Feb. 6, 1951 D. E. HERVEY 2,540,482

WOODEN STRUCTURE AND METHOD

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FIG. 1

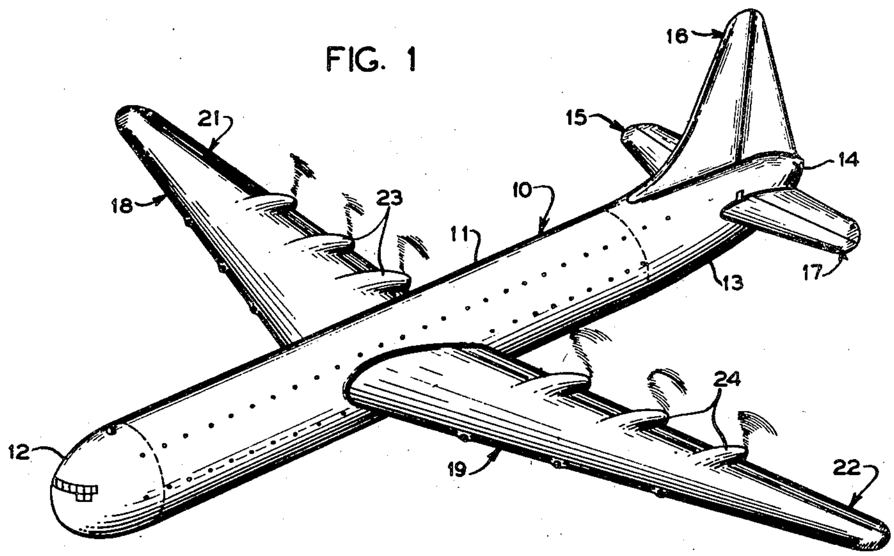


FIG. 2

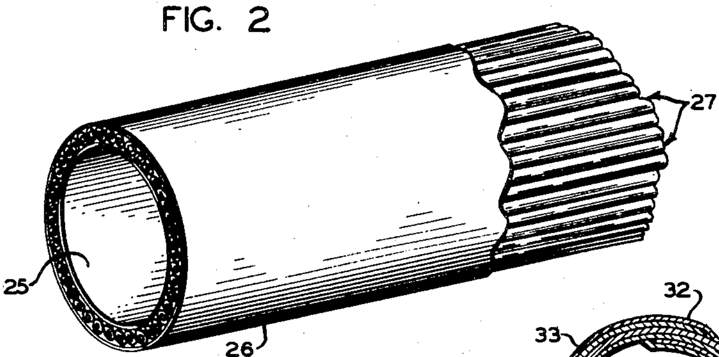


FIG. 4

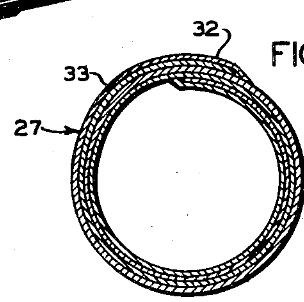
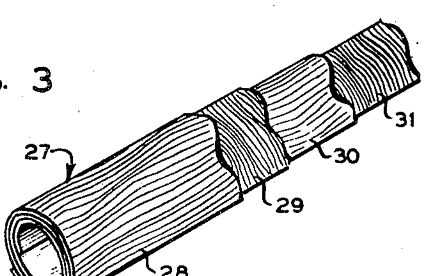


FIG. 3



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WOODEN STRUCTURE AND METHOD

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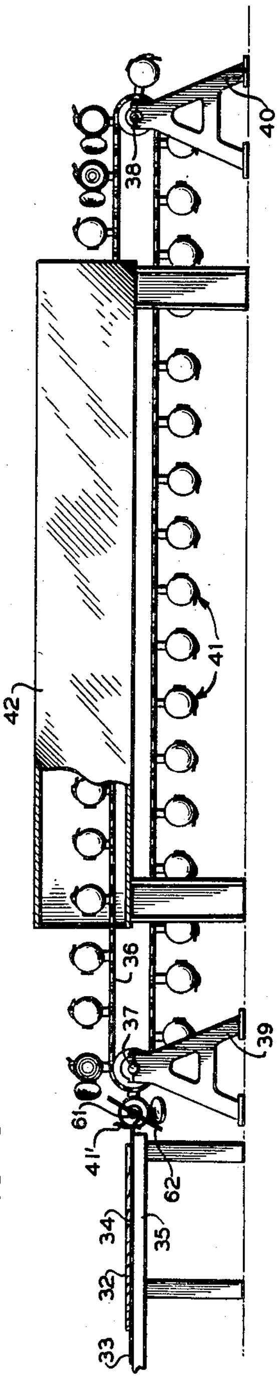

FIG. 5

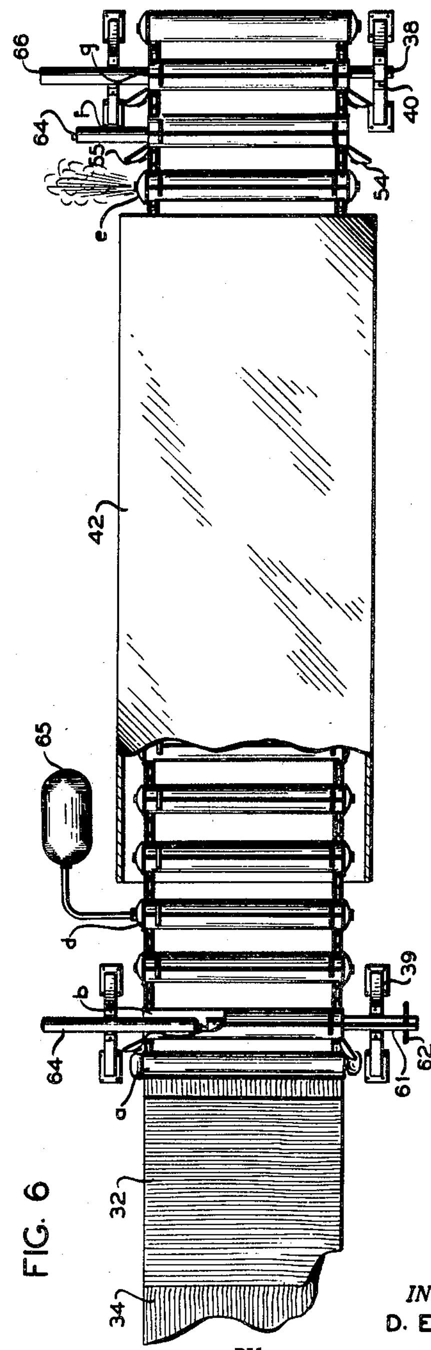

FIG. 6

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FIG. 7

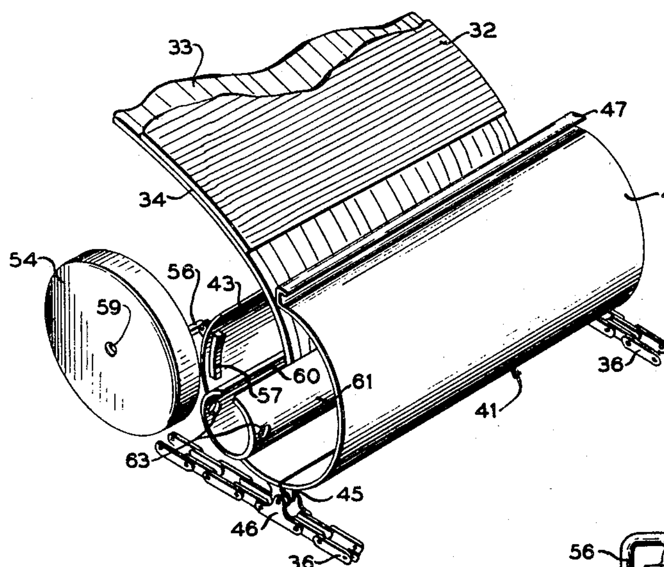


FIG. 8

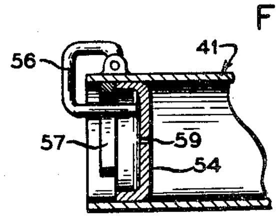


FIG. 9

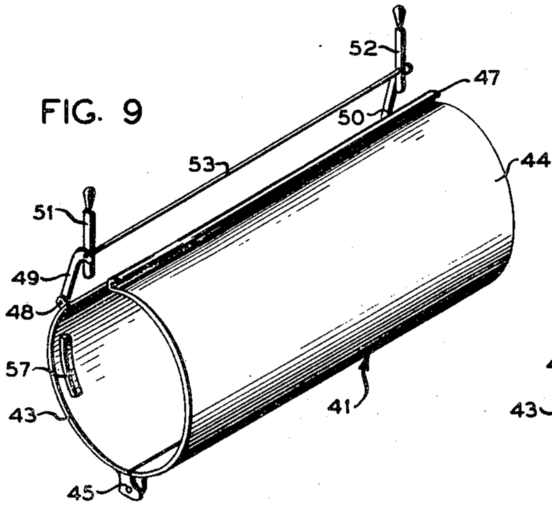
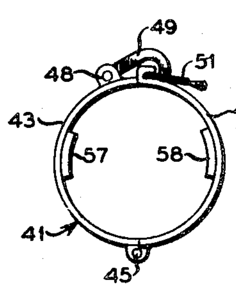


FIG. 10



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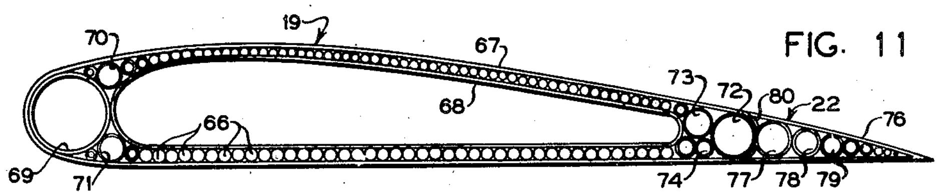

FIG. 11

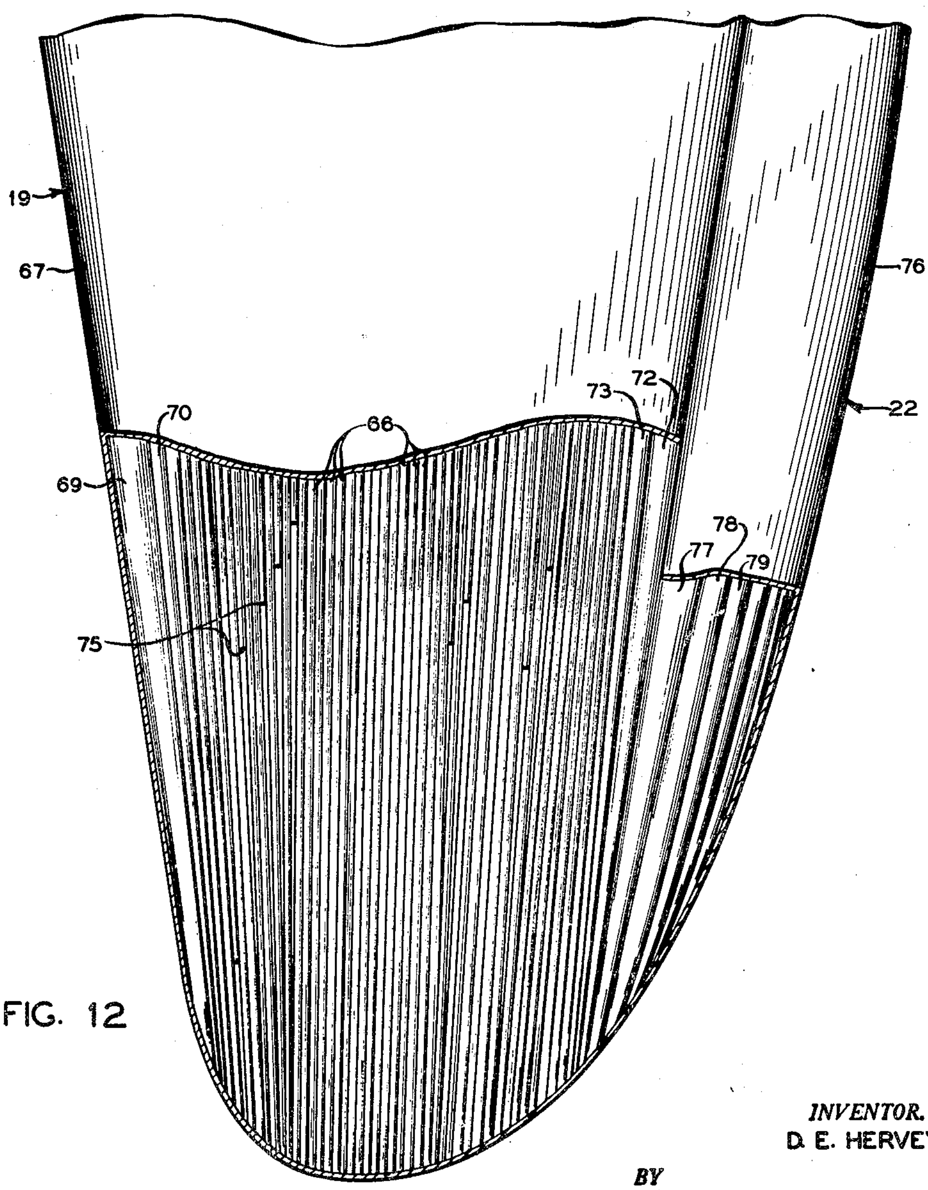

FIG. 12

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FIG. 13

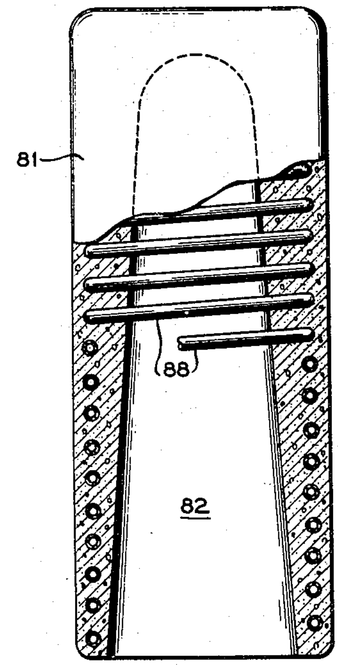


FIG. 15

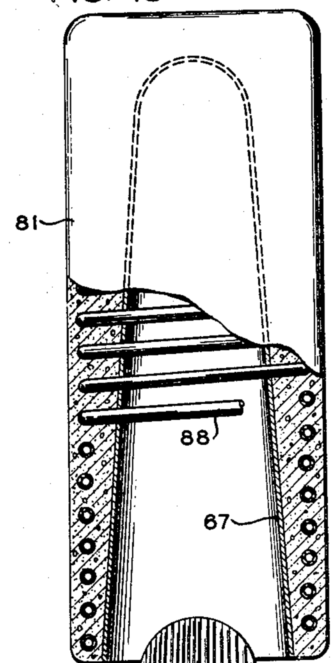


FIG. 14

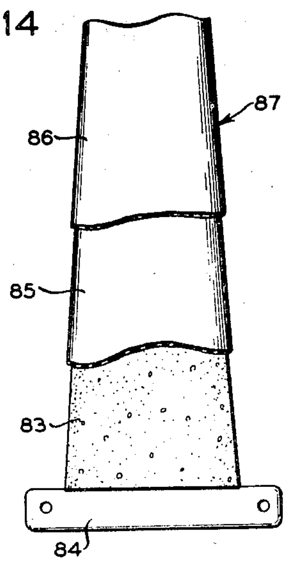
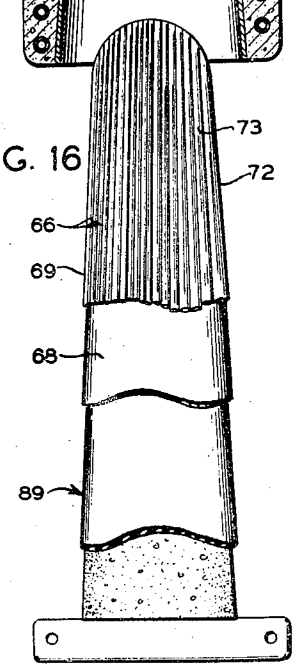


FIG. 16



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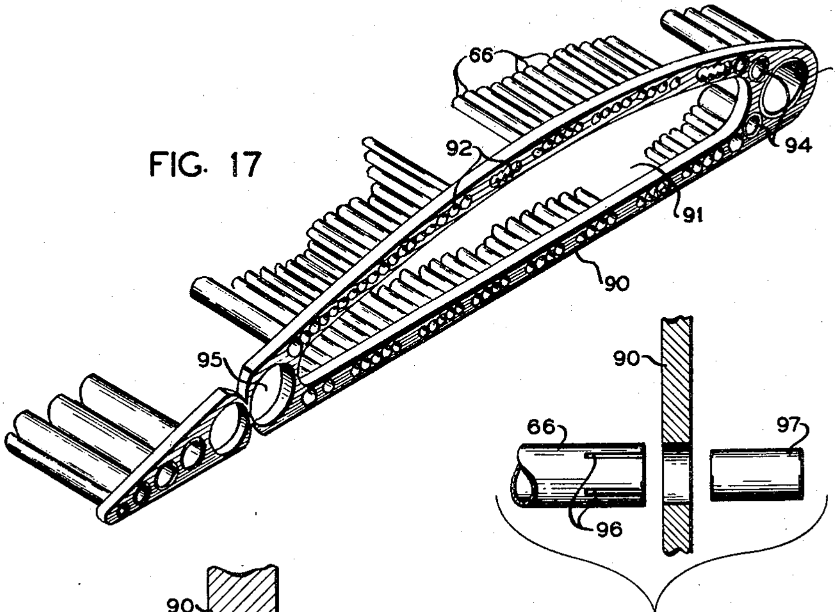

FIG. 17

FIG. 18

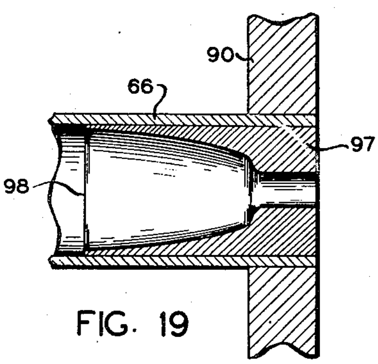

FIG. 19

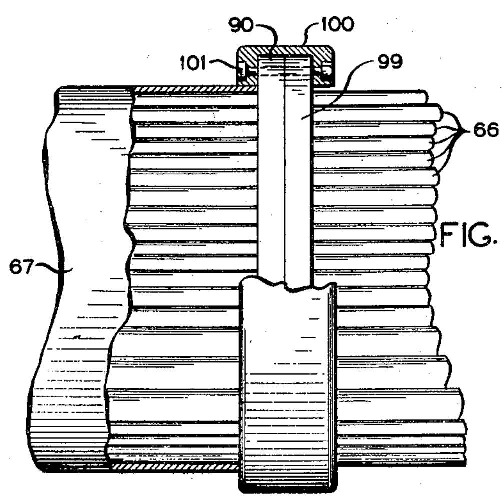

FIG. 20

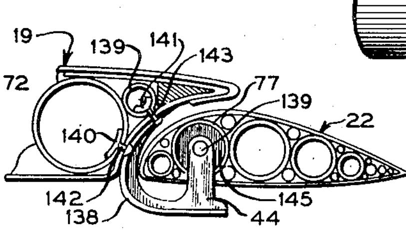

FIG. 29

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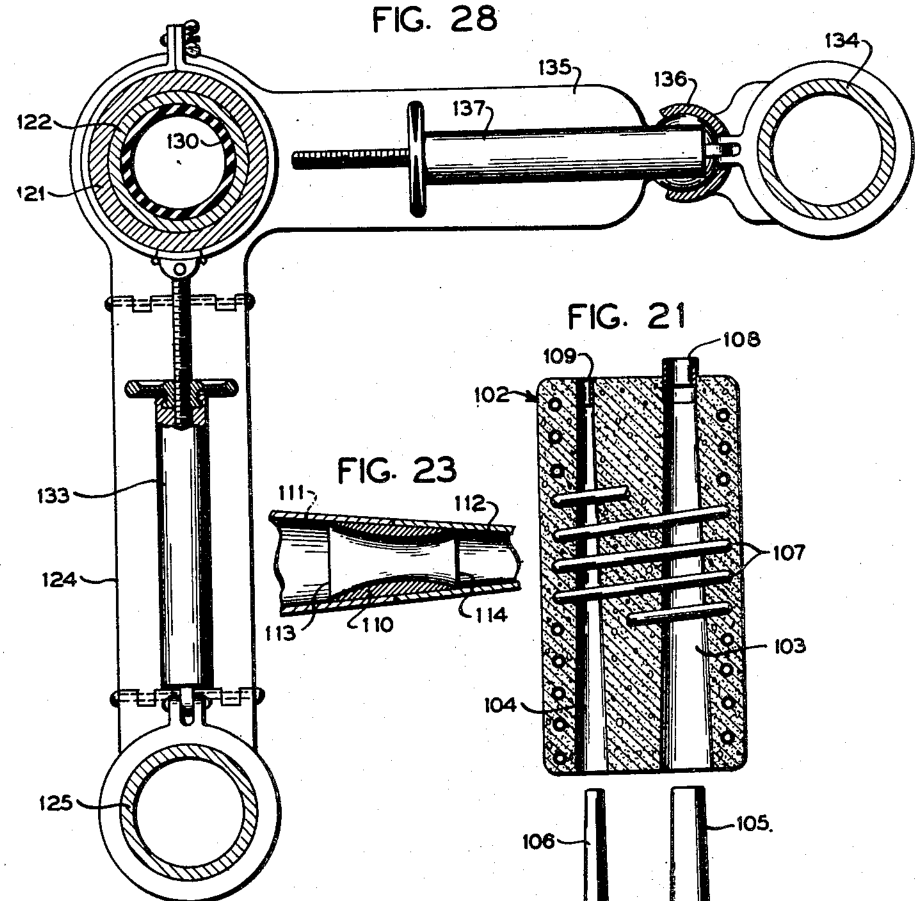
FIG. 28

FIG. 21

FIG. 23



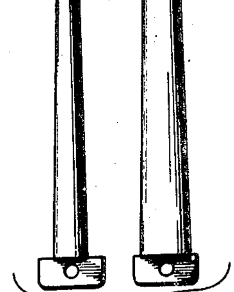
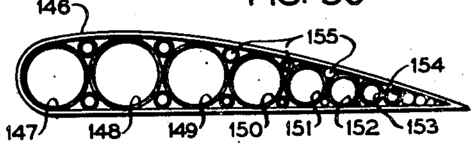


FIG. 22

FIG. 30



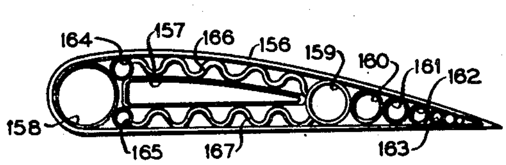


FIG. 31

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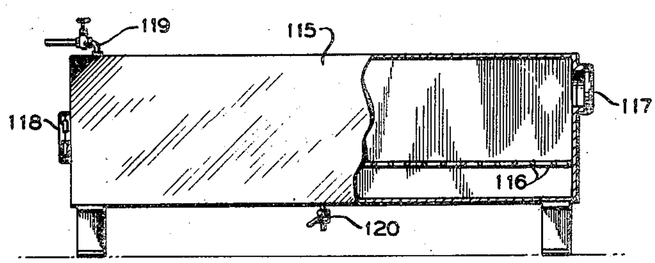

FIG. 24

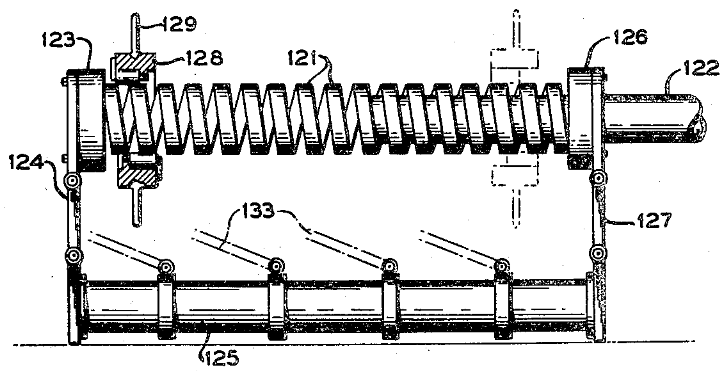

FIG. 25

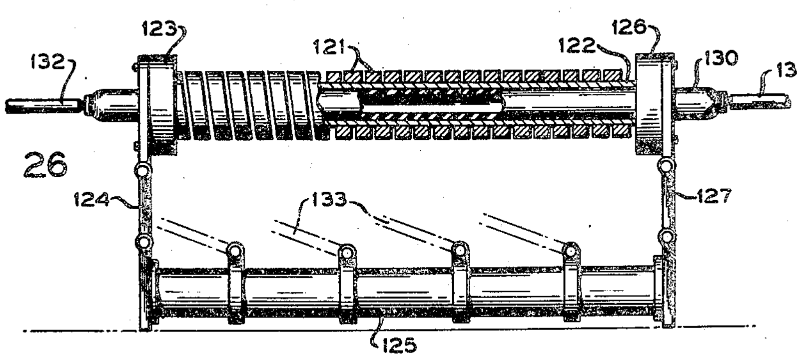

FIG. 26

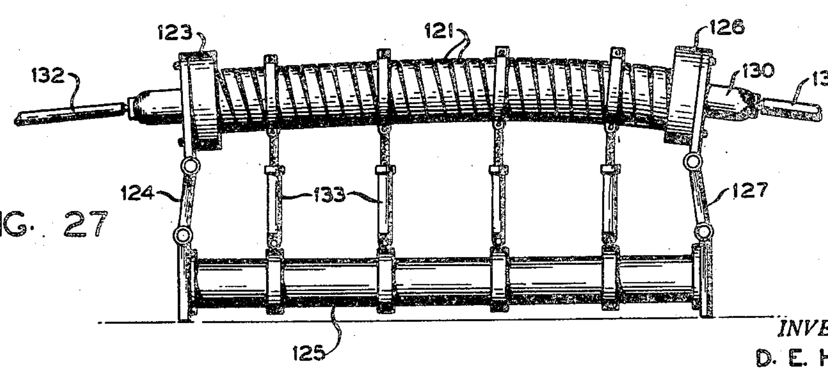

FIG. 27

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Patented Feb. 6, 1951 **2,540,482**

UNITED STATES PATENT OFFICE

2,540,482

WOODEN STRUCTURE AND METHOD

David E. Hervey, Old Fort, N. C., assignor to Hervey Foundation, Incorporated, a corporation of Maryland

Application October 1, 1946, Serial No. 700,502

11 Claims. (Cl. 244—123)

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This invention relates to improvements in wood structures and particularly to an improved construction for airplanes having major structural parts made principally or entirely of wood.

Various constructions have been proposed for manufacturing aircraft parts of wood in which thin wood veneer is used for the skin or covering of such parts. These previously proposed constructions, however, have been subject to various deficiencies and defects which have curtailed the use of wood for aircraft construction to such an extent that nearly all present day aircraft comprise expensive and relatively heavy sheet metal parts, most of the exceptions having the flimsy, out-moded, construction comprising a wood or metal frame and a fabric covering.

Such previously proposed wood veneer constructions have been found to lack the necessary strength and flexibility for the heavy stresses incurred in aircraft operation, to lack adequate facilities for transferring forces from locations of high stress concentration uniformly through the adjoining structure, to have a relatively low strength to weight ratio, and to involve manufacturing difficulties that render that type of aircraft construction unduly expensive.

The wood veneer type of construction has also been found objectionable because of the relatively low scorching and ignition temperatures of the wood veneer heretofore available, its hygroscopic nature, and relatively rapid deterioration under operating conditions.

At the same time, wood veneer construction for the structural units of aircraft possesses many advantages provided the major defects can be successfully overcome. The wood veneer is relatively inexpensive as raw material, it has, under favorable conditions, an extremely high strength to weight ratio, and has sufficient inherent resiliency to render it satisfactory aircraft material provided it is so applied that reasonable advantage is taken of its inherent qualities of strength, stiffness and elasticity.

It is therefore among the objects of the present invention to provide an improved construction for aircraft structural parts formed of wood veneer, and improved methods for manufacturing such parts and the components thereof whereby such structural parts may be produced on a mass production basis with a minimum of hand labor and at minimum expense, and wherein the natural strength and resiliency of the wood is used to the highest advantage.

A further object resides in the provision of an improved aircraft structure formed of wood

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veneer wherein the structural components uniformly distribute forces between locations of high stress concentration and the adjoining structure.

A still further object resides in the provision of an improved aircraft construction having load transmitting tubular members formed of wood veneer.

Another object resides in the provision of an improved method and improved apparatus for performing the components of aircraft structural parts from wood veneer, on a mass production basis and assembling such preformed components without substantial modification of the components during assembly.

Another object resides in the provision of improved method and apparatus for manufacturing wood veneer tubes to be used as components of aircraft structures and for other purposes, and to provide such tubes in a straight, tapered or curved form.

Another object resides in the provision of an improved method and improved apparatus for forming the skin or cover portions of aircraft parts and for assembling such cover portions and reinforcing tubular components into completed structural parts of aircraft, all with a minimum amount of manual labor.

Yet another object resides in the provision of improved structural parts for aircraft which parts are formed of plywood or laminated wood veneer which has a high scorching and ignition temperature and is relatively non-hygroscopic.

Other objects and advantages will become apparent as the description proceeds in conjunction with the accompanying drawings, wherein:

Fig. 1 is a perspective view of an aircraft, various major structural parts of which may advantageously be constructed of components formed of wood veneer or equivalent sheet material;

Fig. 2, a perspective view of a fragmentary portion of an aircraft part, such as a fuselage, showing the manner of constructing such a part of inner and outer cover members and reinforcing tubular spar members between the cover members;

Fig. 3, a perspective view of a fragmentary portion of a tubular spar member illustrating the manner in which it is formed;

Fig. 4, a transverse sectional view on a somewhat enlarged scale of the tubular spar member illustrated in Fig. 3;

Fig. 5, a somewhat diagrammatical elevational side view of suitable apparatus for manufacturing tubular spar members from sheets of wood veneer;

Fig. 6, a top plan view of the tubular spar manufacturing apparatus shown in Fig. 5;

Fig. 7, a perspective view on an enlarged scale illustrating in detail a suitable mold in which the tubular spar members are formed, and a mandrel for rolling veneer sheets into tubular form within the mold;

Fig. 8, a longitudinal sectional view of a fragmentary end portion of the mold shown in Fig. 7, illustrating the manner in which the end closure door is held in closing position.

Fig. 9, a perspective view of the forming mold shown in Fig. 7, showing in detail a suitable latch means for securing the two parts of the mold together in operative condition after a roll of veneer sheet has been placed therein;

Fig. 10, an end elevational view of the mold shown in Fig. 9 showing the latch in mold closing position;

Fig. 11, a cordwise sectional view of an airfoil member illustrative of the improved construction of the invention;

Fig. 12, a top plan view of a fragmentary portion of an airfoil member illustrative of the invention, a portion of the outer covering being broken away to better illustrate the construction of the member;

Fig. 13, a plan view of a suitable mold in which a cover of a tapered structural part of an aircraft, such as an airfoil member, may be formed;

Fig. 14, an elevational view of a fragmentary portion of a suitable form or plunger for pressing the cover member into the desired shape in the mold illustrated in Fig. 13 and holding it under compression during the joining process;

Fig. 15, a plan view of a mold in which the outer cover member of the tapered structural part is formed with the outer cover member in place therein;

Fig. 16, a plan view of a form on which the inner cover member is formed, showing reinforcing tubular spar members in place on the inner cover member ready to be inserted into the outer cover member positioned in the mold shown in Fig. 15;

Fig. 17, a perspective view of a fragmentary portion of the root end of an airfoil member showing the manner of attaching the ends of the reinforcing tubular spar members to a suitable transom by means of which the airfoil member may be assembled with other structural parts of the aircraft;

Fig. 18, a sectional view showing in detail the manner of securing the ends of the reinforcing members to the transom;

Fig. 19, a sectional view on an enlarged scale showing the end of a tubular spar member properly secured in the transom at the root end of an airfoil member;

Fig. 20, an elevational view of fragmentary portions of two structural parts showing a suitable arrangement for securing the two parts together;

Fig. 21, a sectional view of a suitable mold for forming tapered tubular spar members;

Fig. 22, a plan view of suitable plunger or form members which cooperate with the mold shown in Fig. 27 to form tapered tubular spar members;

Fig. 23, a sectional view of a fragmentary portion of a tubular spar member showing the manner of securing the adjoining end portions of two tapered sections together;

Figs. 24 to 27 inclusive illustrate apparatus for bending tubular spar members to a permanently curved condition; Fig. 24 showing a steam box for softening the members before bending; Fig. 25 showing apparatus including a flexible spring member for applying external pressure to the tubular member during the bending operation; Fig. 26 showing the flexible spring member tightly wrapped about the tubular member and a pressure bag inserted into the tubular member to apply internal pressure thereto; and Fig. 27 showing the assembly in bent or curved condition;

Fig. 28, a transverse sectional view on a somewhat enlarged scale showing the tube bending apparatus arranged to curve the tube in two different directions;

Fig. 29, a cordwise sectional view of the trailing edge portion of a wing section showing the manner of attaching a movable flap or aileron member to the fixed portion of the wing section;

Fig. 30, a cordwise sectional view of an airfoil member of modified construction; and,

Fig. 31, a cordwise sectional view of a further modified form of airfoil member.

With continued reference to the drawings, the aircraft illustrated in Fig. 1 and which may be of any conventional or desired form, has various structural parts. The fuselage, generally indicated at 10, comprises a substantially cylindrical center portion 11, a front end portion 12 of somewhat spheroid shape, and a rear portion 13 curvingly tapered from its connection with the rear end of the cylindrical fuselage portion 11 to its terminal point 14 and supporting the empennage members 15, 16 and 17. The aircraft also has tapered wing members 18 and 19 of airfoil form, each provided with one or more relatively movable portions 20 and 21 at the trailing edges thereof to provide flaps and ailerons for maneuvering the aircraft. The aircraft is also provided with one or more power plants as indicated at 22 and 23 and with landing gear units, not illustrated, and other necessary components. The present invention contemplates constructing the various structural parts of the airplane, such as the fuselage 10, wings 18 and 19, flaps and ailerons 21 and 22, and empennage members 14, 15 and 16 of reinforced plywood formed from wood veneer sheets in a manner to be later described in detail. The power plant units, landing gear units, and other necessary aircraft components are mounted onto the appropriate structural units formed of wood veneer and the various structural units are secured together in their operative relationship.

The manner of forming the substantially cylindrical center portion 11 of the aircraft fuselage, is particularly illustrated in Fig. 2. Other similar parts are formed in the same manner. In this construction a tubular inner cover member 25 and a complementary outer cover member 26 are preformed in suitable molds. It has been found that a suitable mold for this purpose may conveniently be made from reinforced concrete in which are embedded fluid conduits for applying heat to the cover member during the bonding operation by passing steam or other hot fluid or liquid through the conduits. Pieces of wood veneer sheet having bonding material applied to the proper surface portions thereof are laid up in the mold to the desired thickness and with the grain structure of the various sheets extending in different directions as may be desired. A suitable internal pressure member, such as a pneumatic bag or a rigid plunger, is then inserted into the mold to apply internal pressure to the plywood pieces. Where the cover is for a tapered member it has been found convenient to use a tapered plunger for applying different internal pressure and where the part does not have sufficient taper to use a plunger a pressure exerting device in the form of a pneumatic bag may be conveniently used. A pneumatic bag can be used, of course, under both conditions. Heat may be applied to the inner surface of the cover member by forcing fluid at the proper temperature through the pneumatic bag under the desired pressure.

Since the wood veneer is bonded under heat and pressure, the bonding material may be a thermosetting synthetic resin or plastic having a high scorching and ignition temperature and may be caused to penetrate or impregnate the thin sheets of plywood to an extent sufficient to render the wood non-inflammable and non-hygroscopic to an entirely satisfactory degree. The temperature and pressure can also be made high enough to substantially avoid the use of inflammable solvents and plasticizers.

The two cover members are thus preformed and have different diametrical dimensions so as to provide between them a space in which the reinforcing tubular spar members 27 are disposed. The width of the space between the two cover members and the corresponding diameter of the tubular spar members is determined by an analysis of the stresses to which the particular structural part of the aircraft is subjected and of the strength factors of the cover members and reinforcing tubes necessary to resist such stresses with the desired factors of safety.

The assembly is preferably made by placing the reinforcing members on the outer surface of the inner cover member with bonding material between the reinforcing members and the cover, applying bonding material to the outer portions of the reinforcing members and assembling the inner cover and reinforcing members with the outer cover, after which heat and pressure are applied to bring the reinforcing members into firm contact with both cover members and with each other and to set up the bonding material to securely bond the reinforcing members to both cover members and to each other.

It has been found that the assembly of such members is greatly facilitated if the structural part is tapered, a very slight taper, being sufficient where a substantially cylindrical part is desired.

The construction of the tubular reinforcing members or spars is particularly indicated in Figs. 3 and 4. The tubular member 27, as illustrated in Figs. 3 and 4, is formed of several layers of wood veneeer as indicated at 28, 29, 30 and 31. While some of these layers will have their grain structure extending lengthwise of the tubular member, it is usually desirable that one or more of the layers have the grain structure of the wood extending circumferentially of the tubular member. In the arrangement illustrated the layers 28 and 30 have the grain structure disposed generally lengthwise of the tube while the layers 29 and 31 have the grain structure disposed generally circumferentially of the tube form.

This arrangement may be varied depending upon the direction in which it is desired to have the maximum strength of the tube. For example, if the strength is to resist crushing of the tube it would be desirable to have more than the indicated layers with the grain arranged circumferentially. However, if the maximum strength is to resist lengthwise tension and compression on the tube then it is desirable to have the grain structure of the greater number of layers extending generally lengthwise of the tube. If desired, one or more of the layers may be so arranged that the grain structure of the wood runs in an oblique or spiral direction around the tube.

While a substantially cylindrical tube form is illustrated, it is to be understood that the tubes may have any desired cross sectional shape such as polygonal, elliptical, oval, etc.

As shown in Fig. 4, a suitable manner of forming the tubular spar members is to secure together two sheets of veneer 32 and 33 to form a plywood sheet with the grain structure of one plywood sheet extending across the grain structure of the other sheet and to roll the plywood sheet thus formed into tubular form. In the tube illustrated in Fig. 4, the plywood has been wrapped twice to provide a wall of two-ply thickness or a thickness corresponding to four of the veneer sheets. It is obvious, however, that plywood sheet may be wrapped as many times as may be desired to give any desired wall thickness.

Suitable apparatus for manufacturing the tubular spar members on a mass production basis is illustrated in Figs. 5 to 10 inclusive.

As shown in Figs. 5 and 6, the plywood sheet 34 formed of the two laid up veneer sheets 32 and 33 is supported on a suitable table or platform 35 located at one end of a suitable conveyor 36. This conveyor may conveniently comprise two or more parallel endless chains supported on sprockets carried by axles 37 and 38 journalled in bearings on the upper ends of corresponding supporting standards 39 and 40. A plurality of hollow molds, generally indicated at 41, are secured to the conveyor chains and are carried from the table 35 at the loading end of the mechanism through a heating oven 42 to the discharge end of the apparatus.

For a more complete description of the molds 41 reference may now be had to Figs. 7 to 10 inclusive. As illustrated in these figures each mold comprises two semi-cylindrical parts 43 and 44 hinged together along one pair of abutting edges by suitable pivoted hinge members as indicated at 45. These hinge members also secure the molds to the chains by having the hinge pins extend through special chain links, as indicated at 46. At the opposite side of the mold one of the edge portions is provided with a grooved bead or ledge 47, illustrated as applied to an edge of the portion 44, while the portion 43 has adjacent the corresponding edge portion outwardly extending apertured lugs, as indicated at 48, to which are pivotally secured the ends of corresponding lever members 49 and 50. Lever members 51 and 52 are pivoted to the free ends of respective levers 49 and 50 and are connected together by a suitable torque bar or rod 53. When it is desired to secure the two parts 43 and 44 of the mold together in cylindrical shape the inner ends of the ledge members 51 and 52 are engaged in the groove of the head 47 and one of the ledge members is then manually turned about its pivotal connection with the corresponding lever until the ledge mechanism is brought to the condition illustrated in Fig. 10 in which the two parts 43 and 44 are releasably locked together in cylindrical form.

While the interior of the molds 41 are shown as cylindrical they may be of any other desired form to produce tubular members of non-circular cross sectional shape if desired.

A pair of end closure members or doors, as indicated at 54 and 55 in Fig. 6, are secured one to each end of each mold 41. The construction and mounting of the closure member 54 is particularly illustrated in Figs. 7 and 8, and may comprise a disk which may, if desired, have a peripheral reinforcing flange and is mounted on the mold by means of a bent hinge 56 which permits it to swing from its closing position shown in Fig. 8 to its open position shown in Fig. 7. A pair of abutment members 57 and 58 within the end portion of the mold overlie corresponding edge portions of the closure member to hold the closure member in position when the mold is closed, as illustrated in Fig. 10. When the mold is open as shown in Fig. 7, the door 54 may be swung outwardly to uncover the end of the mold. The closure members at both ends of the mold are similar in construction and operation except that one of them is provided with an aperture as indicated at 59 through which the air injecting tube of a pneumatic pressure device may be extended.

The loading end of the conveyor between the table 35 and the adjacent end of the oven 42 contains four different loading stations. In the first of these when the mold is at the end of the conveyor, as indicated at 41' in Fig. 5, the mold is opened and the adjacent edge of the plywood sheet 34 is inserted through the mold opening and into a longitudinal slot 60 in a tubular mandrel 61, which is positioned in the mold. The mandrel is then turned by suitable means, such as by a bar 62 inserted through apertures 53 in one end portion thereof. The mandrel is rotated until the desired amount of the plywood sheet has been wound upon the mandrel to form the desired tubular member. If desired, some suitable clipper may be associated with the table 35 to sever the sheet at the desired location or the sheets may be supplied in the proper lengths for particular tubular members.

While the rolling mandrel 61 has been provided to facilitate rolling the veneer sheet material into the mold it may be eliminated if desired and the sheet material rolled by some other means or by hand and a roll of sheet material inserted into the mold through one end thereof.

When a mandrel is used, after the plywood material has been wound into the mold, the mandrel 61 is rotated backwardly a slight distance to free it from frictional engagement with the sheet material, such as plywood, and is then withdrawn from the mold. Just before the mandrel is withdrawn one end of a tubular pneumatic bag 64 is attached to the end of the mandrel and as the mandrel is withdrawn the pneumatic bag is pulled into the plywood wrapped in the mold. In Fig. 6 the stage indicated at A is the wrapping stage in which the plywood is wound into the mold; the stage indicated at B is the stage in which the mandrel is withdrawn and the pneumatic bag pulled into the plywood.

When the mandrel has been completely withdrawn from the mold and the pneumatic bag pulled into it the end closure members, such as 54 and 55, are closed at the stage C and the air injection tube of the pneumatic bag is extended through the aperture in the corresponding closure member. At the next stage D compressed air from container 65 is fed into the pneumatic tubular bag to compress the plywood against the sides of the mold.

The mold then enters the front end of the oven 42 and passes through the oven for an amount of time sufficient to set up the bonding material on the veneer sheets, of which the plywood sheet is formed.

As a certain a mount of time is required to wrap the plywood into the molds, extract the mandrel and pull in the pneumatic bag, close the end closures and inflate the bag, the molds are loaded in a step by step manner so that each loaded mold remains stationary in the oven for successive intervals. It is therefore necessary to use only a relatively short oven. For example, if it requires two minutes to complete the loading of a mold and it requires 10 minutes of heating in the oven to set up the bonding material, the oven would only have to contain five or six molds at one time.

When the molds leave the oven at the opposite end thereof the air in the pneumatic bag is first released at stage E, the end closures are opened and the pneumatic tubular bag removed at stage F, and the completed tube 66 is removed from the mold at stage G after which the molds travel back past the oven to the initial loading stage A, the return travel of the molds being sufficient to permit them to cool off so that the new tube can be wound into them.

The above described apparatus is primarily designed for forming straight tubes of substantially uniform diameter but it is apparent that tapered tubes could be manufactured in the same type of apparatus by providing molds of frustro-conical shape and pneumatic tubular bags of corresponding shape.

Figs. 11 and 12 show the manner of producing an aircraft structural part such as a tapered wing section from the straight tubular members above described and additional members, the construction of which will later be described in detail.

As is shown in Figs. 11 and 12, the wing section, for example the wing section 19 of Fig. 1, has an outer cover member or skin 67 formed of laminated material, such as plywood 30, to the outer surface is bonded a layer of thin sheet material such as sheet aluminum. This outer cover member is preformed as a complete unit before its assembly with the remaining components of the wing section. Within the outer cover 67 there is an inner cover or hollow core 68 which is also preformed of laminated material such as plywood. The inner cover is smaller than the outer cover by an amount which provides spaces between the two cover members at the upper and lower surface of the airfoil section and larger spaces at the leading and trailing edges of the wing section. A tapered tubular spar member 69 is disposed in the leading edge portion of the outer cover and has a radius substantially equal to the radius of curvature of the leading edge of the wing section. Adjacent this tubular member and substantially filling each triangular space between the members 69 and the adjacent portion of inner cover 68 are two tapered tubular spar members 70 and 71, of less diameter than member 69.

At the trailing edge of the wing section 29 there is a tapered tubular spar member 72 having a diameter substantially equal to the thickness of the trailing edge portion of the wing section and adjacent this member 72 are smaller tapered spar members, as indicated at 73 and 74. The remaining portion of the space between the inner cover member 68 and the outer cover member 67 is filled with tubular spar member 66. As is particularly shown in Fig. 12, the smaller end of the tubular members 66 need not be tapered but some of them may be terminated at various locations, as indicated at 75, in order to accommodate them to the tapered form of the wing section. The ends of these members at the tip end of the wing section may be flattened and bonded together to provide a wing tip portion of maximum strength.

As is clearly illustrated in Fig. 12, the leading edge spar member 69 tapers in accordance with the tapering thickness of the wing section and is brought substantially to a point at the tip end of the wing section. This is also true of the members 70, 71, 72, 73 and 74. These tubular spar members all lie in side by side relationship extending spanwise of the wing section and are bonded to the outer and inner cover members 67 and 68 and to each other.

The movable wing portion 22 has an outer cover 76 within which are disposed a plurality of tubular spar members as indicated at 77, 78 and 79 which have diameters substantially equal to the thickness of the member 22 at the locations of these various tubular members. These tubular spar members are bonded to the inner surface of the cover 76 and to each other and are tapered in form, as is clearly shown in Fig. 12. In the illustrated arrangement, the end portions of these spar members at the wing tip are bent as well as tapered to cause them to conform to the particular shape of the wing section. A closure member 80, which may be formed from part of a tubular spar member, is secured to the edge of member 22 which is adjacent the trailing edge of wing section 19. The trailing edge of section 19 may be closed by bringing the outer cover 67 around the surface of the tubular spar 72.

This construction including the tubular spar members 69 and 72 of relatively large diameter, the outer and inner cover members and the reinforcing tubular spar members in the space between the inner and outer cover members, provides an exceedingly strong and flexible construction of very light weight as compared to an equivalent structure of sheet metal and one which is economical to manufacture and the material of which is relatively inexpensive.

It has already been explained how the tubular spar element 66 may be economically produced on a mass production basis. All of the other elements of the improved structural part may be manufactured on such a basis with equal facility.

Figs. 13 and 14 illustrate economical apparatus for manufacturing the outer and inner cover members 67 and 68. This apparatus comprises a mold 81 which may conveniently be provided by placing reinforced concrete about a suitable form, permitting the concrete to harden and removing the form to leave a cavity 82 in the form of the outer surface of the structural part, such as the wing section 19, to be produced. A form or plunger 83, as illustrated in Fig. 14, is provided, which plunger also preferably has a core of reinforced concrete to which is attached a bar 84 by means of which the plunger may be forced into the mold cavity 82 and withdrawn therefrom. Upon the core 83 there is secured a layer 85 of relatively stiff resilient material, such as synthetic rubber and on this resilient material there is provided a covering or sheathing 86 of smooth thin sheet metal, the outer surface of which will have a shape corresponding to the shape of the inner surface of the outer wing section cover 67.

In order to form the outer cover member, wood veneer sheets, to which bonding material has been applied, and a sheet metal outer covering are folded to the shape of the outer cover and placed in the mold cavity 82. The plunger, generally indicated at 87, is then forced into the mold cavity to compress the wood veneer and the sheet metal between the plunger and the mold. Heat may then be applied to the veneer by passing heated fluid, such as steam, through the conduits 88 placed in the mold, and the heating continued until the bonding material has set. If desired, cooling fluid may then be passed through the conduits to cool the bonded material and the plunger 87 then withdrawn.

If a cold setting bonding material is used, it will not be necessary to apply heat to the assembly but merely necessary to maintain the pressure on the material a sufficient length of time for the bonding material to set up.

The inner cover member is made in the same manner except that the mold corresponding to the mold 81 will have a shape corresponding to the external shape of the inner cover and the plunger corresponding to the plunger generally indicated at 89 in Fig. 16, will have an external shape corresponding to the internal shape of the inner cover 68.

For purposes of assembly, when the bonding of the outer cover member 67 is completed and the complementary plunger or form withdrawn, the cover member will be left temporarily in the mold 81 while the corresponding inner cover member 68 will be withdrawn on its plunger 89. A complete set of tubular spar members 69, 66, 73 and 72 will then be positioned upon the outer surface of the inner cover member and secured thereto, bonding material having been applied to the outer surface of the inner cover member. This assembly, as illustrated in Fig. 16, is then inserted into the outer cover member 67 retained in mold 81, as illustrated in Fig. 15 and sufficient pressure is exerted to bring all of the tubular spar members firmly in contact with each other and with both of the cover members. Heat may then be applied, if the bonding material used requires heat, or the pressure may be maintained until a cold setting bonding material has set up. After the bonding has been completed the composite wing section is then removed from the mold 81 and from the plunger or form 89.

It is desirable that in forming the outer cover member a layer of thin sheet metal, such as aluminum, be placed in the mold outside of the wood veneer pieces and bonding material applied so that this metal covering will be firmly bonded to the veneer pieces during the manufacture of the outer cover so that when the wing section is completed, it will have a covering of thin sheet metal securely and continuously bonded thereto.

In order to complete the wing section, a transom 90 is provided having a planform somewhat larger than the cross sectional arrangement of the root end of the wing section. This transom may be provided with a weight reducing opening 91 and surrounding this opening is provided with apertures indicated at 92, 93, 94 and 95. End portions of reinforcing tubular spar members 66 are received in the apertures 92 disposed between the larger apertures at the opposite ends of the transom. In the arrangement illustrated the apertures 92 are arranged in groups of four adjacent apertures, one aperture being omitted between the adjacent ends of each two groups so that the tubular spar element between each group of four such elements will be cut off at the inner side of the transom and will not extend therethrough. The groups of apertures and the spacing between them may be varied as may be found desirable to assure adequate strength for the transom. The end of the leading edge spar member 69 is received in the aperture 93, the corresponding ends of spar members 70 and 71 are received in apertures 94 and the end of trailing edge spar member 72 is received in aperture 95.

Before the ends of the various tubular spar members are placed in the apertures in the transom they are provided with longitudinal saw cuts, as indicated at 96 in Fig. 18, and have bonding material applied thereto. After the end of a spar member has been inserted through the corresponding aperture in the transom a plug, as indicated at 97 in Fig. 18, is forced into the open end of the tubular spar member to compress the material of the spar member between the plug and the wall of the aperture. When the bonding material has set up this provides a secure joint between each tubular spar member and the transom adequate to resist all operational stresses to which the aircraft part may be subjected.

The joint between a tubular spar member and the transom is particularly illustrated in Fig. 18, wherein the spar member has been indicated as one of the members 66 but may be any one of the spar members in the construction. As is clearly shown in this sectional view, the plug 97 is hollow and is internally bevelled to provide a feathered edge 98 at its inner end. This construction of the plug effectively distributes forces exerted between the spar member and the transom along a sufficient length of the spar member to avoid any concentration of stresses such as would tend to rupture the spar member.

The apertures for the tapered spar members are preferably tapered to the same extent as the corresponding spar members to provide complete surface contact between the spar members and the walls of the corresponding apertures and afford additional resistance to any forces tending to pull the end of the spar member out of the transom.

Fig. 20 illustrates one manner of attaching the transom 90 to a supporting structure such as a complementary transom 99. As illustrated, the two transoms 90 and 99 are abutted so that the outer edges are substantially flush with each other. A binding member 100 of channel shaped section is then positioned around the outer edge portions of the two members 90 and 99 and held in position by suitable through bolts 101. Any other means for securing together two structural parts constructed in the above indicated manner may be used as may be found necessary or desirable.

Suitable apparatus for manufacturing tapered tubes such as the tubes 69 to 74 inclusive of Fig. 11, is illustrated in Figs. 21 and 22. In this arrangement a mold, generally indicated at 102 and preferably formed of reinforced concrete, is provided with tapered bores 103 and 104 into which a rolled sheet of laminated material, such as plywood material, may be inserted. Complementary plungers, as indicated at 105 and 106 in Fig. 22, are then forced into the bores to compress the laminated material between the plunger and the walls of the bores until bonding material applied to the laminated sheet material has set. If desired, the laminated material may be heated during the bonding process by passing heated fluid, such as steam, through conduits 107 surrounding the bores in the mold. After the bonding material has set the plungers are withdrawn, after which the completed tube sections may be withdrawn from the molds using the cylindrical plungers 108 and 109 to loosen the tube sections. If desired, pneumatic bags of tubular shape may be used instead of tapered plungers to apply internal pressure to the sheet material in the tapered mold cavities.

The tapered spar members may be formed in one continuous piece in a mold of sufficient length or may, alternatively, be formed in several sections, which sections may be secured together in the manner indicated in Fig. 23. In this arrangement, a section uniting sleeve member 110 is pulled through the section 111 into the smaller end portion thereof in which it is bonded by suitable bonding material. The larger end of section 112 is then inserted over a portion of the sleeve which extends beyond the end of section 111 and is bonded to the sleeve. The sleeve preferably has a double internal flare providing a feather edge at each end thereof, as indicated at 113 and 114, to distribute any stresses to which the joint is subjected over a sufficient length of the tube section end portions to avoid a tube rupturing stress concentration. The sleeve 110 is made as short as possible consistent with the necessary strength of the bonds between it and the tapered tubular sections so as not to introduce unnecessary stiffness into this portion of the tapered spar element.

While these tapered spar elements have been indicated as particularly useful in the construction of aircraft wing section or other parts, it is obvious that they would also have substantial utility in other applications, such as masts for sail boats, furniture parts, towers for radio equipment and electric transmission lines, packaging objects for shipment and casting forms. The invention is thus not limited to any particular use for this or any other component of the improved structure but such components including the substantially straight tubular members may be employed in any application in which they are found to have utility and may be modified to adapt them to any desired use without in any way exceeding the scope of the invention.

Suitable apparatus for bending either straight or tapered tubular members is shown in Figs. 24 to 28 inclusive.

In Fig. 24, a closed steam box 115 is provided which may have a perforated supporting floor 116 above the bottom thereof, a door 117 through which tubular members may be inserted into the steam box and a door 118 through which they may be withdrawn. Steam is applied to the interior of the box through a valved conduit 119 and steam and condensate may be exhausted from the box through the valved conduit 120. Tubular members are first placed in the steam box 115 and permitted to remain in contact with the steam until both the wood fiber and the bonding material has been softened. When a tubular member is in a sufficiently softened condition, it is withdrawn from the steam box and inserted into the interior of a flexible spring-like member 121, shown in Figs. 25, 26 and 27. The spring 121 has a number of coils or loops of rectangular cross section, as shown in Fig. 26, and originally has an internal diameter somewhat greater than the exterior diameter of the wooden tube 122.

At one end the spring is connected to a supporting member 123 rigidly secured to one end of a hinge arm 124, the opposite end of which is rigidly secured to the end of a rigid member 125. The other end of the spring is secured to an end member 126 which is adjustably secured to a hinged arm 127, the opposite end of which is rigidly secured to the corresponding end of rigid member 125. A spring winding device 128 surrounds the spring and has oppositely disposed friction rollers bearing on the spring coils and radially projecting handles 129, for rotating it about the spring. After the tube 122 has been inserted into the spring 121, the device 128 is rotated until it passes from one end of the spring to the other simultaneously wrapping the various spring coils tightly about the tube 122. When the spring coils have been tightly wrapped about the tube, the end member 126 is secured to the arm 127 in position to maintain the spring in its wrapped condition. A tubular pneumatic bag 130 is then drawn through the tube and connected at its ends to conduits 131 and 132 through which heated fluid is passed under pressure to subject the already softened tube to pressure and additional heat. After the heat has been applied to the tube a sufficient time to complete the softening of the bonding material in the tube, means, such as the screw devices 133 of Fig. 27, are used to exert pressure on the spring to cause the spring to bend between the end members 123 and 126. The double hinged arms 124 and 127 will permit these end members to occupy positions incident to bending the spring member 121 as is clearly illustrated in Fig. 27.

When the spring member has been brought to the desired curvature, the heat applied through the pneumatic bag 130 is discontinued and the tube is allowed to reharden in its bent or curved condition after which the spring 121 is unwrapped and the curved tube withdrawn therefrom.

Fig. 28 shows an apparatus having provision for applying pressure to the tube in two directions at the same time. In this arrangement an additional rigid element 134 is disposed in a position angularly spaced from the member 125 and is secured to the corresponding spring end members 123 and 126 by suitable arms, one of which is indicated at 135. These arms are provided with ball and socket joints, as indicated at 136, so that they do not interfere with the repositioning of the end members as the tube is bent and pressure exerting members as indicated at 137 are interposed between the rigid member 134 and the spring member 121 to exert pressure on the spring in a direction different from the direction in which pressure is exerted by the devices 133. By this means the tube can be given compound curvature if such a curvature is desired.

By means of such tube curving apparatus curved tubes may be provided for reinforcing the parts having curved external surfaces such as the movable wing portions and the end parts 12 and 14 of the fuselage 10. These tapered or curved fuselage parts may be made in a manner similar to the manner of constructing the wing section as described above, outer and inner cover members being formed in suitable molds and secured together in spaced relationship by interposed curved tubular reinforcing members, which reinforcing members may be extended in a direction to resist the major stresses to which the part is subjected.

Fig. 29 illustrates a manner of mounting a movable wing element such as a landing flap to a fixed portion of a wing constructed in the manner described above. In this arrangement, a hinge 138 is provided having a portion extending between the fixed wing portion 19 and the movable portion 22. This hinge is secured to the spar members 72 and 139 of the fixed portion by means of respective stiffening plates 140 and 141 inserted into the spar members and provided with screw threaded apertures, which receive screw threaded fastening elements 142 and 143 extending through the hinge. The hinge has another portion 144 which extends upwardly into the interior of the member 122 and is apertured to receive a shaft 139 extending through tubular spar 77 in which it is centered by suitable means such as spaced disks, one of which is indicated at 145.

Fig. 30 shows an alternative form of construction for a structural part, such as an airfoil member, in which an outer cover 146 of airfoil shape is provided and within which is disposed a series of tubular spar members as indicated at 147, 148, 149 to 154 inclusive. In this construction there is no inner skin or cover member such as the member 68 of Fig. 11 and the tubular spar members of this series have diameters corresponding to the thickness of the airfoil section at the locations of the various spar members. Additional spar members 155 of smaller diameter are positioned in the spaces between the main tubular spar members and the cover member to reinforce the cover member and add additional strength to the structural part. The various spar members are bonded to each other and securely bonded to the cover member so that the construction provides a firmly united substantially integral structure.

In the arrangement shown in the further modified arrangement shown in Fig. 31, an outer cover 156 and an inner cover 157 are provided in spaced relationship to each other. This construction has a main leading edge spar 158 and a series of trailing edge spars, as indicated from 159 to 163 inclusive. Supplementary tubular spars 164 and 165 are disposed adjacent the leading edge spar 158 and between these spars and the larger trailing edge spar 159 there are disposed reinforcing plywood members 166 and 167 of corrugated form positioned one above and one below the inner cover member 157. This provides a construction generally similar to that shown in Fig. 11 but in which the corrugated reinforcing members are substituted for some of the tubular reinforcing spar members. This construction is somewhat simpler to manufacture and has desirable applications, such as in the construction of the empennage members shown in Fig. 1. The corrugated plywood material may also be used as a furring element in various applications and as a reinforcement for fairing on different parts of an aircraft as it may be made in any size and thickness of material desired.

It will be obvious to those skilled in the art that various changes may be made in the invention without departing from the spirit and scope thereof and therefore the invention is not limited by that which is shown in the drawings and described in the specification but only as indicated in the appended claims.

What is claimed is:

1. An aircraft wing section comprising an

outer cover, an inner hollow core the outer surface thereof being spaced from the inner surface of said outer cover, tubular spar members disposed in the space between said cover and core and inlcuding a tubular spar member in the leading edge of said wing section having a radius substantially equal to the radius of the leading edge portion of the wing section.

2. An aircraft wing section comprising a portion normally fixed relative to the aircraft and a portion movable relative to said fixed portion, said fixed portion comprising an outer cover, an inner hollow core the outer surface thereof being uniformly spaced from the inner surface of said outer cover, tubular spars disposed in the space between said cover and core and including two tubular spars disposed one at the leading edge and the other at the trailing edge of said fixed wing portion, said spar at the leading edge having a radius substantially equal to the radius of the leading edge of said wing and said spar at the trailing edge portion providing a hinge support for said relatively movable wing portion.

3. An aircraft wing section as defined in claim 2 wherein said wing section includes relatively movable flap and aileron members and said spar at the trailing edge of said relatively fixed portion providing a hinge support for both said flap and aileron members.

4. An aircraft wing section as defined in claim 2 wherein said tubular spar members at the leading edge and at the trailing edge of said relatively fixed wing portion are tapered from a relatively large diameter at the root portion to a relatively small diameter at the tip portion of said wing section.

5. An aircraft wing section comprising an outer cover, an inner hollow core the outer surface thereof being spaced from the inner surface of said outer cover, tubular spar members disposed in the space between said cover and core secured to said cover and core and to each other, a transom at the open root end of said wing section having apertures therein receiving end portions of said tubular spar members, and plugs in the ends of said tubular spar members compressing the walls of said members between said plugs and the walls of the apertures in said transom.

6. The method of manufacturing a tapered wing section for an aircraft which comprises placing a layer of flexible sheet material having bonding material on the surfaces thereof in a hollow mold, forcing a tapered plunger into said mold to compress the layer of sheet material between the plunger and the mold, applying heat to the sheet material until said bonding material has been conditioned to securely bond together the superimposed surfaces of said sheet material, withdrawing the plunger from said mold leaving the completed outer cover therein, forming an inner hollow core by securing to the surface of a form a layer of flexible sheet material having bonding material on the surface thereof, forcing said form with said layer of sheet material into a complementary mold to compress the sheet material between said form and said mold, applying heat to said layer of sheet material until said bonding material is conditioned to securely bond together the superimposed surfaces of the sheet material, withdrawing the form with the inner core member thereon from the complementary mold, securing tubular spar members in side by side relationship onto the inner core member to completely surround the outer surface thereof, applying bonding material to the surfaces of said spar members, inserting said form with said inner core member and said spar members thereon into the outer cover member in the mold in which it was formed, applying heat to said wing section while holding the tubular spar members under compression between said inner and outer cover members until the bonding material on said tubular spar members has securely bonded said tubular spar members to the inner core and outer cover members, withdrawing the form from said inner core member and withdrawing the completed wing section from the mold.

7. The method of manufacturing a reinforced tapered tubular structure which comprises forming an outer cover member by applying pressure internally to a tubular layer of flexible sheet material held in a hollow mold and applying heat to said sheet material to bond together superimposed surfaces thereof, forming an inner core member in the same manner, securing tubular members to the outer surface of the inner core member to extend lengthwise thereof in side by side relationship, inserting the inner core member with the tubular members thereon into the outer cover member and bonding the tubular members to the cover and core members by applying heat and pressure to the assembled structure.

8. A tapered wing section for an aircraft comprising a pair of tapered tubular spar members disposed one at the leading edge and one at the trailing edge of said wing section; a plurality of substantially straight tubular spar members of relatively small diameter disposed in side by side relationship between said tapered tubular spar members, certain of said straight tubular spar members terminating short of the tip and of said wing section and the remainder of said straight tubular spar members having their end portions at the tip end of said wing section flattened and bonded together to provide a thin tip portion of maximum strength for said wing and a cover member extending over and bonded to said spar members.

9. A tapered wing section for aircraft comprising a pair of tapered tubular spar members disposed one at the leading edge and one at the trailing edge of said wing section, reinforcing members of corrugated plywood disposed between said tubular spar members one at the upper and one at the lower side of said wing section, and a cover member for said wing section extending over and bonded to said tubular spar members and said reinforcing members.

10. A tapered wing section for aircraft comprising a pair of tapered tubular spar members disposed one at the leading edge and one at the trailing edge of said wing section, reinforcing members of corrugated plywood disposed between said tubular spar members one at the upper and one at the lower side of said wing section, an inner unitary core member in contact with the inner surfaces of said spar members and said reinforcing members and bonded thereto and an outer cover member overlying the outer surfaces of said tubular spar members and said reinforcing members and bonded thereto.

11. The method of manufacturing a tapered structural member which comprises preforming an outer cover member by bonding together pieces of sheet material in a mold under pressure applied to said pieces internally of the outer cover member, forming an inner core member by bond-

ing together pieces of sheet material in a mold under pressure applied internally of the inner core member, forming tubular reinforcing members by bonding together layers of sheet material in a mold while applying pressure internally of the tubular members, assembling tubular reinforcing members between said outer cover member and inner core member, and applying pressure externally of said outer cover member and internally of said inner core member for bonding said tubular reinforcing members to said cover and core members and to each other.

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