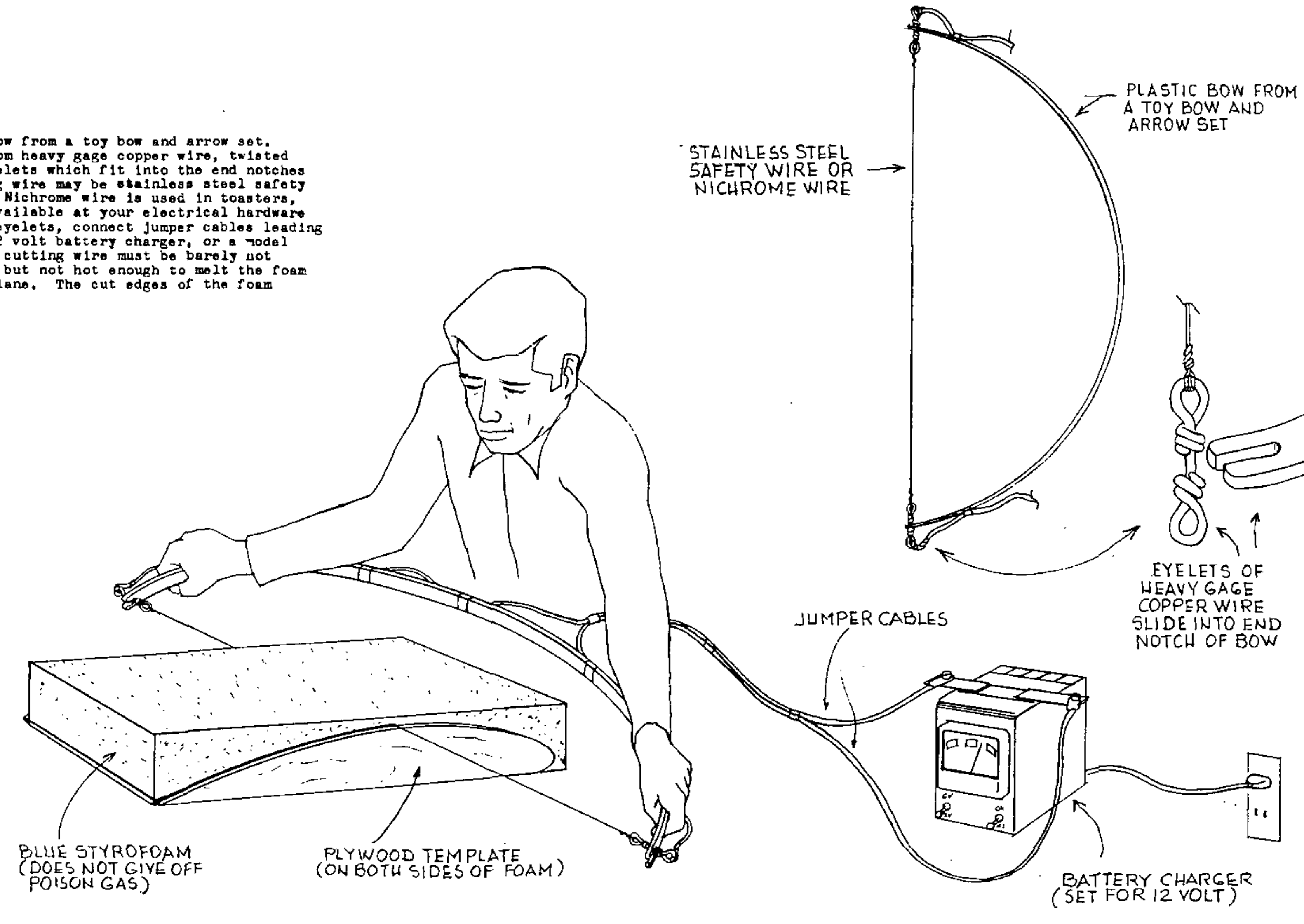
FOAMS

Polystyrene (light blue color), 2 lbs./cu. ft. density.
9" x 18" x 41"
9" x 18" x 67"

Polyurethane (green color), 2 lbs./cu. ft. density
1" x 24" x 96"
2" x 24" x 96"
1" x 24" x 48"

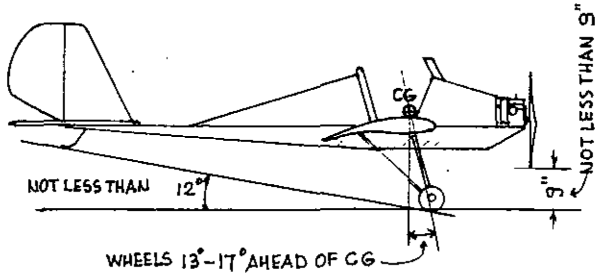
HOT WIRE CUTTING BOW

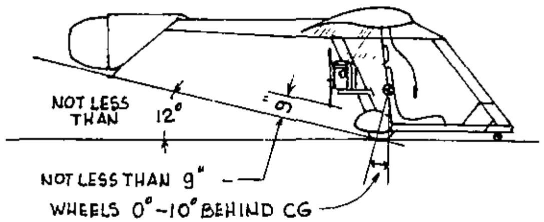
Use an actual plastic bow from a toy bow and arrow set. Form connecting ends from heavy gage copper wire, twisted as shown into double eyelets which fit into the end notches of the bow. The cutting wire may be stainless steel safety wire or nichrome wire. Nichrome wire is used in toasters, heaters, etc., and is available at your electrical hardware store. At your copper eyelets, connect jumper cables leading to a 12 volt battery, 12 volt battery charger, or a model train transformer. The cutting wire must be barely hot enough to cut the foam, but not hot enough to melt the foam away from the cutting plane. The cut edges of the foam must be smooth.

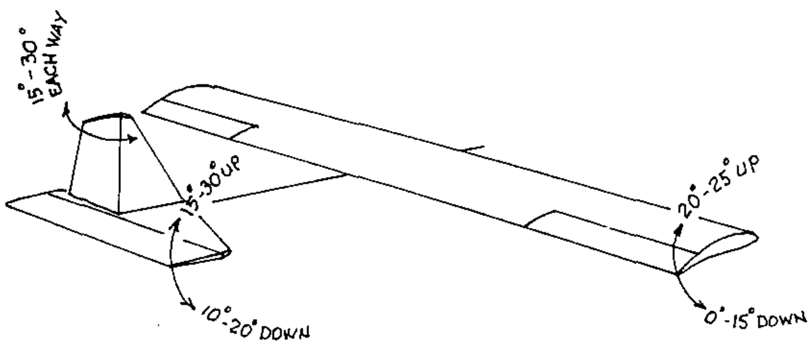


GENERAL DESIGN REQUIREMENTS

④







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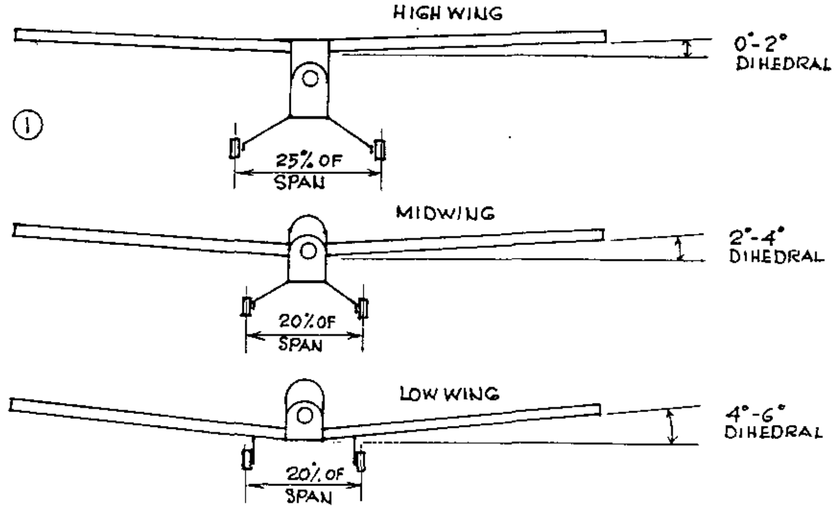


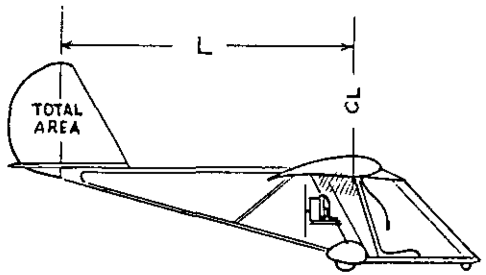
⑤

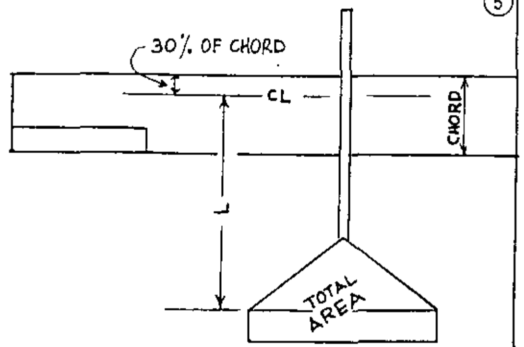
AILERONS = ± 10% WING AREA

NOTE: BEST L = 2.5 x CHORD

TOTAL VERTICAL TAIL AREA =

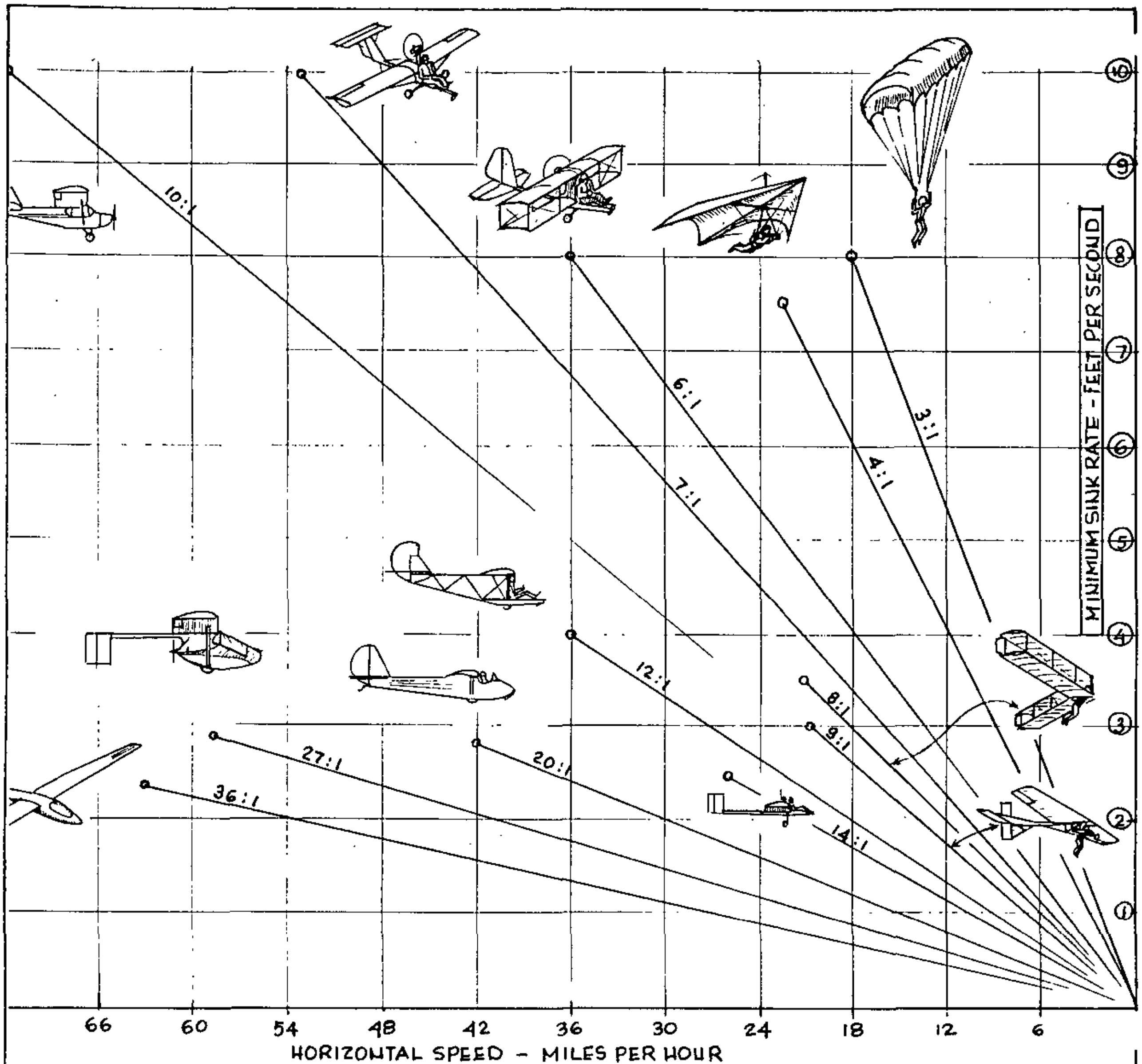
$$\frac{\text{GROSS WT.} \times \text{WINGSPAN} \times .07}{(L)^2}$$

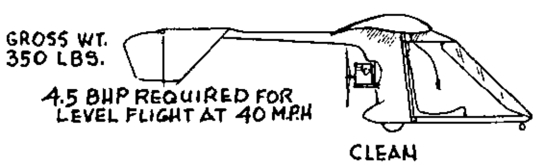


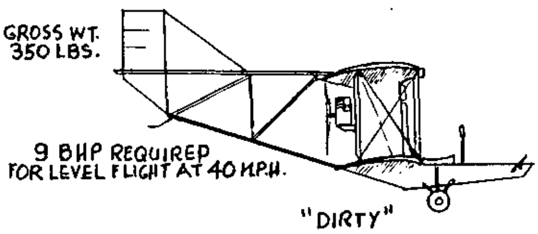


TOTAL AREA ELEVATOR & STABILIZER

$$= \frac{\text{WING SPAN}}{L} \times (\text{CHORD})^2 \times .6$$







SPEED AND SINK OF VARIOUS AIRCRAFT

From the above graph, it becomes immediately obvious that the most efficient aircraft will have the lowest speed and sink rates. Such aircraft will require the least amount of power to maintain level flight. To achieve this goal, an aircraft must have low span loading, low wing loading, and a clean design. Gliding parashutes and rogallos have very low wing loadings, but relatively high span loadings. This, plus an aerodynamically "dirty" design, accounts for the steep glide angle. A powered rogallo with a gross weight of 220 lbs. would require 9 BHP to maintain level flight at a speed of 25 MPH. A 1200 lbs high performance sailplane will maintain level flight at 60 MPH with the same 9 BHP. Very often, ultralight airplanes defeat their own purpose with excess drag that must be compensated for with a powerful engine capable of pulling a conventional aircraft through the air. Strike a happy medium. Keep your ultralight simple, but clean it up as much as possible. See sketches above

POWER REQUIRED VERSUS SPAN LOADING

For a given weight aircraft, increasing the wing span decreases the thrust HP necessary for level flight. The thrust HP required is proportianal to...

$$\left(\frac{\text{WEIGHT}}{\text{SPAN}}\right)^2$$

Thus, increasing the span of a 400 lb. gross aircraft from 15 feet to 20 feet, will reduce the requird thrust HP to only 57% of the original power needed for level flight.

$$\left(\frac{400}{20}\right)^2 / \left(\frac{400}{15}\right)^2 \times 100 = 57\%$$

Maintaining the same chord, but increasing the span, will reduce span loading and induced drag. The lower your span loading, the less power is needed to maintain your aircraft in level flight. High performance sailplanes have high aspect ratios and low span loadings. Rogallos are just the opposite, and have a very steep glide ratio.

Thrust HP for level flight at sealevel is equal to

$$\left(\frac{.83}{\text{Best Climb Speed}}\right)\left(\frac{\text{Weight}}{\text{Span}}\right)^2$$

If your ultralight weighs 400 lbs gross, has a wing span of 30 feet, and climbs best at 48 MPH, then you will need...

$$\left(\frac{.83}{48}\right)\left(\frac{400}{30}\right)^2 = 3 \text{ Thrust HP}$$

Let's assume that you have purchased a Rockwell JLO Model L-395 engine rated at 24.5 HP at 5500 RPM. At 4500 RPM (recommended RPM) it will give 22 BHP with a 36 inch diameter propeller (16" pitch). The efficiency of a 36" prop is .50. This means that you will get only 22 BHP x .50 = 11 Thrust HP. Your ultralight will weigh 400 lbs. gross, and must climb at 300 feet per minute. You estimate your best climb speed at 45 MPH. Find the right wing span.

First we find the thrust HP consumed to climb at a rate of 300 ft/min.

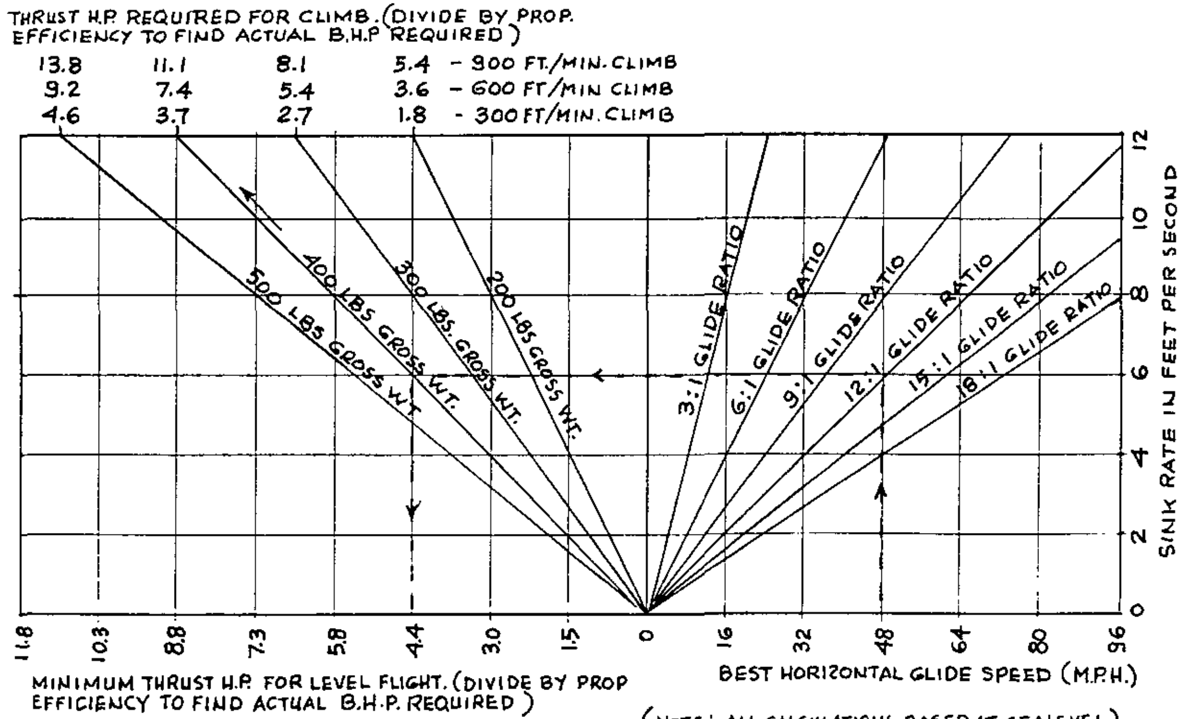
$$\text{THP for climb} = \frac{\text{Gross Weight} \times \text{rate of climb}}{33{,}000}$$

$$\text{Or: } \frac{400 \times 300}{33{,}000} = 3.6 \text{ THP}$$

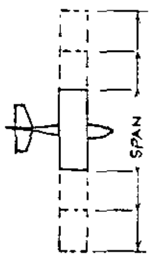
This leaves us 11 - 3.6 = 7.4 THP for level flight.

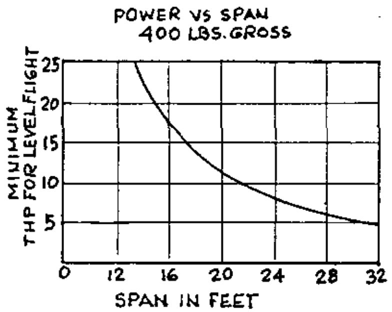
$$\text{Required wing span} = \frac{\text{Gross Weight} \times .91}{\text{Level Flight THP} \times \text{Best Climb Speed}}$$

$$\text{Or: } \frac{400 \times .91}{7.4 \times 45} = 20 \text{ foot wing span}$$



(NOTE: ALL CALCULATIONS BASED AT SEALEVEL)





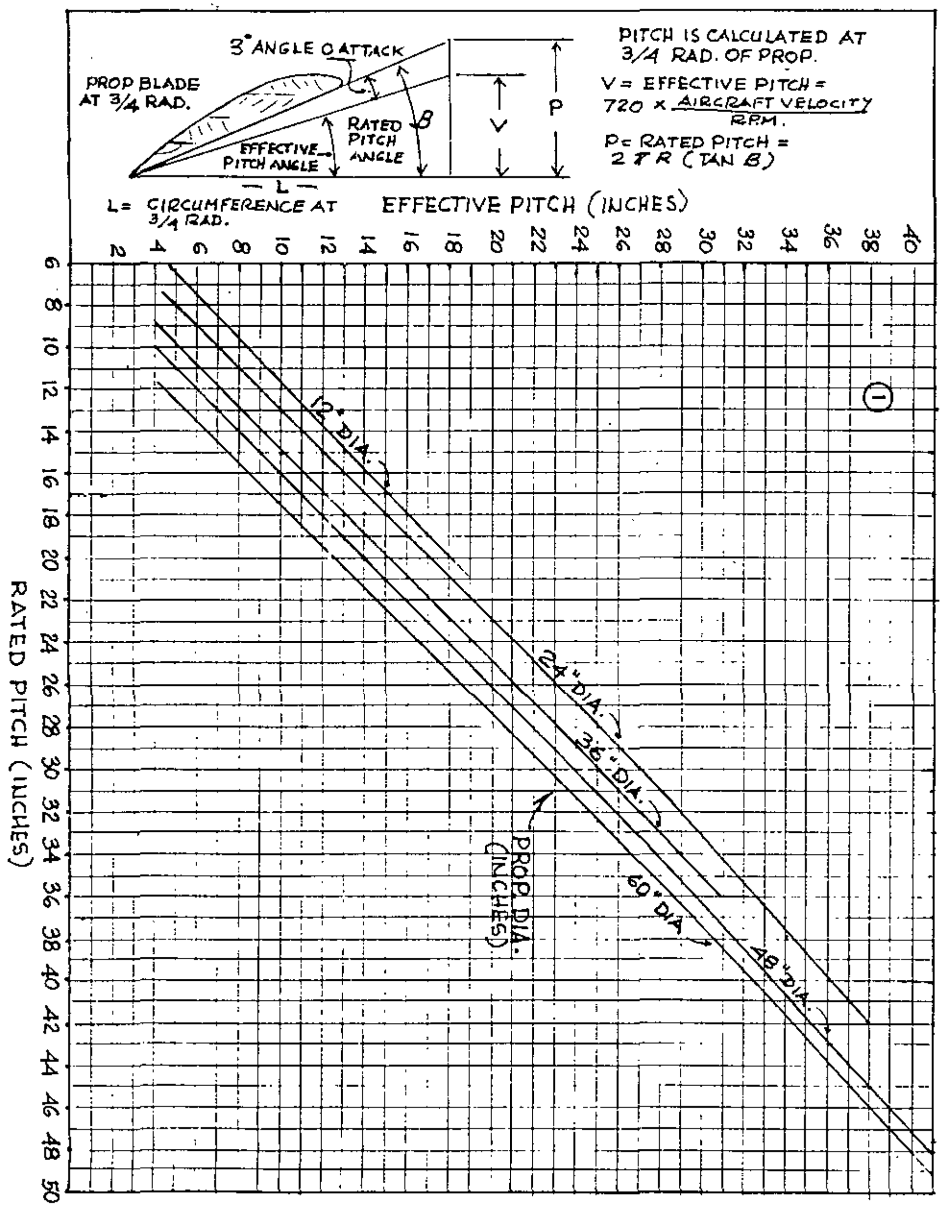
Example: An ultralight aircraft weighs 400 lbs gross. The design, when compared to the chart on the previous page, indicates a glide ratio of 12:1 at a forward speed of 48 MPH. A climb rate of 300 ft/min. is desired.

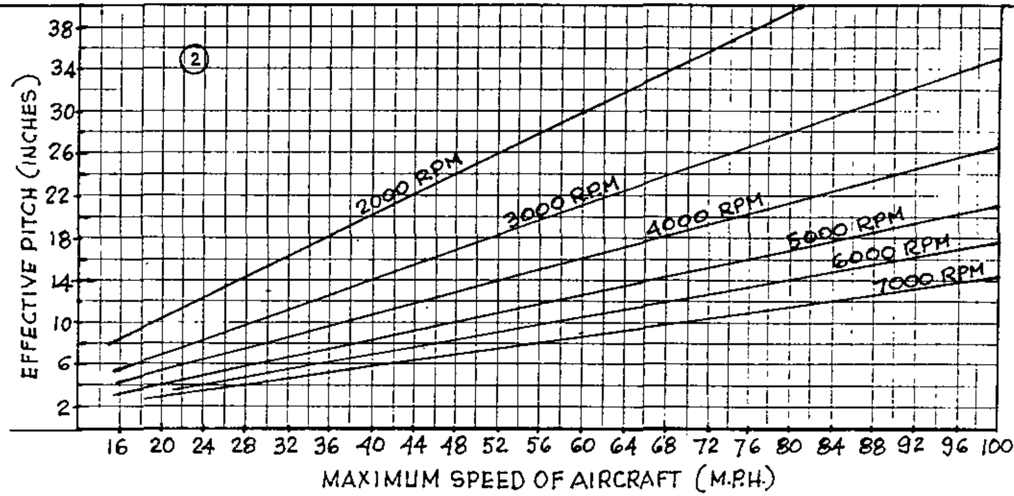
Find the minimum brake horsepower needed.

Where the graph says 'Best Horizontal Glide Speed' find 48 MPH. Move up until you meet the line indicating 12:1 glide ratio. Move left to the 400 lbs line, then down to 4.4 THP. To find climbing power, follow the 400 lbs line up and left to 3.7 THP needed for a 300 ft/min. climb. 4.4 + 3.7 = 8.1 THP, or the total thrust horsepower needed. The actual brake HP required depends on the efficiency of the propeller. If you use a 36" diameter propeller, your efficiency rating is .50. (see tables at upper right corner of page).

$$\text{BHP} = \frac{\text{Thrust HP}}{\text{Efficiency rating}} \quad \text{or} \quad \frac{8.1}{.50} = 16.2 \text{ BHP}$$

Your last figure represents the maximum brake horsepower output at the rated RPM of your engine. To be on the safe side (engines don't always perform at maximum) add 50%, or about 8 BHP to give you 24.2 BHP.





THRUST VERSUS SPEED FOR VARIOUS ENGINES
(Calculations based on most efficient prop for each speed)

McCULLOCH 101 A/A Single Cyl. 2 Cycle
Displ. 123 cc/ Wt. 12 lbs./
13 HP @ 9000 RPM.
Derated to 7 HP @ 5500 RPM

SPEED MPH	15	25	35	45	55	65	75	85	95
THRUST LB	30	26	21	17	14	12	10	9	8

ROCKWELL JLO MODEL L-230 Single cyl.
2 Cycle/ Displ. 223 cc/ Wt. 29 lbs./
15.5 HP @ 6000 RPM
Derated to 12 HP @ 4500 RPM

SPEED MPH	15	25	35	45	55	65	75	85	95
THRUST LB	58	50	40	33	28	24	20	18	16

JLO ROCKWELL MODEL L-395 Single cyl.
2 Cycle/ Displ. 395 cc/ Wt. 59 lbs/
24.5 HP @ 5500 RPM
Derated to 22 HP @ 4500 RPM

SPEED MPH	15	25	35	45	55	65	75	85	95
THRUST LB	135	114	94	76	64	54	48	42	39

JLO ROCKWELL MODEL 2F-440-7 Single cyl.
2 Cycle/ Displ. 440 cc/ Wt. 62 lbs/
40 HP @ 6500 RPM
Derated to 28 HP @ 4500 RPM

SPEED MPH	15	25	35	45	55	65	75	85	95
THRUST LB	175	155	126	100	87	73	65	56	51

BRIGGS & STRATTON SERIES 190400 Single cyl
4 cycle/ Displ. 19.44 Cu. In./ Wt. 45 lbs/
8 HP @ 3600 RPM
Derated to 7.3 HP @ 3000 RPM

SPEED MPH	15	25	35	45	55	65	75	85	95
THRUST LB	46	42	33	26	22	19	17	14	13

BRIGGS & STRATTON SERIES 401417 Twin
cyl. 4 cycle/ disp. 656 cc/ Wt. 82 lbs
16 HP @ 3600 RPM
Derated to 15 HP @ 3200 RPM

SPEED MPH	15	25	35	45	55	65	75	85	95
THRUST LB	125	108	87	71	60	50	45	38	36

YAMAHA Y 292 Single Cyl.
2 Cycle/ Displ. 292 cc/ Wt. 46 lbs./
21 HP @ 5500 RPM
Derated to 17 HP @ 4500 RPM

SPEED MPH	15	25	35	45	55	65	75	85	95
THRUST LB	100	87	70	57	48	40	36	31	29

YAMAHA Y 433 2 Cyl
2 Cycle/ Displ, 433 CC/ Wt. 68 lbs./
31 HP @ 5500 RPM
Derated to 26 HP @ 4500 RPM

SPEED MPH	15	25	35	45	55	65	75	85	95
THRUST LB	165	142	116	95	80	67	60	51	46

NOTE: Tip speeds of wood props do not exceed 700 ft/sec. For tip speeds between 700 and 880 ft/sec., one must use all metal or metal tipped wood props with a tip thickness not exceeding 6% of the tip chord. Prop tips must not exceed 880 ft/sec., as air compressibility places undue strain on the prop and also absorbs energy which is not translated into propulsion.

The right diameter prop will work efficiently within the best horsepower and RPM combination available from a given engine.

Example: Find the prop diameter for a two stroker producing 20 BHP at 4000 RPM. Find 20 BHP at the bottom of the graph at right, follow vertically to the 4000 RPM line, thence left to your prop diameter of 43 inches.

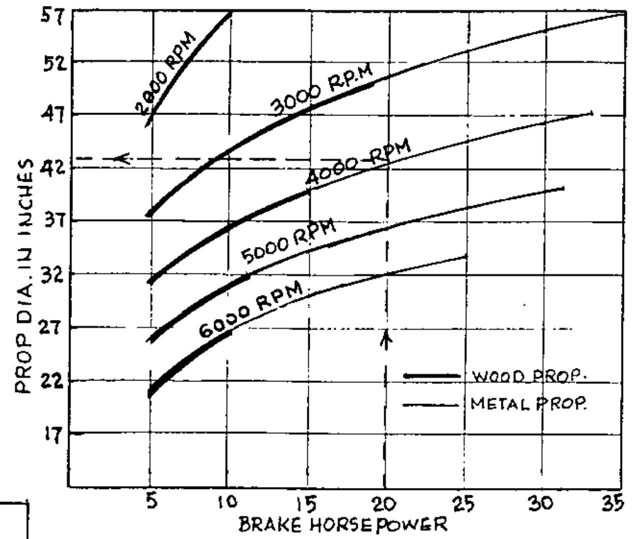
FOR AIRCRAFT SPEEDS BETWEEN 30 and 80 MPH

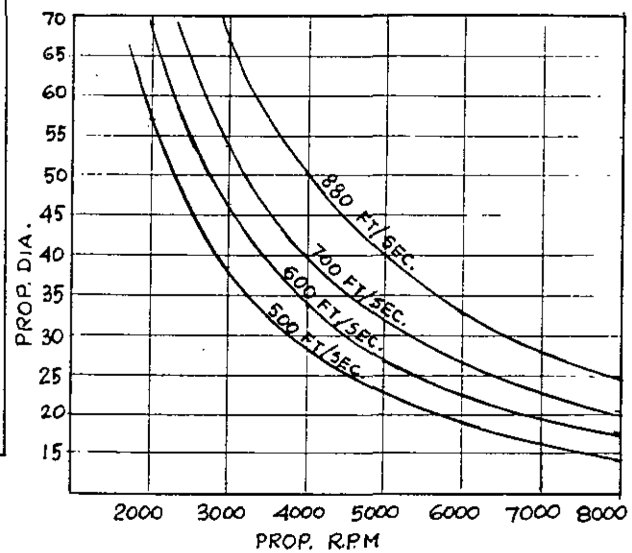
PROP RPM	BRAKE HP	THRUST HP	PROP DIA.	TYPE MAT'L
2000	5	3	49″	wood
	10	6.5	54″	wood
	15	10	58″	wood
	20	13.8	62″	wood
2500	5	2.9	43″	wood
	10	6	47″	wood
	15	9	50″	wood
	20	13	54″	wood
	25	16.8	58″	wood
	30	20.5	61″	wood
3000	5	2.6	38″	wood
	10	5.6	41″	wood
	15	8.7	44″	wood
	20	12	48″	wood
	25	15	50″	wood
	30	19	52″	wood
	35	22.6	54″	wood
	40	26.2	55″	metal
3500	5	2.3	34″	wood
	10	5.1	37″	wood
	15	8.2	40″	wood
	20	11.5	43″	wood
	25	14.4	45″	wood
	30	18	47″	metal
	35	21	49″	metal
	40	25	50″	metal

PROP RPM	BRAKE HP	THRUST HP	PROP DIA.	TYPE MAT'L
4000	5	2.2	31″	wood
	10	4.7	34″	wood
	15	8	36″	wood
	20	10.6	39″	wood
	25	14	41″	metal
	30	17.1	43″	metal
	35	20	44″	metal
	40	23.5	46″	metal
4500	5	2.1	29″	wood
	10	4.4	32″	wood
	15	7	34″	wood
	20	10	36″	wood
	25	13	38″	metal
	30	16.5	40″	metal
	35	19.5	41″	metal
	40	22.2	42″	metal
5000	5	2	28″	wood
	10	4.3	30″	wood
	15	6.6	32″	wood
	20	9.3	34″	wood
	25	12.5	36″	metal
	30	15.2	37″	metal
	35	18.2	38″	metal
	40	21	39″	metal

PROP RPM	BRAKE HP	THRUST HP	PROP DIA.	TYPE MAT'L
5500	5	1.8	26″	wood
	10	4.1	28″	wood
	15	6.4	30″	wood
	20	9	32″	metal
	25	11.6	34″	metal
	30	15	35″	metal
6000	5	1.6	25″	wood
	10	3.8	27″	wood
	15	6.3	29″	metal
	20	8.8	31″	metal
	25	11.4	33″	metal

FOR SPEEDS BETWEEN 30 - 70 MPH





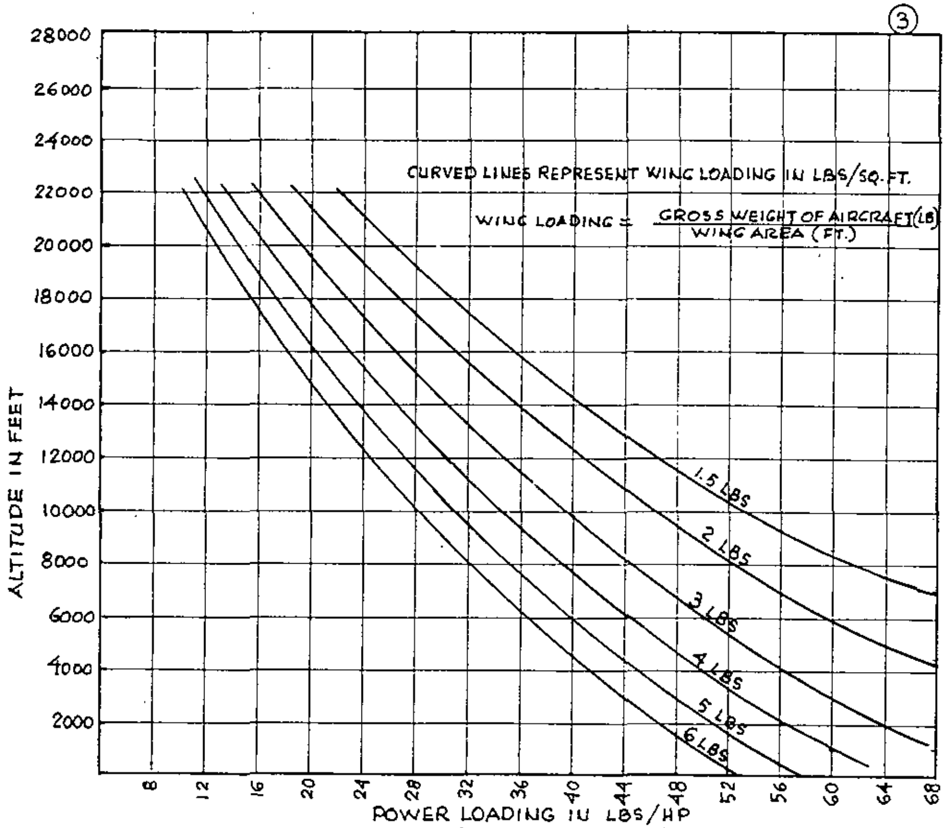
PROPELLER EFFICIENCY VERSUS DIAMETER
Applicable to most ultralight aircraft

24" Dia. - .33	54" Dia. - .65
30" Dia. - .43	60" Dia. - .68
36" Dia. - .50	66" Dia. - .71
42" Dia. - .57	72" Dia. - .73
48" Dia. - .61	

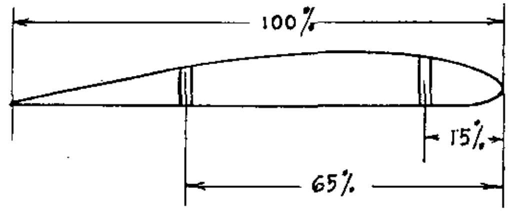
Example: You need 5.8 thrust HP for level flight, plus 3.7 thrust HP for a 300 ft/min. climb. Total thrust HP required is
5.8 + 3.7 = 9.5
Your prop diameter is 30 inches, and has an efficiency rating of .42. To find actual BHP required, divide thrust HP by efficiency rating. 9.5/.42 = 22.5 BHP

Example: Your engine is rated at 22.5 BHP with a 30 inch diameter prop. To find thrust HP, multiply BHP by efficiency rating.
22.5 x .42 = 9.5 Thrust HP.

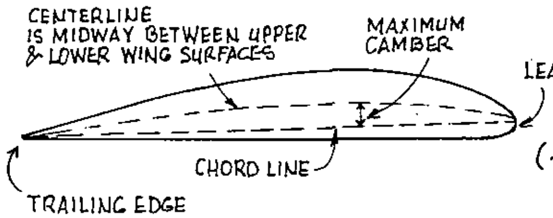
WING LOADING LBS/SQ.FT.		1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
STALL SPEEDS IN M.P.H.	THIN WING	20	23	28	32	36	39	43	45	48	51
	THICK WING	17	20	24	28	32	35	37	39	42	45



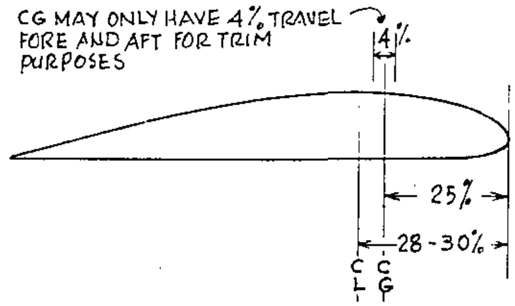
POWER LOADING = GROSS WT. OF AIRCRAFT / MAX. BRAKE H.P.



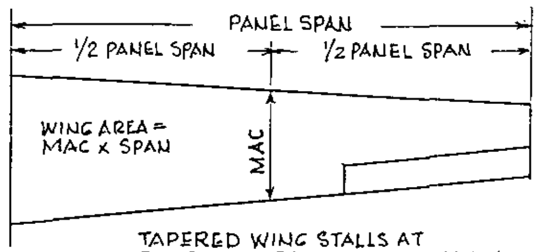
PLACING FRONT & REAR SPARS AS SHOWN WILL DISTRIBUTE THE LOADS IN PROPORTION TO THE SPAR HEIGHTS. EQUAL SAFETY FACTORS ARE INCORPORATED IN BOTH SPARS.



THE GREATER THE MAX. CAMBER, THE GREATER WILL BE THE LIFT (..AND DRAG.)

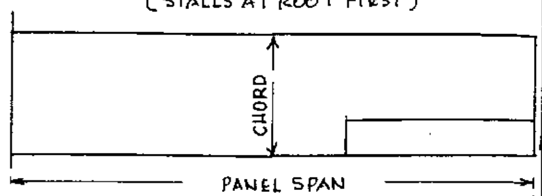


THE CENTER OF LIFT (CL), ALSO CALLED CENTER OF PRESSURE (CP) MOVES FOREWARD AT HIGH ANGLES OF ATTACK. THE CENTER OF GRAVITY (CG) MUST ALWAYS REMAIN AHEAD OF THE CL TO PREVENT CATASTROPHIC STALLS IN ENGINE OFF FLIGHTS



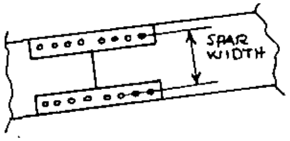
TAPERED WING STALLS AT TIP FIRST. REQUIRES DOWN WASH AT TIP.

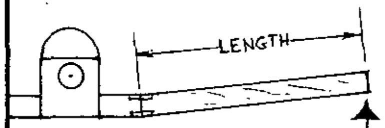
CONSTANT CHORD WING (STALLS AT ROOT FIRST)



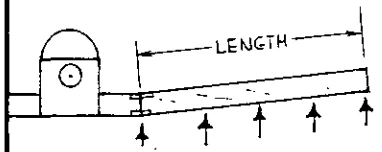
AIRCRAFT SPRUCE SPARS
PLAIN & BOX SPARS
BENDING LOADS

A safety factor of 5 has been included in the loads indicated at right. Under ideal conditions the true maximum load is five times greater.

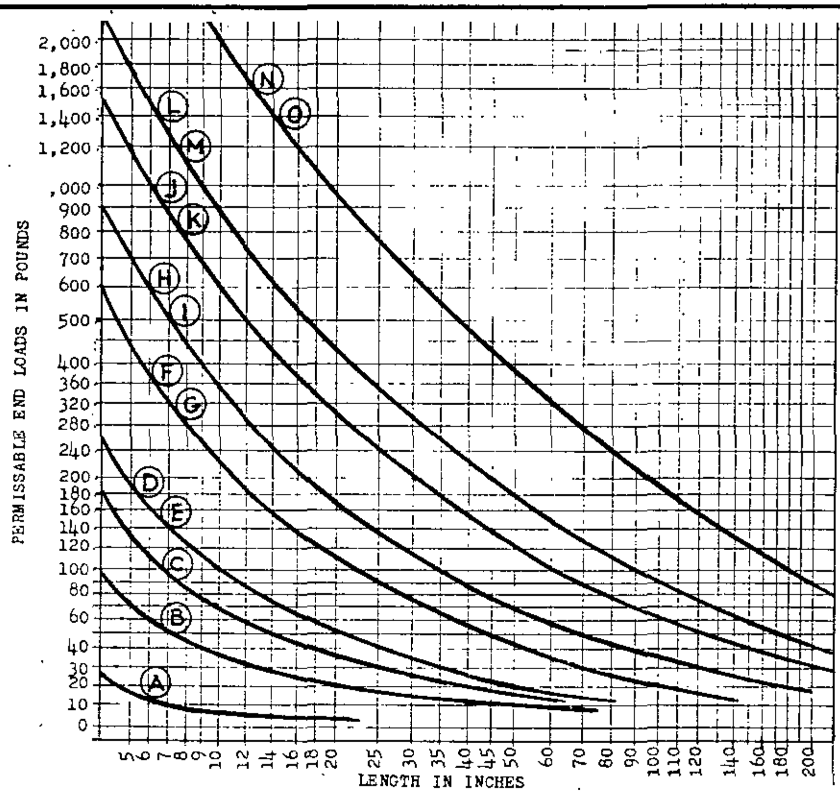




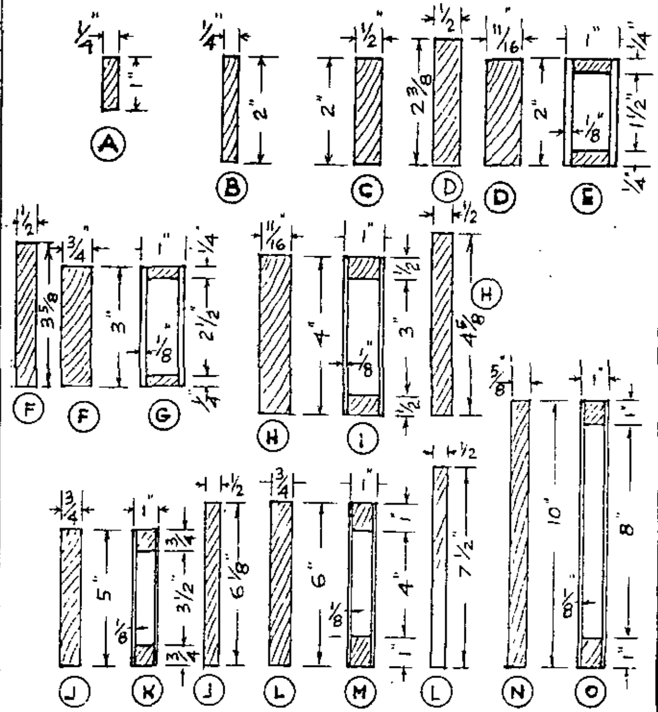
END LOAD - Use load indicated on graph.

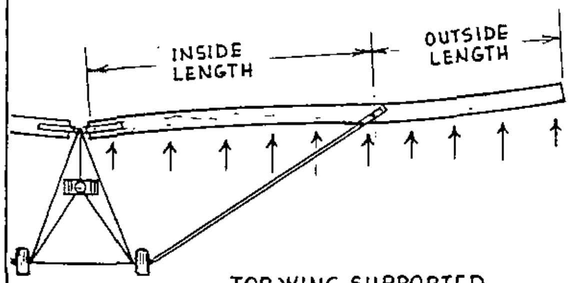


EVENLY DISTRIBUTED LOAD - Use 2 x load indicated on graph.



PLAIN SPARS, BOX SPARS





TOP WING SUPPORTED BY TENSION STRUT

SPAR BENDING STRESSES IN FLIGHT
EVENLY DISTRIBUTED LOAD

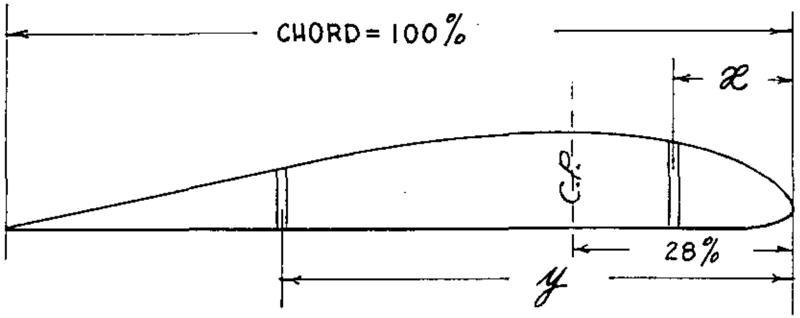
OUTSIDE LENGTH: Use 2 x end load indicated on graph at left.

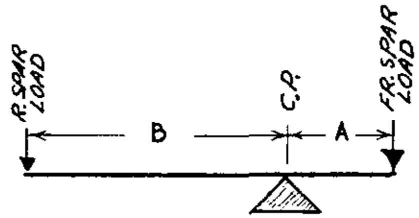
INSIDE LENGTH: Use 5 x end load indicated on graph at left. The inside length is under both compression and bending stresses

POSITION & % OF LOAD CARRIED BY FRONT & REAR WING SPAR

The center of pressure of an airfoil represents a point where all forward and rearward lift forces are balanced. The exact location varies with the type of airfoil and the angle of attack. For most common airfoils riding at 0 - 4 degrees angle of attack, the center of pressure is located approximately 28% of the chord, measured from the leading edge.

Spar loads will depend on their position relative to the center of pressure. For illustrative purposes, the center of pressure may be considered a pivot point on a seesaw bounded at one end by the front spar, and at the other end by the rear spar. The end loads must keep the seesaw in a level position.



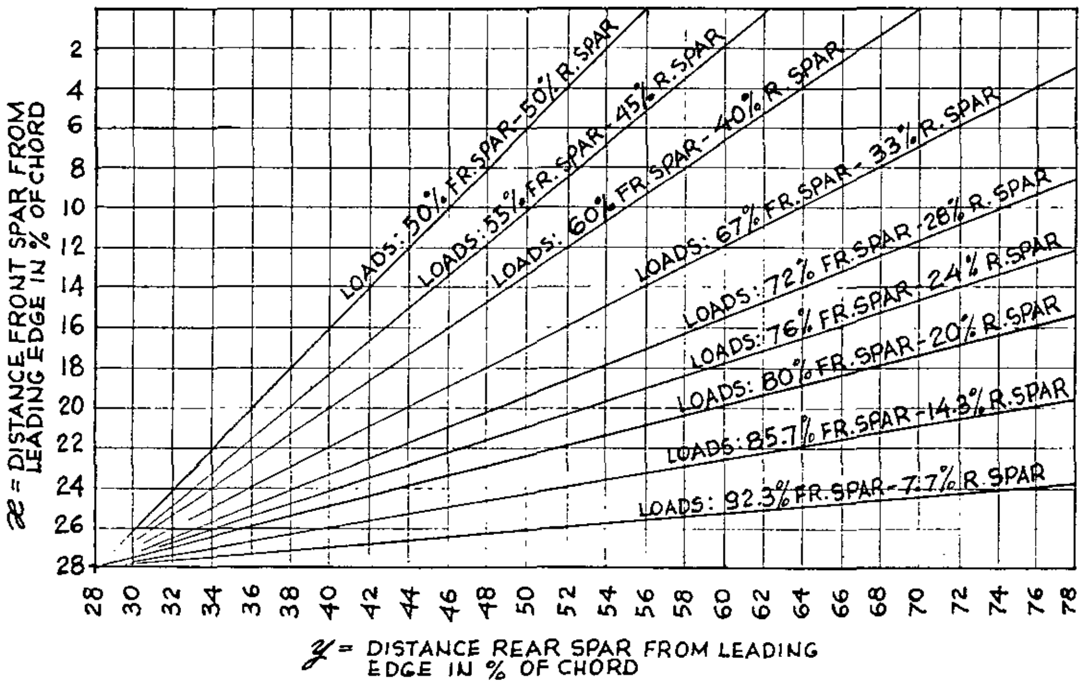


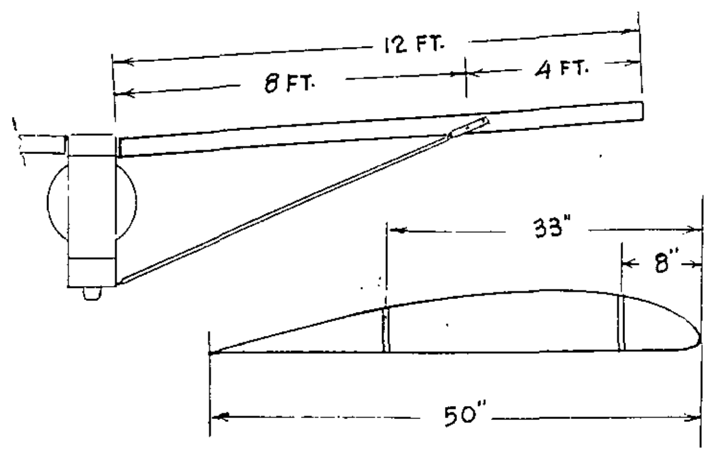
$$\text{LOAD FR. SPAR} = \frac{\text{DIST. B}}{\text{DIST. A+B}} \times \text{TOT. LOAD}$$

$$\text{LOAD R. SPAR} = \frac{\text{DIST. A}}{\text{DIST. A+B}} \times \text{TOT. LOAD}$$

The Ultralight Aircraft below must withstand a maximum of 3.8 G's, or 3.8 x 400 lbs. = 1520 lbs. Find the lightest spars capable of supporting this load.

The front spar is 8/50 x 100 = 16% from the leading edge. The rear spar is 33/50 x 100 = 66% from the leading edge. From the above graph we see that the front spar supports 76% of the wing load. The rear spar supports 24% of the wing load. Each wing panel must support 1/2 x 1520lbs = 760 lbs. The outer 4 feet of the wing panel must support 4 feet/12 feet x 760 lbs. = 253 lbs. The front spar takes up 76% of this load, or .76 x 253 lbs. = 192.3 lbs. This load is evenly distributed along the length, and can be considered concentrated at a point midway, or at 2 feet from the strut support. Thus we have the equivalent of an end load at 24 inches. On graph #9 we follow the end load and distance coordinates to the next highest curved line marked (J) (K). Refer to the spars designated by these letters. Use the same procedure in finding the outboard load of the rear spar, and the inboard loads of both front and rear spars.





GROSS WEIGHT: 400 LBS.
STRESSED 3.8 G'S
FRONT & REAR SPARS STRUT SUPPORTED

STRESSES IN FRAMED STRUCTURES

A line may be used to represent direction and magnitude of a given force or stress. The magnitude of a straight line is measured in weight per given length, or generally in lbs. per inch of length. In Fig. 1, induced drag can be measured when the angle of attack (providing resultant) and lift (weight of aircraft acting vertically) are known. In Fig. 2, 3, 4, and 5, a force triangle is formed by following the force directions in a clockwise manner. Fig. 6 and 8 are extensions of the force triangle into a force polygon showing method of measuring the resultant force needed for equilibrium.

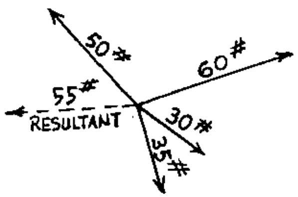


FIG.6

FORCE POLYGON

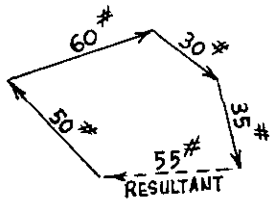


FIG.7

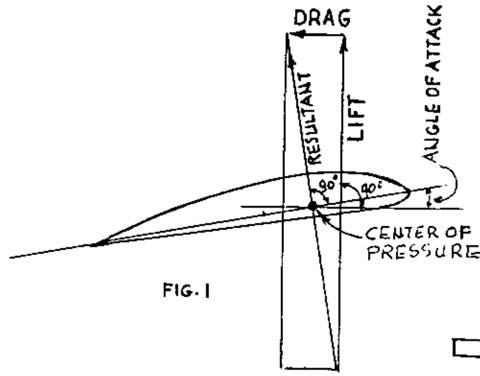


FIG. 1

FIG. 2

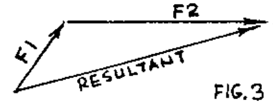


FIG. 3

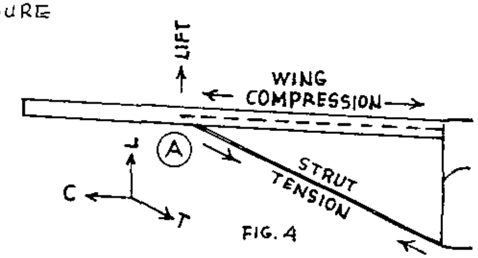
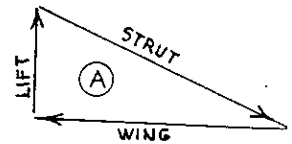


FIG. 4



FORCE TRIANGLE

FIG. 5

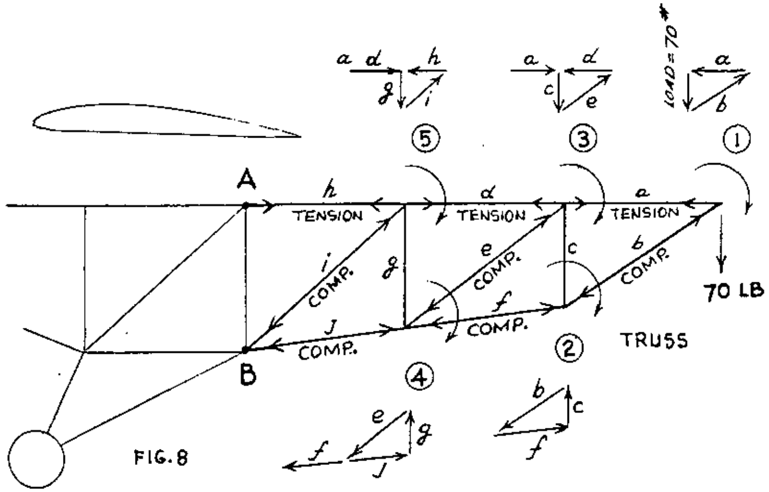
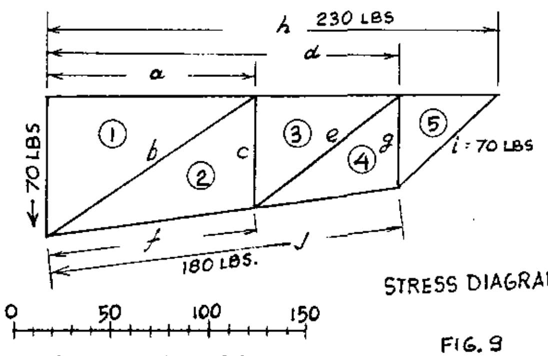


FIG. 8



STRESS DIAGRAM

FIG. 9

Given: The truss shown above with an end load of 70 lbs.
Find: The tension load acting at point A. The compression loads acting at point B.

Compression loads act into a joint. Tension loads act away from a joint. Starting at junction 1 , fig. 8, form a force triangle as indicated by small sketch shown immediately above. Always measure load directions clockwise. Using the scale shown, mark a vertical distance of 70 lbs. in fig. 9. Your force triangle at 1 , fig. 8, is drawn in fig. 9 as the force triangle shown by lines 70 lbs, a, and b. Junction 2 , fig. 8, is drawn in fig. 9 as the force triangle b, c, f. Follow through, remembering that no single force may be extended beyond itself. All your graphic forces 1 , 2 , 3 , 4 , 5 , should fit together to form the complete force frame in fig. 9. The tension at A, fig. 8, is equal to the measured length of line h, fig. 9, or 230 lbs. By the same token, the compression loads at B are 70 lbs. and 180 lbs. (i, j)

STRENGTH OF MATERIALS

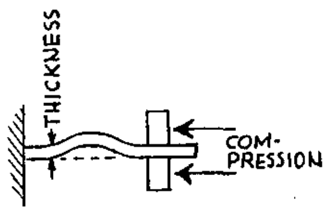
MATERIAL	YIELD STRENGTH P.S.I.	ULTIMATE TENSILE STRENGTH P.S.I.	SHEAR STRENGTH P.S.I.	WEIGHT/ CU. IN. (LBS)
4130 CHROME MOLY ST'L	60.000	95.000	60,000	.284
1025 MILD CARBON ST'L	36.000	55.000	35.000	.275
2024-T3 ALUMINUM	50.000	70,000	42,000	.100
6061-T6 ALUMINUM	39,000	45.000	30.000	.100
6061-T4 ALUMINUM	21,000	35,000	24,000	.100

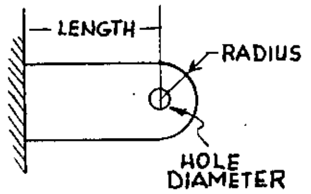
MATERIAL	MODULUS OF RUPTURE P.S.I.	ULTIMATE TENSILE STRENGTH P.S.I.	SHEAR STRENGTH P.S.I.	COMPRESSION PARALLEL TO GRAIN P.S.I.	COMPRESSION VERTICAL TO GRAIN P.S.I.	WEIGHT/ CU. IN. (LBS)
SITKA SPRUCE	9.400	10,000	750	5.000	750	.016
ASH	14.800	16,000	1,380	7.000	2,000	.023
BIRCH	15,500	17.000	1.300	7,300	1,300	.025
BALSA	3,000	4.000	200	2.200	100	.006
PLYWOOD, SPRUCE 3PLY/90			1,300			.017
PLYWOOD, BIRCH 3PLY/90			2,200			.027

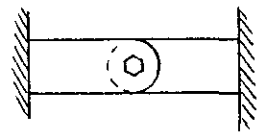
MATERIAL	TENSILE STRENGTH P.S.I.	SHEAR STRENGTH P.S.I	COMPRESSION STRENGTH P.S.I	WEIGHT/ CU.FT. (LBS)
URETHANE FOAM (TAN)	45	30	20	2.0
EXTRUDED FOAM (BLUE)	95	65	40	2.2

MATERIAL	TENSILE STRENGTH P.S.I.	SHEAR STRENGTH P.S.I.	COMPRESSION P.S.I.	WEIGHT/ CU.FT. (LBS)
EPOXY GLUE	6.000	4000	25,000	69
AIRCRAFT GLUE	4.500	3.000		

MATERIAL	WEIGHT/ SQ.YARD (OZ)	TENSION LBS PER 1" WIDE STRIP.
DACRON GREIGE	1.8	60
" "	2.7	95
" "	3.7	150
GRADE "A" COTTON	4.4	80
DYNEL FABRIC	4.0	250



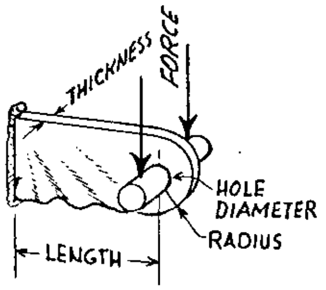




FOR TWO EQUAL FITTINGS DIVIDE LOAD IN HALF

MAXIMUM COMPRESSION OF FITTINGS

THICK-NESS	HOLE DIA.	RAD.	LENGTH	4130 CHROME MOLY LBS.	2024-T3 ALUMINUM LBS.
.040	3/16"	1/4"	1/2"	770	540
			3/4"	600	420
			1"	420	290
.040	1/4"	3/8"	1/2"	1100	770
			3/4"	900	630
			1"	630	440
.063	3/16"	1/4"	1/2"	1260	880
			3/4"	1220	850
			1"	1120	780
.063	1/4"	3/8"	1/2"	1900	1320
			3/4	1820	1270
			1"	1640	1140
.063	1/4"	1/2"	1/2"	2500	1750
			3/4	2350	1640
			1"	2150	1500
.090	1/4"	3/8	1/2"	2800	1960
			3/4	2700	1900
			1"	2600	1800
.090	1/4"	1/2	1/2"	3700	2600
			3/4"	3600	2500
			1"	3450	2400

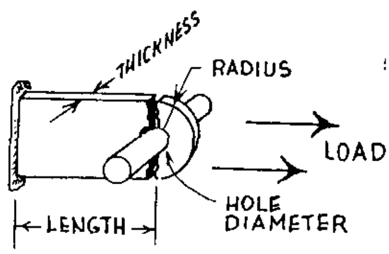


MAXIMUM BENDING LOADS OF FITTINGS

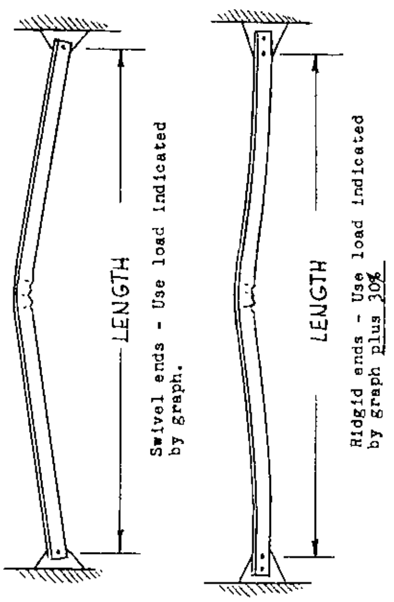
THICK-NESS	HOLE DIA.	RADIUS	LENGTH	4130 CHROME MOLY	2024-T3 ALUMINUM
.063	3/16"	1/4"	1/2"	450	315
			3/4"	320	223
			1"	250	175
			1 1/2"	160	110
.063	1/4"	3/8"	1/2"	1100	770
			3/4"	800	560
			1"	600	420
			1 1/2"	400	280
.063	1/4"	1/2"	1/2"	1700	1200
			3/4"	1300	900
			1"	950	670
			1 1/2"	650	450
.090	1/4"	3/8"	1/2"	1400	980
			3/4"	1100	770
			1"	820	570
			1 1/2"	550	380
.090	1/4"	1/2"	1/2"	2700	1900
			3/4"	2100	1480
			1"	1600	1120
			1 1/2"	1100	770
.090	1/4"	5/8"	1/2"	3500	2450
			3/4"	2700	1780
			1"	2100	1480
			1 1/2"	1400	980

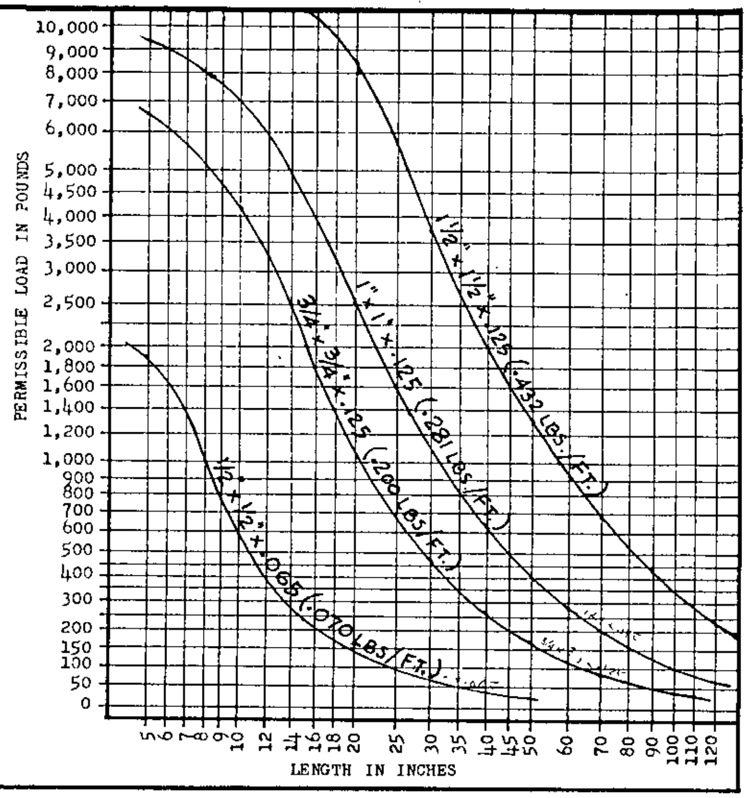
MAXIMUM TENSILE STRENGTH OF FITTINGS

THICK-NESS	HOLE DIA.	RADIUS	BREAK AREA	4130 CHROME MOLY	2024-T3 ALUMINUM
.040	3/16"	1/4"	.012"	830 LBS.	580 LBS.
.040	1/4"	3/8"	.02"	1350 "	950 "
.040	1/4"	1/2"	.03"	2000 "	1400 "
.063	3/16"	1/4"	.02"	1300 "	900 "
.063	1/4"	3/8"	.032	2100 "	1480 "
.063	1/4"	1/2"	.047	3100 "	2200 "
.090	1/4"	3/8"	.045	3000 "	2100 "
.090	1/4"	1/2"	.067	4150 "	2900 "

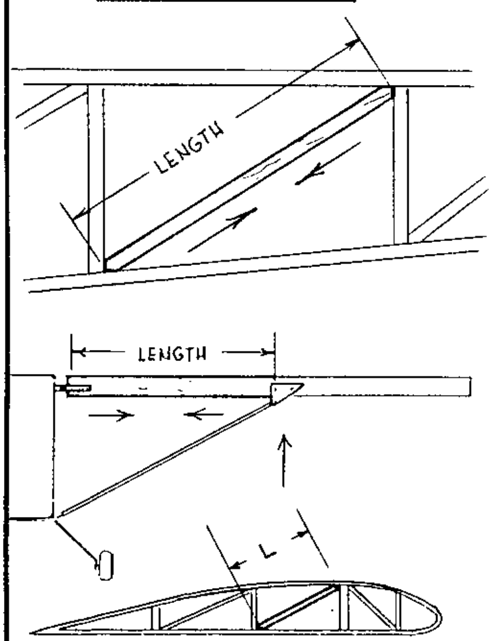


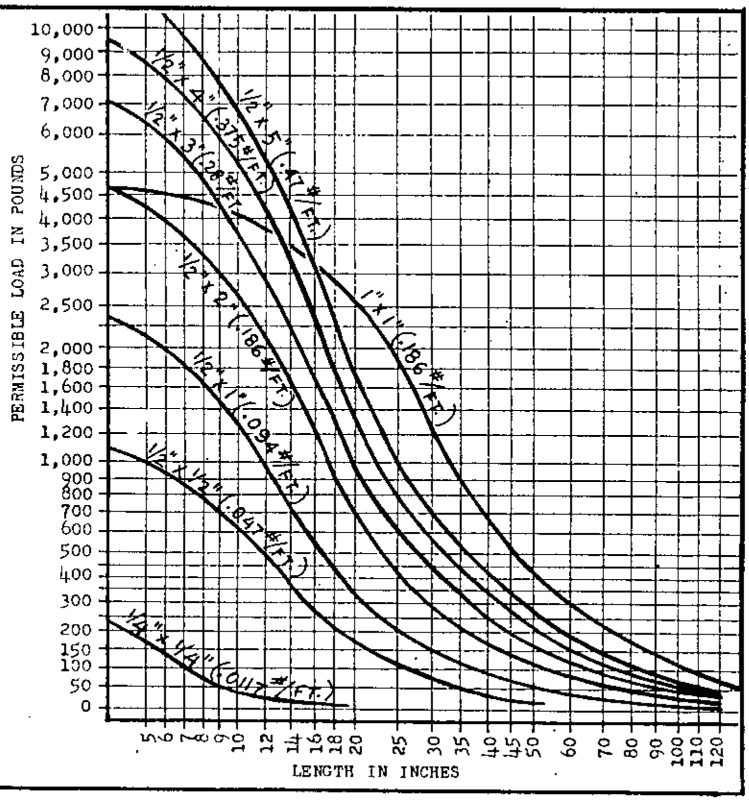
6061 ALUMINUM ANGLE COMPRESSION LOADS



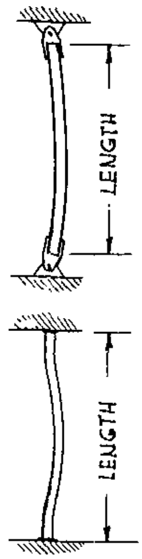


AIRCRAFT SPRUCE COMPRESSION LOADS



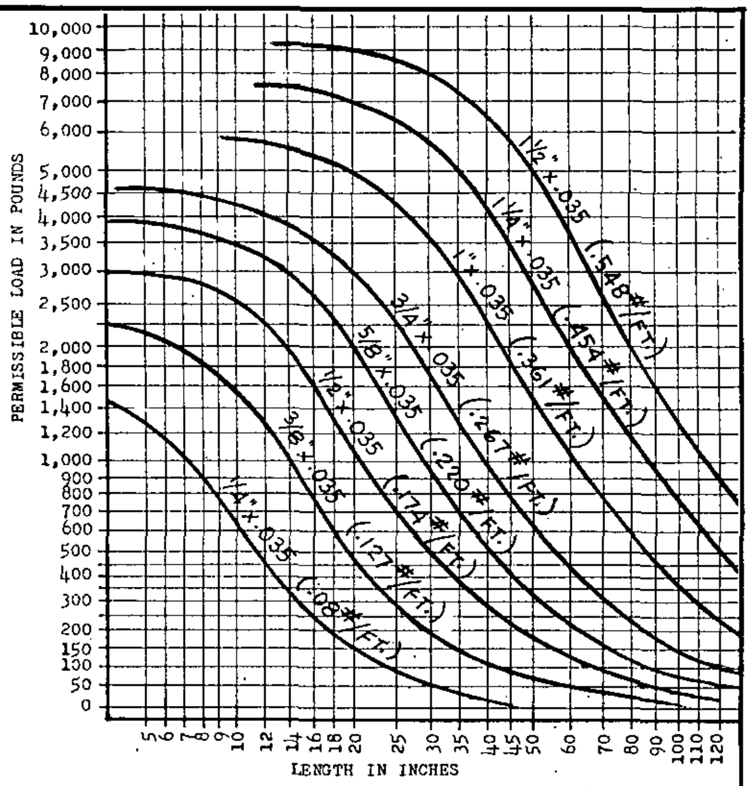


4130 CHROME MOLY SEAMLESS STEEL TUBING COMPRESSION LOADS

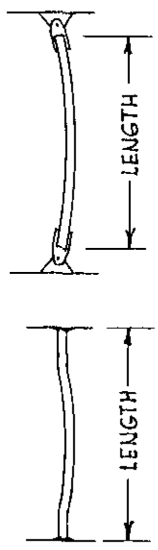


Swivel ends - Use load indicated by graph

Welded ends - use load indicated by graph plus 30%

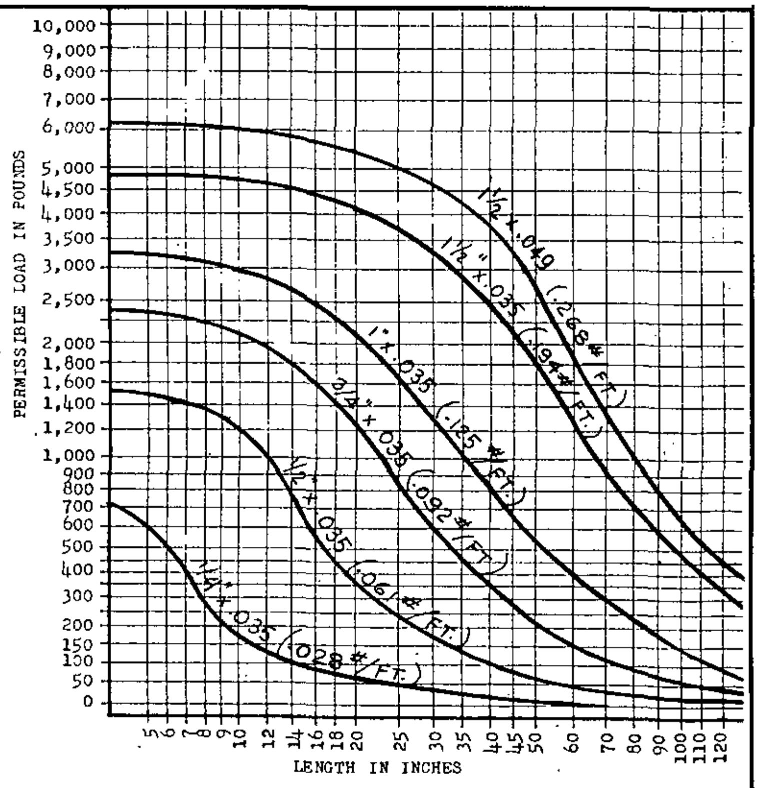


6061 ALUMINUM TUBING COMPRESSION LOADS

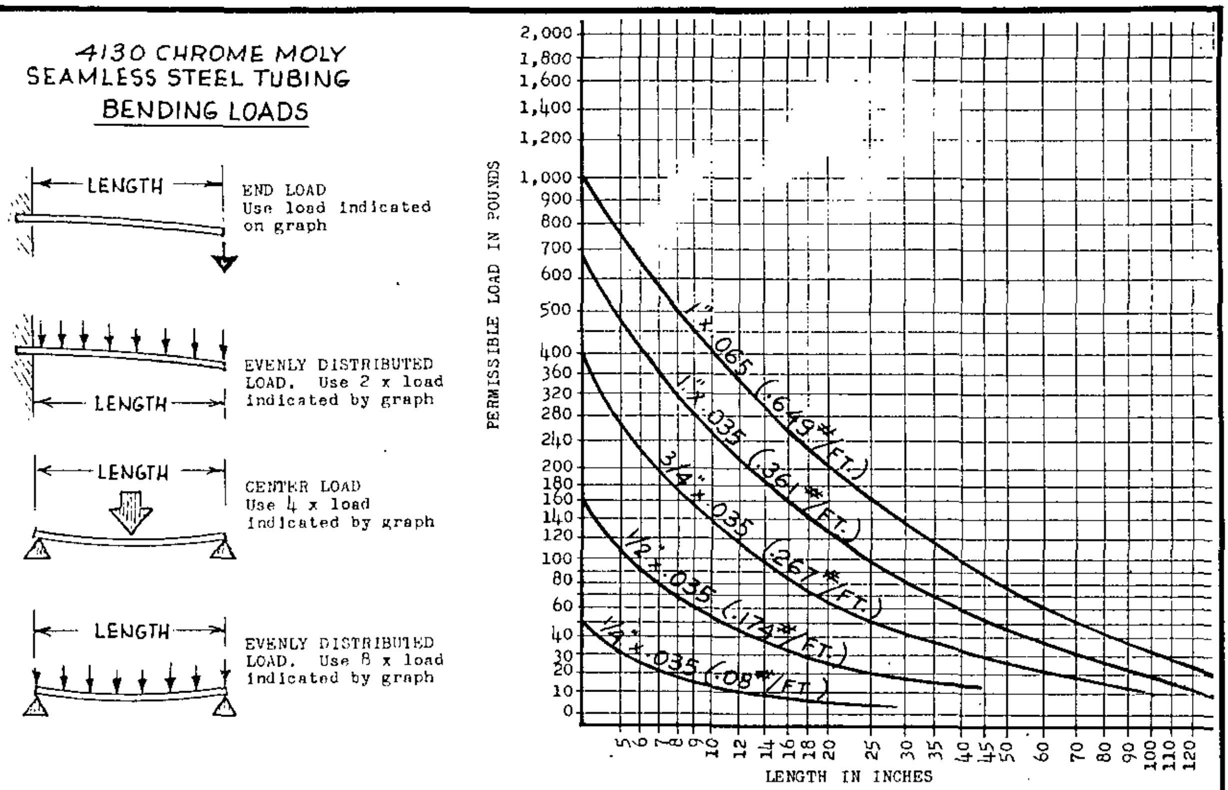


Swivel ends - Use loads indicated by graph

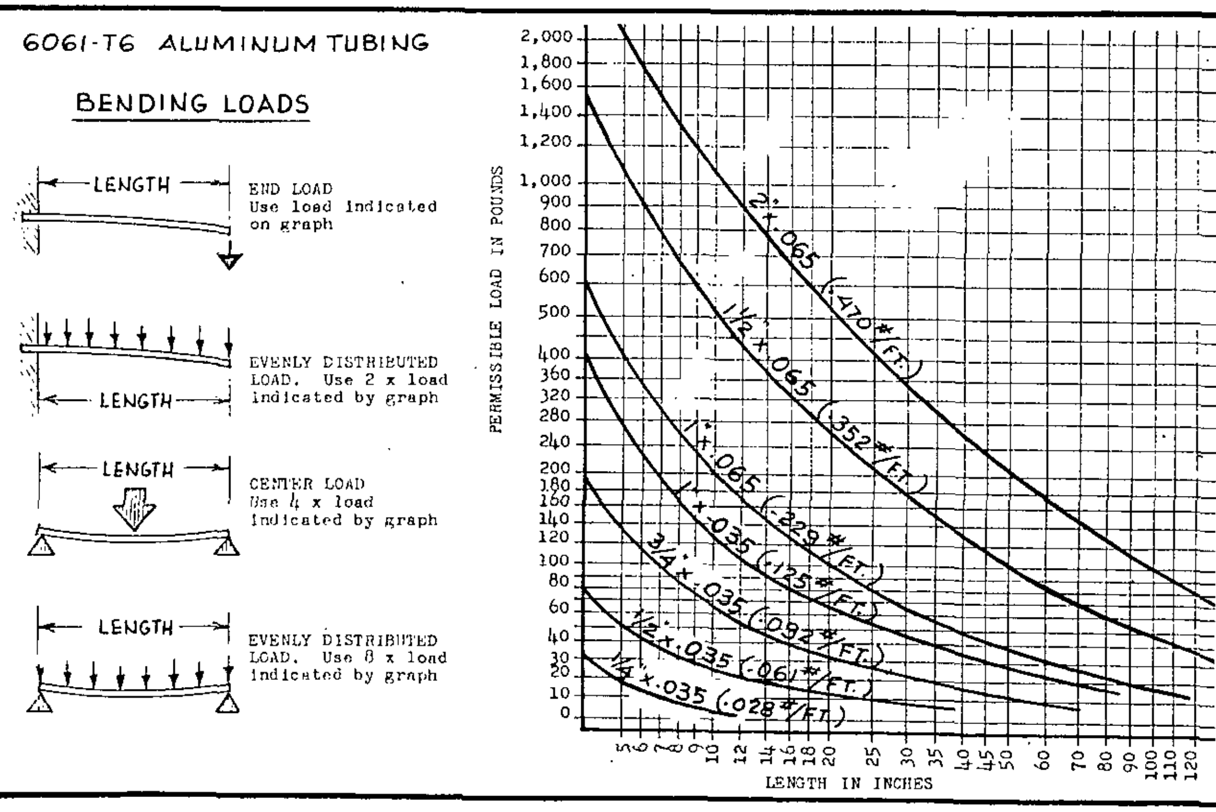
Welded ends - use load indicated by graph plus 30%



4130 CHROME MOLY SEAMLESS STEEL TUBING BENDING LOADS

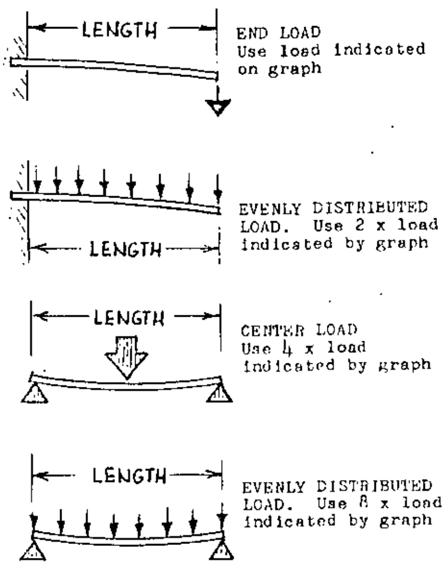


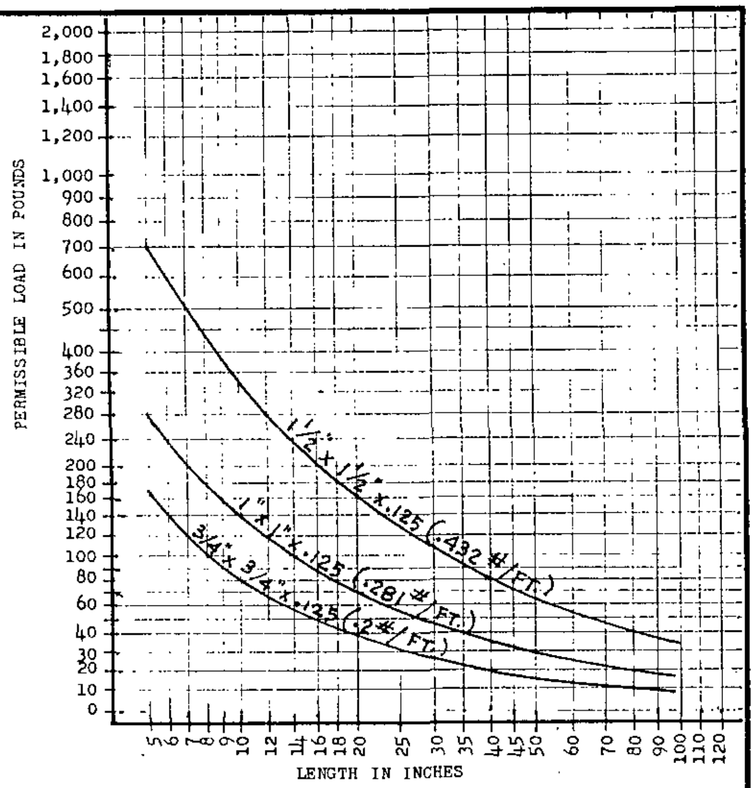
6061-T6 ALUMINUM TUBING BENDING LOADS



6061-T6 ALUMINUM ANGLE

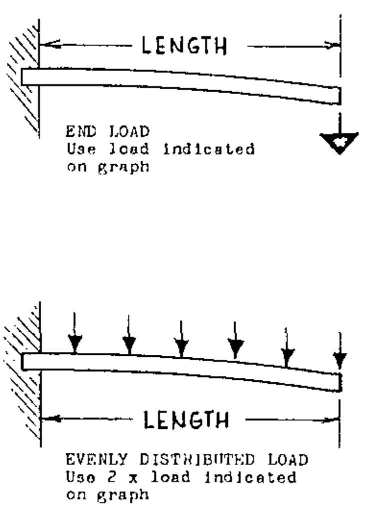
BENDING LOADS

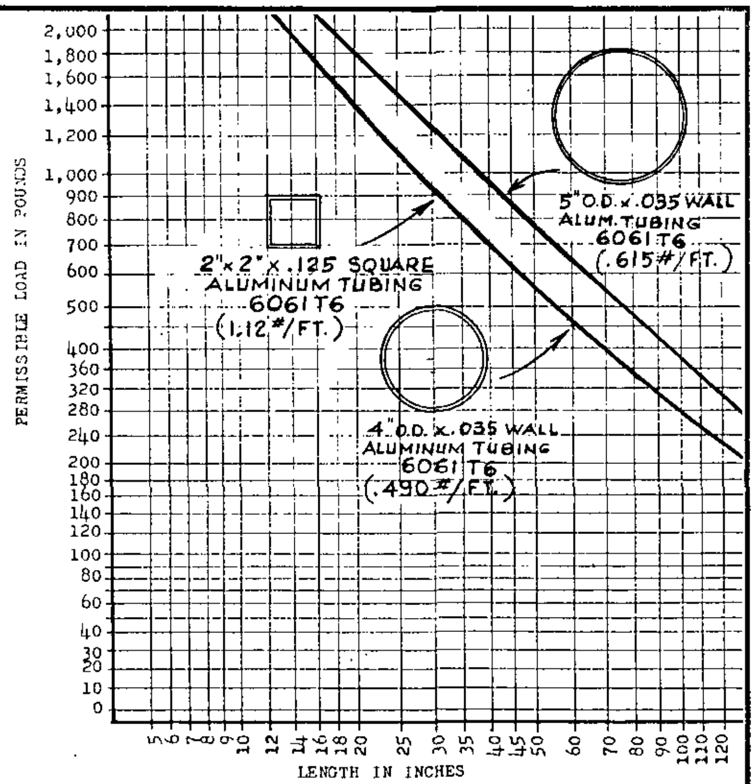




6061-T6 ALUMINUM TUBING

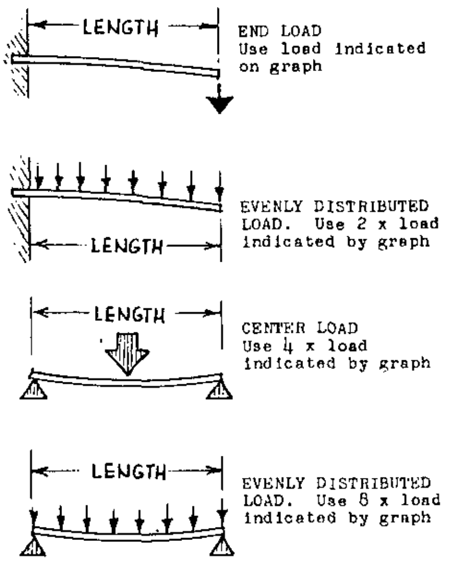
BENDING LOADS

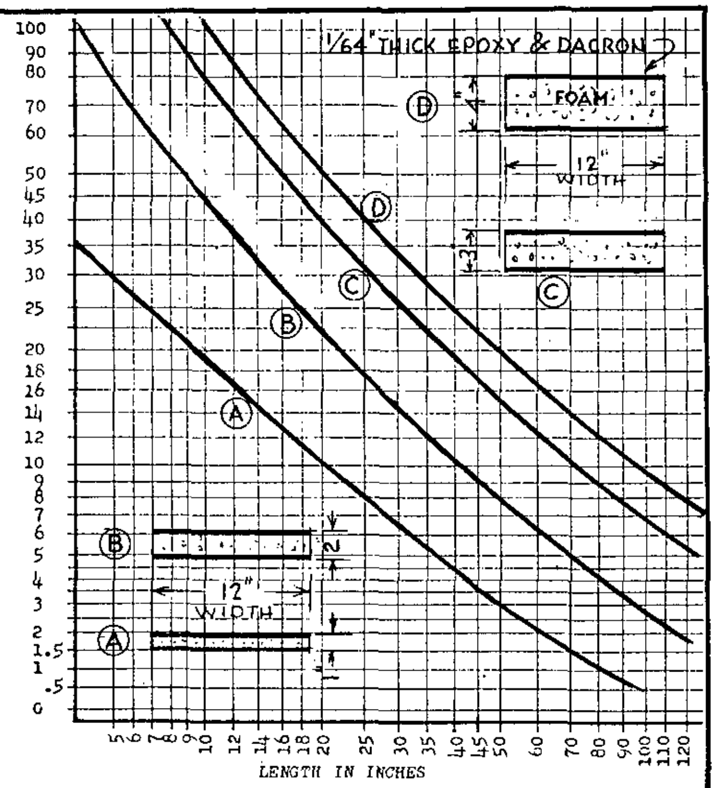




POLYURETHANE FOAM (TAN)
1/64" EPOXY/DACRON COVER TOP AND BOTTOM

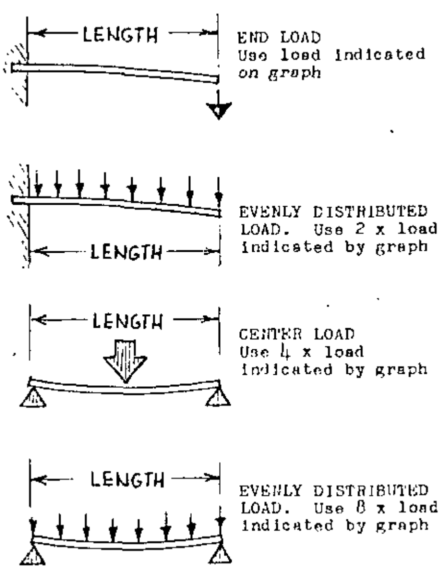
Foam in aircraft is considered highly experimental. These figures should not be used for structural loads

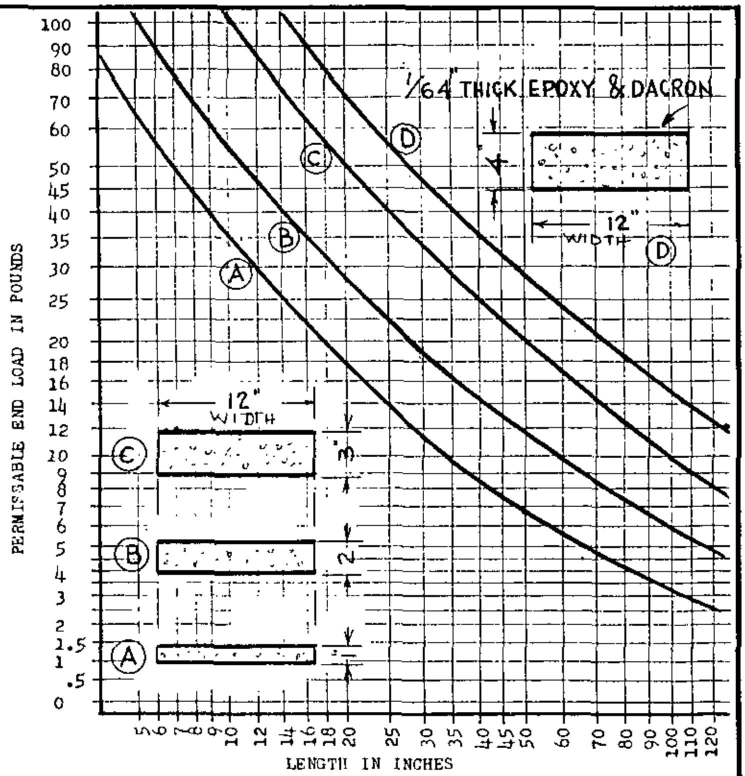




EXTRUDED FOAM (BLUE)
1/64" EPOXY/DACRON COVER TOP AND BOTTOM

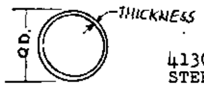
Foam in aircraft is considered highly experimental. These figures should not be used for structural loads.





WEIGHTS OF AIRCRAFT MATERIALS

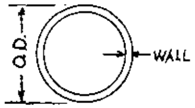
(4)



4130 CHROME MOLY ROUND STEEL TUBING

1/4" O.D.	x	.028 wall		.0664	lbs./ft.
1/4	,,	x .035	,,	.0804	,,
3/8	,,	x .028	,,	.1038	,,
3/8	,,	x .035	,,	.1271	,,
1/2	,,	x .028	,,	.1411	,,
1/2	,,	x .035	,,	.1738	,,
5/8	,,	x .028	,,	.1785	,,
5/8	,,	x .035	,,	.2205	,,
3/4	,,	x .035	,,	.2673	,,
3/4	,,	x .065	,,	.4755	,,
1.	,,	x .035	,,	.3607	,,
1.	,,	x .065	,,	.6491	,,
1 1/4	,,	x .035	,,	.4542	,,
1 1/4	,,	x .065	,,	.8226	,,
1 1/2	,,	x .035	,,	.5476	,,
1 1/2	,,	x .065	,,	.9962	,,
2	,,	x .049	,,	1.021	,,
2	,,	x .065	,,	1.343	,,

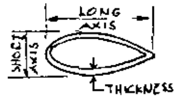
(7)



2024-T3 ROUND ALUMINUM TUBING

1/4"O.D.	x	.035 wall		.0281	lbs./ft.
3/8	,,	x .035	,,	.0449	,,
1/2	,,	x .035	,,	.0612	,,
5/8	,,	x .035	,,	.0775	,,
5/8	,,	x .049	,,	.1060	,,
3/4	,,	x .049	,,	.1288	,,
3/4	,,	x .065	,,	.1670	,,
1	,,	x .035	,,	.1250	,,
1	,,	x .049	,,	.1754	,,
1	,,	x .065	,,	.2295	,,
1 1/4	,,	x .049	,,	.2213	,,
1 1/2	,,	x .049	,,	.2683	,,

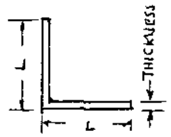
(6)



4130 CHROME MOLY STREAMLINE TUBING

1.180" x .500" x .035" wall		.3140	lbs./ft.
1.685 x .714 x .049	,,	.6285	,,
2.360 x1.000 x .049	,,	.8902	,,

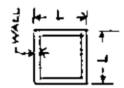
(9)



2024-T3 ALUMINUM ANGLE

1/2" x 1/2" x .062"thick	.070	lbs./ft.
5/8 x 5/8 x .062 ,,	.095	,,
3/4 x 3/4 x .062 ,,	.109	,,
1 x 1 x .062 ,,	.154	,,
1 1/2 x 1 1/2 x .125 ,,	.432	,,

(8)



6061-T6 SQUARE ALUMINUM TUBING

2" x 2" x .125" wall 1.120 lbs./ft.

(1)

EQUIVALENTS IN MEASURING

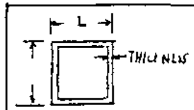
Fraction of inch	Decimal equivalent	Gauge
1/64	.015625	28
1/32	.03125	20
3/64	.046875	18
1/16	.0625	16
5/64	.078125	14
3/32	.09375	13
7/64	.109375	12
1/8	.125	11
9/64	.140625	10
5/32	.15625	9
11/64	.171875	8
3/16	.1875	7
13/64	.203125	6
7/32	.21875	5
15/64	.234375	4
1/4	.25	3

(15)

PLEXIGLAS SHEETS

.060" thick	.37 lbs./sq. ft.
.080 ,,	.49 ,,
.125 ,,	.62 ,,

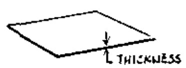
(5)



4130 CHROME MOLY SQUARE STEEL TUBING

1/2" x 1/2" x .035 wall	.2213	lbs./ft.
5/8 x 5/8 x .035 ,,	.2808	,,
3/4 x 3/4 x .035 ,,	.3403	,,
7/8 x 7/8 x .035 ,,	.3998	,,
1 x 1 x .035 ,,	.4593	,,

(10)



2024-T3 ALCLAD ALUMINUM SHEET

.016" thick	.230 lbs./sq. ft.
.025 ,,	.360 ,,
.032 ,,	.461 ,,
.063 ,,	.907 ,,
.090 ,,	1.300 ,,
.125 ,,	1.800 ,,

(3)

4130 CHROME MOLY STEEL SHEETS

.025" thick	1.00 lbs./sq. ft.
.036 ,,	1.45 lbs./sq. ft.
.063 ,,	2.55 ,,
.090 ,,	3.66 ,,
.125 ,,	5.10 ,,

(16)

FLUIDS

Gasoline	6.0 lbs./gal.
Oil	7.5 lbs./gal.
water	62.5 lbs./cu. ft.

(13)

Layer of epoxy/ 1.8 dacron/ epoxy	approx.	.06 lbs./sq. ft.
Single layer epoxy over foam	approx.	.04 lbs./sq. ft.
Single layer epoxy over plywood	approx.	.03 lbs./sq. ft.

(14)

GLUES AND EPOXIES

RECORCINOL - FORMALDEHYDE GLUES. Most highly recommended. Use on wood. Completely waterproof. Withstands high temperatures. Marketed under various trade names such as Amberlite, Cascophen, Weldwood, etc. Hardens through catalytic action of resin and hardener. Do not use on foams, as it will shrink and crack.

UREA - FORMALDEHYDE GLUES. Waterproof. Excellent for wood. Sensitive to high moisture content of wood. Marketed as Aerolite, LePages Panite, Casco, Plaskon, etc. Hardens through catalytic action of resin and hardener. Never use on foam.

EPOXIES. Excellent for almost all materials. Does not shrink. Recommended for foam. Hardens through curing action of resin and hardener. Does not loose weight during curing. Varies from liquid to paste. Marketed under many trade names, including Flyte Bond, Epon 815, Loctite, etc.

(11)

FABRICS

Dacron Greige, 66" wide	1.8 oz./sq. yard or	.0125 lbs./sq. ft.
,, ,, ,, ,,	2.7 ,, ,, ,, ,,	.0186 ,, ,, ,,
,, ,, ,, ,,	3.7 ,, ,, ,, ,,	.0255 ,, ,, ,,
Grade "A" cotton, 60" wide	4.4 oz./sq. yard or	.030 lbs./sq. ft.
Dynel, 39" wide	4.0 oz./sq. yard or	.028 lbs./sq. ft.

(12)

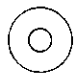
FOAMS

Urethane foam (tan)	2 lbs./cu. ft.	sizes: 1/2"x 2' x 4' 1 " x 2' x 4' 2 " x 2' x 4'
Extruded foam (blue)	2.2 lbs./cu. ft.	sizes: 1/2"x 2' x 4' 1" x 2' x 4' 2" x 2' x 4'

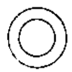
(2)

WOOD

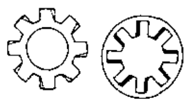
Sitka Spruce	.016 lbs./cu. in.
Pine	.016 lbs./cu. in.
Birch	.025 lbs./cu. in.
Balsa	.006 lbs./cu. in.
1/32" Birch Plywood	.156 lbs./sq. ft.
1/32" Mahogany Plywood	.125 lbs./sq. ft.
1/16" Birch Plywood	.225 lbs./sq. ft.
1/16" Mahogany Plywood	.180 lbs./sq. ft.
1/8" Birch Plywood	.470 lbs./sq. ft.
1/8" Mahogany Plywood	.375 lbs./sq. ft.
1/4" Birch Plywood	.98 lbs./sq. ft.
1/4" Mahogany Plywood	.78 lbs./sq. ft.



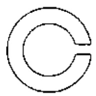
AN 970 Flat Wood Washer



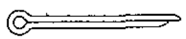
AN 960 Flat Washer



AN 936 A Lock
AN 936 B Washers

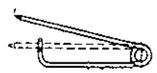


AN 935 Lock Washer



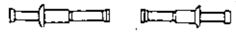
AN 380 Cotter Pin

AN 415-2
Lock Pin



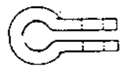
AN 416
Safety Pin

AN 426 Alum. Flathead Rivet
AN 470 Alum. Universal head Rivet



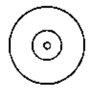
CR 162
CR 163
Cherry Rivets

AN 100 Thimbles



AN 115 Cable Shakle

CONTROL CABLES
7 x 7 Flexible Control Cable
7 x 19 Extra Flexible Control Cable
1 x 19 Non Flexible Cable

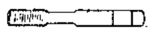


AN 210
AN 220
Flight Control Pulleys

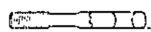
Turnbuckle Parts

AN 155 Barrel

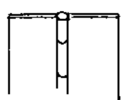
AN 161 Fork



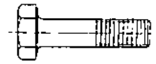
AN 165 Pin Eye



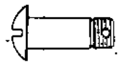
AN 170 Cable Eye



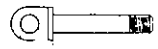
Piano Hinge
MS 20257P
MS 20001



AN 3 - AN 20
Airframe Bolts

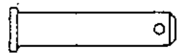


AN 21 - AN 36
Clevis Bolts



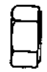
AN 42 - AN 49
Clevis Bolts

AN 73 - AN 81
Prop/Engine Bolts



AN 392 - AN 395
Clevis Pins

AN 364, AN 365
Elastic Stop Nuts



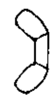
AN 315 Full Hex
Airframe Nut

AN 316
Thin Check Nut

AN 310
Castle Nut

AN 320
Shear Nuts

MS 17825 Self Locking
Castle Nut



AN 350 Wing Nut

AN 366
Two lug anchor nuts

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For full and detailed information, write Aircraft Spruce and Specialty Co., Box 424, Fullerton, California, 92632

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