Jan. 12, 1954 F. B. BEAR 2,665,678

COMPOSITE ARCHERY BOW

Filed April 21, 1950

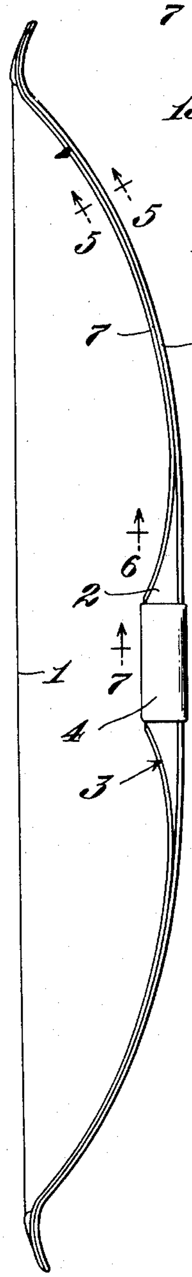


Fig. 1

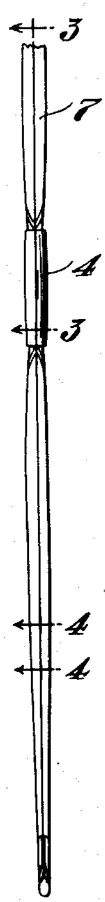


Fig. 2

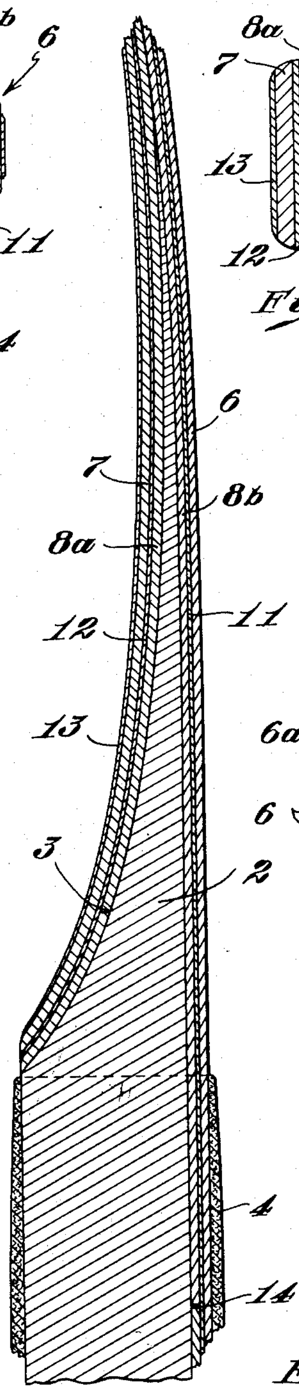
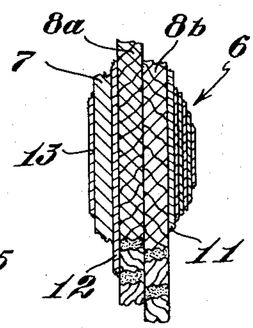


Fig. 3



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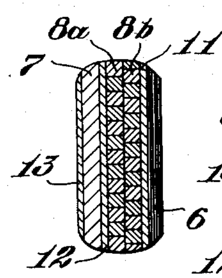
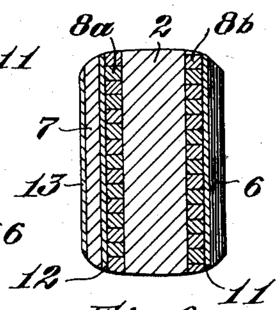


Fig. 5



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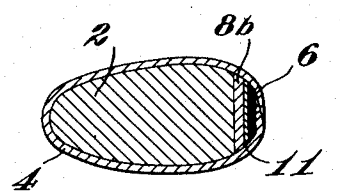

Fig. 7

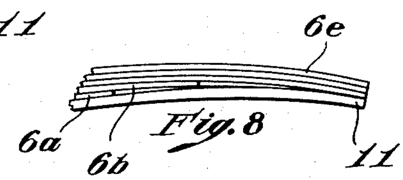

Fig. 8

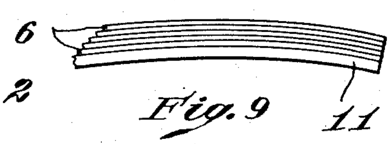

Fig. 9

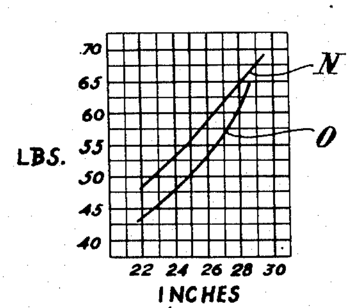

Fig. 10

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Patented Jan. 12, 1954 2,665,678

UNITED STATES PATENT OFFICE

2,665,678

COMPOSITE ARCHERY BOW

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Application April 21, 1950, Serial No. 157,213

10 Claims. (Cl. 124—23)

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This invention relates to archery and more particularly to bows, and has for an object the provision of improvements in bows and in the art of bow construction.

In order to be effective for the propulsion of an arrow, the active limbs of a bow must be of resilient material. When a bow limb is bent longitudinally, its concave side is subject to longitudinal compression and its convex side is subject to longitudinal tension, according to the well-known mechanical laws of beams.

Reduced to simplest terms, what is required of a bow is that it shall shoot an arrow. There are good, indifferent and bad bows; and all of them can shoot an arrow. In order to differentiate among them it is necessary to establish criteria of quality. Among these is a force-draw characteristic so unvarying that the total energy for propelling a shaft may be the same in each successive shot and that the limbs of the bow may work without sensible variation in their mode of motion in successive shots. There are also the highly desirable qualities of lightness in the hand and freedom from jar or "kick" at the instant the propelled arrow leaves the string. All other factors being apparently equal, bows may be differentiated from one another by a criterion of effectiveness. One element of this criterion is called "cast."

Cast is defined as that property of a bow which enables it to impart velocity to an arrow. It may be expressed in terms of that velocity which a bow imparts to an arrow of stated mass and material. However, since arrows of different masses, materials and stiffness—or "spine"—acquire different velocities when shot from the same bow at the same draw-length, it is customary—when comparing different bows as to cast—to choose aluminum arrows, of optimum spine in relation to the bow to be tested, because they fly more consistently although slightly more slowly than do otherwise comparable wooden arrows; and to maintain a constant ratio between the mass of the test arrow and the draw weight of the bow at the most usual full draw-length, which is 28 inches. For the present purposes, the ratio of 8 grains of arrow weight, at optimum spine, to one pound of draw-weight at full draw will be used.

Draw-length means the distance of the drawn string from the back of the bow, and not the lesser actual distance that the string is drawn from its position-of-rest, or the so-called braced position.

The term "full draw" as herein used shall be taken to mean that length of string-draw which

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will bring the pile, or head, of a nocked 28-inch arrow to the back of the bow. All numerical values relating to bow action herein reported are referred to full draw at a draw-length of 28 inches.

In all bows, cast is influenced by the "fistmele," or distance from the face of the handle of the bow to the string at the braced position. The optimum fistmele varies according to the geometry and construction of the particular bow in question. Whenever cast, in terms of velocity, is hereafter mentioned, it is to be understood that the fistmele is at the optimum.

In order that the mass and spine of the test arrow be the only sensible variables, aluminum arrows are used, as stated; and the dimensions of these arrows—including the number and character of the feathers and the height, length and total area of the fletching—are kept constant.

For the present purposes, the reported values of arrow velocity are those representing the average velocity over a distance of 20 feet from the tip of the arrow—at the instant it leaves the string—to the face of the target. The precision of measure, by the method employed, is about plus or minus 0.25%. Thus, in the range to be reported, a difference of one foot per second is a significant figure.

In order to achieve accuracy in the shooting of successive arrows, their average velocity over the distance from bow to target must be kept constant to better than one foot per second. Hence, a variation in average velocity of one foot per second over the short test distance is of real significance to the archer. A change from normal to hot, humid weather may reduce the cast of a bow constructed of organic material. Another factor that reduces cast is elastic hysteresis.

If a bow is kept at full draw for an appreciable length of time—as ten seconds, for instance, the force corresponding to the thus-produced amount of distortion ordinarily diminishes. The bow "lets down," or loses draw-weight. This let-down is characteristic of all prior bows constructed of organic materials, as wood, or laminations of wood and horn, sinew, silk or plastics. If the let-down results in a permanent set of the limbs, the bow is said to have "followed the string." To the extent that there is string-follow, there is a permanent loss of cast. If, however, the let-down is of a transient nature and is one from which the bow substantially recovers within a short period of time—as between successive shots, for instance—elastic hysteresis is involved.

Elastic hysteresis is a detrimental variable factor in the performance of prior bows constructed of organic materials: variable because its magnitude is influenced by temperature and relative humidity; and detrimental because of its variable reduction of cast.

Bows of all-metal construction do not exhibit sensible hysteresis. Steel bows date back at least several centuries and possibly more, inasmuch as they are mentioned in the Bible. Specimens that have come down to us from the Persians, as well as their modern counterparts—whether tubular steel or solid aluminum alloys—are not only heavy in the hand but notoriously hard on the bow-hand because they all exhibit to some degree a distressing "kick" or jar of recoil. Modern aluminum bows are usually provided with a heavy metal handle that absorbs some of the jar yet necessarily adds to the weight in the hand. The kick or recoil of a bow has been found generally to be small in bows of good cast having light-weight limbs, and large in sluggish bows having heavy limbs.

The production of a bow having maximum cast with a minimum weight of materials—which is an important object of this invention—involves a compromise between using as little material as possible and yet as much as is needed in order to avoid the hazards of breakage, and more particularly such breakage as may put the archer in jeopardy.

Bows may be classified as to type by the length between nocks when unstrung and by the unstrung position of the limbs. Bows whose limbs, in the unstrung position, are either straight and set backwards from the handle or are curved backwards from the handle throughout any part of their active limb-length are called "reflexed" or "pre-stressed."

The famous Turkish flight bow of several centuries ago is an example of extreme pre-stressing by reflexing. These bows, especially when short-limbed, were very fast; that is, they had good cast. They and their modern counterparts were designed primarily for maximum cast. Short, heavily pre-stressed bows are not suitable for precision shooting because of at least two reasons. First, all heavily pre-stressed bows are extremely sensitive to minor variations in the archer's loose or release of the string from his drawing fingers, and hence they tend to magnify these variations with consequent loss of consistency in performance. Second, when the limbs and connecting handle are short, the angle made by the string at the archer's fingers at full draw is very acute and tends to increase the difficulty of his making successively consistent and clean releases.

The standard length of the famous English longbow was approximately 72 inches. The Turkish flight bow was usually about 46–48 inches in length along the bow from nock to nock, as are the present day flight bows. The modern target and hunting bows, to improvements in which this invention relates, are in the range of 58–68 inches. Hunting bows are usuallly towards the lower part of this range, while the precision target bows are usually in the upper part.

In a beam of homogeneous material and of substantially rectangular or transversely symmetrical cross-section, the neutral layer is midway between the tension and compression sides. This condition holds for the all-metal bows in which the amount of stretch of the surface material on the tension side or back of the bow is substantially equal to the amount of compression of the face, or "belly" side, of the bow.

In bow woods, such as yew and osage orange for instance, the strength in tension is greater than that in compression. Bows made of these woods tend to fail in compression by a crushing of the fibers on the belly side; this is called "chrysalling." There has been a marked tendency in recent years to still further increase the strength of the back of the bow by the application thereto of materials having greater tensile strength than wood. For many centuries sinew has been used as a backing, notably in the Turkish bow where the high tensile value of the sinew was balanced by the high compression value of a horn facing. More recently, silk threads and glass fabrics have been adhesively fastened to the backs of bows as tension elements. Such backings greatly increase the compressive strain on the belly of the bow and therefore increase the hazard of failure through chrysalling. Even sheet steel and steel wire have been suggested as a backing for wood bows, notwithstanding the fact that there is no known bow wood which could possibly balance in compression the high tensile values of steel.

The effect of greater strength in tension than in compression—due to the application of backing materials highly resistant to stretch—is that the surface of the belly of the bow is compressed more than the back of the bow is extended under tension. The crushing effect of excessive compression not only shortens the life of the bow by chrysalling but endangers it in still another manner. While, as stated, the tension value of bow woods is generally greater than their compression value, any crushing of the surface fibers of the belly side greatly lowers the tension value of that side as well. The tension value of the fibers of the belly side of the bow is of importance in ordinary use because, when that side is longitudinally compressed, it is also subjected to correspondingly heavy transverse tension. This is the so-called St. Venon effect. Failure in transverse tension on the belly side results in longitudinal hairline cracks.

When, as sometimes accidentally happens, the string of a fully-drawn bow is loosed without an arrow's being nocked thereon—as, for instance, because of a defective or broken arrow nock—the bow must dispose of all its stored-up energy unaided; and it almost invariably breaks through tension failure on the belly side.

It is an object of this invention to provide a bow having a backing and a facing, said facing being characterized by greater resistance to longitudinal compression than the resistance of said backing to longitudinal tension; and further characterized by its ability to withstand, without breakage, the tension stresses imposed upon it by the release of the string at full draw without the energy-absorbing presence of an arrow engaged therewith.

For any bow the draw characteristics may be shown by a curve plotted with force as the ordinates and the length of draw as abscissas. This is the so-called force-draw curve, the shape of which depends mainly upon the dimensions and the geometry of the bow. Many prior bows were characterized by an increase in the upward slope of the force-draw curve just before full draw. This so-called "stacking up" at the last of the draw is not only detrimental to accuracy but very unpleasant to the archer. Since the energy input and therefore the available energy are represented by the area under the force-draw curve, it is evident that the last increment of draw contributes vastly more to the stored energy than does an increment of draw near the beginning. From this it is apparent that the slightest difference in the length of draw will make a large difference in the resulting velocity of the arrow release of the string.

Accuracy is best obtained when the force-draw curve is linear in that portion approaching and passing through full draw. Under the heavy strain on the drawing fingers of holding a bow full-drawn while the archer is taking aim, there is a tendency for the fingers to "creep" forwards; this is highly detrimental to accuracy. This tendency is at a minimum when the force-draw curve is linear approaching and through full draw. Such a bow is said to have a "smooth draw."

Assuming that a bow's lightness in the hand, its sweetness or relatively small jar or recoil, its smoothness of draw and its over-all length in relation to its draw-length are all at the optimum, there is still the question of its effectiveness in terms of cast.

The traditional English longbow had a cast corresponding to a velocity in the neighborhood of 165 feet per second. The modern steel bows impart to an 8:1 arrow velocities in the range of 175–180 feet per second. The modern aluminum-alloy bows correspondingly impart velocities in the range of 180–190 feet per second. The fastest modern all-wood bows, so far as known, are comparable to those of the famous hunting archer, Howard Hill, and the equally renowned bowyer, Russell Willcox. The first of these is a straight bamboo bow 70 inches long; the second is an osage orange bow backed with a thin lamina of hickory, highly reflexed towards the tips, and 63 inches long. They both impart a velocity of 180 feet per second to an 8:1 arrow. The Willcox bow is illustrated opposite page 241 in Elmer's "Modern Archery."

The fastest modern prior composite bows, so far as known, are backed with two plies of glass fabric over a subbacking of plastic and faced with a layer of plastic. They range in length from 62–67 inches, and impart velocities to an 8:1 arrow within the range of 190–192 feet per second.

Considering that the improvements in the cast of bows—over the last hundred years or more—corresponds to a velocity increment of less than 16%, it is obvious that to obtain a further significant increment of 2% or more cannot be viewed as a mere matter of degree, for such an improvement would be a real advance in the art. Bows according to this invention have exhibited cast in the range of 198 to 205 feet per second.

It has long been held that a fully-drawn bow of good cast is nine-tenths broken; and no archer up to now would permit his bow to be drawn beyond the length for which it was designed. The breaking of a bow at full draw can have serious consequences to the archer involved. With the advent of the modern all-metal bows—and more particularly the aluminum-alloy bows, all of which tend to fail through vibrational fatigue—the consequences of breakage can be, and in fact have been, serious indeed. The always sharp and sometimes jagged edges of the broken metal moving at high speed are far more dangerous than are the broken ends of a wooden bow.

One of the offsetting advantages of the modern all-metal bows is that they are completely unaffected by moisture and are practically unaffected by change in temperature over the normal range in which a bow may be used; whereas the draw weight of wooden bows—or of composite bows, in which either or both the tension and compression elements are of organic origin—may change as much as, or even more than, 1% for every 10 degrees Fahrenheit change in ambient temperature, with a corresponding though not directly proportional change in cast. These bows notoriously "let down" in hot, humid weather and tend to more or less "follow the string," or lose draw-weight from much shooting. They also have the detrimental characteristic of temporarily gaining draw-weight at low ambient temperatures. Thus, a bow having a draw-weight suitable to its user at normal temperatures may so increase in draw-weight at temperatures encountered in hunting (as 0° F., for instance) that the user may no longer be able to bring it to full draw. And, even if he did succeed in so doing, he would not be able from experience to accurately judge its cast and hence the trajectory of the arrow.

It is an object of this invention to provide a composite bow in the length range of 58–68 inches and therefore suitable for hunting and precision target shooting, which bow is characterized by a substantially greater elongation of its tension element than shortening of its compression element at full draw; and further characterized by the fact that it can be drawn several inches beyond the normal draw-length of 28 inches without breakage; and still further characterized by the fact that, when fracture does occur—as after 25,000–30,000 shots, for instance—it does not involve rupture of the compression element and therefore completely eliminates the danger to the archer heretofore always associated with bow breakage at full draw; and further characterized by its ability—at a draw length of 28 inches—to impart to an arrow of optimum spine and having a mass of 8 grains for each pound of bow-draw-weight at 28 inches an average velocity over a distance of 20 feet of at least 195 feet per second.

It is another object of this invention to provide a composite bow having a force-draw curve which is linear from not more than 25 inches through 28 inches to at least 29 inches; and further characterized by a substantially imperceptible hysteresis or loss of cast when held at full draw for one minute at normal ambient temperatures; and still further characterized by such immeasurably small string follow as is reflected in the loss of not more than 0.5% of its original draw-weight for every 5000 shots.

It is another object of this invention to provide a composite bow, comparable in mass to an all-wood bow of like draw-weight and length, characterized in that both the tension and the compression elements are of resilient material having a modulus of elasticity greater than wood.

Other objects of the invention will appear as the description thereof proceeds.

Glass-fabric, as heretofore used as a tension element, has customarily been laminated to a thin subbacking layer of a thermosetting plastic resin, hereinafter referred to as a plastic. It has been stated, by the proponents of the plastic subbacking for glass-fabric bow backings, that the plastic was necessary because the difference in tensile-shear characteristics between the glass-fabric laminate and the wood core of the bow was so great that, without it, the wood was prone to fail at or near the glue joint—or the core and backing interface.

One of the features of this invention is based upon the discovery that when the compression element is made to consist of a thin layer of a suitable metal, sensible hysteresis is eliminated and a substantially better cast is obtained without rather than with the heretofore-considered essential plastic subbacking for a multi-ply glass-fabric backing.

However, the advantageous elimination of the prior plastic subbacking introduced a real difficulty which relates to the fact that the thermosetting cements most suited to the bonding of glass fibers and fabrics to one another require a heat and pressure treatment that is detrimental to the preferred core woods. Moreover, suitable cements for glass-fabric tension elements are not adhesively wet, and hence cannot be satisfactorily bonded, by adhesives which set at such low temperatures as are required to preserve the maximum strength of the core wood.

Obviously, a subbacking is required; and, for reasons which will appear, it should have the same coefficient of expansion as the glass or should be so yielding as not to sensibly pre-stress the glass when later applied to the bow limb as a backing.

Surprising as it may seem, it was discovered as part of this invention that a thin lamina of wood, and preferably maple, was found to answer the requirements when it was so bonded to the plies of glass-fabric that the cement penetrated the wood lamina to an appreciable fraction although less than half its thickness. When this backing with its partially permeated subbacking of wood was bonded to the core wood by a suitably low-temperature setting cement, the latter could penetrate to, or nearly to, the line of penetration of the first-applied high-temperature cement. Both cements thus achieve a good bond, and tend also to reinforce the thin layer of wood against tensile-shear failure notwithstanding the deleterious effect upon the wood subbacking of the high temperature treatment to which it has been subjected.

As stated, pre-stressed bows tend to have improved cast, but at the expense of accuracy of performance. Heretofore, all of the composite bows incorporating glass-fabric as the major tension element have been more or less heavily prestressed. Their exceptionally good cast, as hereinabove noted, is in part due to the pre-stressing obtained by either setting straight limbs back from the handle or by reflexing, although sometimes by a combination of both—in which case the set-back limbs are generally straight for the major portion of their length and heavily reflexed toward their ends. These reflexed ends are commonly called "working recurves" in order to distinguish them from the stiff unbending "ears" of the common recurve. In addition to the so-obtained pre-stressing, still more is attained through stretching the glass-fabric over the straight portion of the limb.

In a multi-ply backing, comprising laminations of glass-fabric, it is obvious that when flexed the outer layer on the convex side is normally put under greater tension than is the next inner layer, and so on—if there be more than two layers of glass-fabric. The two layers of the prior glass backing do not carry an equal share of the tension load.

It is a further object of this invention to provide prelaminated backings comprising a plurality of glass-fabric layers greater than two, which plurality when incorporated in a bow is so arranged that—at the first part of the draw—the tension load on the several layers of glass fabric is greatest on the innermost layer, and increases relatively on successive layers as the draw progresses until the tension load on all layers is substantially equal at approximately three-quarters of full draw: which is of material advantage.

The wood core of a composite bow is put under tremendous strain by the forces acting upon it. The great shearing stresses increase toward the tip, as is well understood. The complicated vectors of tension and compression stresses acting upon the core are not so clearly understood. When, as in the case of the bows of this invention, the modulus of elasticity—of both the tension and compression elements—is very high relative to wood, the resulting stresses on the core wood are correspondingly very great.

Among some 4000 bows made according to the method of this invention, and sold, there were a few which developed a more or less pronounced "dog's leg," or hinge on one limb, with a consequent substantial let-down (loss in draw-weight) although no corresponding or even substantial loss in cast was, when the bow was measured at the resultant draw-weight, found to have resulted. Careful inspection failed to disclose any local weakness in either the tension or the compression elements.

It was thought that there might be an invisible crushing of the corewood fibers. Whether or not this was so is not known. In an endeavor, however, to increase the shear strength of the core, a discovery of a surprising nature was made which provided a solution of the problem presented by the occasional occurrence of hinges.

In the endeavor to increase the shear strength of the core beyond that of otherwise suitable woods, cores were made of thin laminations of wood (about $\frac{5}{64}''$ thick) with the grain of alternate layers at right angles to one another, the assembly being then cut at an angle of 45° to the grain, into strips suitable for the core. Using these bias-cut plywoods, grain on edge (that is, making an angle of 45° with the back and belly of the bow), it was found that the shear strength was some 50% greater than that of a comparable normal strip of the same wood having the shear stresses parallel to the grain. The surprising and wholly unexpected finding was that the prior occasional, inexplicable and detrimental hinges did not occur when the bias-cut core was used on-edge. Many spot-check tests-to-destruction failed to disclose any indication of hinges in the limbs of bows so tested.

The core of composite bows, having tension and compression elements of greater modulus of elasticity than wood, serves primarily to coherently hold these elements spaced apart at precisely predetermined distances. Everything else being equal, the distance these elements are spaced apart, at any point, determines the stiffness of the bow limb at that point.

The width of the bow limb and its taper toward its outer tip is also an important factor in its stiffness.

When the tension and compression elements must each be held to constant thickness throughout their length by reasons of practicality, economy or other production considerations, the stiffness of the limb—or draw-weight of the bow—must depend upon the variables of the width of the limb, the thickness of the core and the taper of the former and preferably though not always nor necessarily of the latter as well.

Moreover, adjustments in the stiffness of the limbs to bring about substantially uniform stress distribution along the length of the limb and to bring about a balanced action of both limbs—called "tillering the bow"—must be made on the edges of the limbs only.

As between two composite bows having the same width and shape of limbs and the same strength in their tension elements and in their compression elements, the draw-weight of the bow having the thinner core will be less than that of the otherwise like bow having a thicker core.

In the 50-pound draw-weight range, a change in core thickness of 10 thousandths of an inch near the base of the active portion of the limb may change the draw-weight by as much as 5 pounds in a bow made according to this invention.

As is well recognized in the art of bowmaking, the handle section of a bow should be unbending. The block of wood customarily applied to the belly at the handle section is called the "riser." The riser is usually tapered at both ends, more or less abruptly, down to the limbs.

If the riser has a very short taper, the resulting increase in stiffness along the taper tends to be very abrupt. The modern metal bows have handle-sections into which the limbs are inserted, which sections end abruptly so that the active portion of the bow limb terminates inwardly at a sharply defined line corresponding to the outward end of the handle. Hence, the limbs of all-metal bows are stiffened abruptly by their insertion into heavy metal handles. This results in nodal vibration and localized vibrational fatigue.

As stated, the limbs of metal bows and particularly those of aluminum-alloy bows fail through vibrational fatigue.

It is an object of this invention to provide a bow having as a compression element a facing of thin metal, which bow is characterized by the substantial absence of vibrational fatigue of the metal compression element.

In prior wood and composite bows, the risers have sometimes been tapered to as much as three inches, and in at least one prior bow they have been tapered to four inches.

The taper of the risers of the bows of this invention are preferably asymptotically tapered about 100% longer than the longest taper in any known prior bow. The purpose of the very long asymptotic taper of the bows of this invention is much more gradually to increase the stiffness of the base of the bow limb than has heretofore been either customary or required in bows comprising compression elements of organic material, and thereby to avoid nodal vibration in the bow limb and thus to eliminate the localized detrimental effects of vibrational fatigue characteristic of all-metal bow limbs.

Conventionally, the riser is applied to the belly side of the bow limb over the tension element.

The zone of least stress in a bow limb is at the base of the limb in the so-called neutral layer transverse of the limb. It has been found by experience, as part of this invention, that best results are obtained when the riser is carried down into the core at the approximate location of the neutral layer. This is most conveniently accomplished by making the core of two laminates of equal thickness, by separating the two at the base of the limb by the dip of the riser and by carrying the core lamina on the belly side with its adherent compression facing up over the taper of the riser.

Instead of snubbing the vibration of the bow limbs suddenly at their junction with the bow handle, as in prior metal bows, the action of the bow limb of this invention is gradually damped by the bending of the long flexible extension of the dips. The result is that, in all the many life tests-to-destruction that have been made on bows of this invention, there has never been an instance in which evidence of vibrational fatigue of the metal compression element has been observed.

As has been stated, the longitudinal elongation of the outer surface of the tension element of prior bows has been either equal to the longitudinal shortening of the outer surface of the compression element—as in the case of all-metal bows—or the elongation of the former has been substantially less than the shortening of the latter, as in wooden bows and in composite bows having organic compression elements.

So far as is known, no prior composite bow has ever been made in which the longitudinal deformations of the backing and facing due to tension and to compression have been equal. The longitudinal deformation of compression has always been greater than the deformation due to longitudinal tension.

The least difference found in prior composite bows corresponds to 7.7% more shortening than extension. The maximum difference found in prior composite bows having a glass-fabric tension element and a wood compression element corresponds to 58.3% more shortening than extension. For a wide variety of prior bows of all-wood or of composite construction involving an inorganic tension element and organic compression element—as a plastic, for instance, the average shortening under compression (at full draw in each case) was found to correspond to 35.4% more shortening than extension.

As stated, it is an object of the present invention to produce a composite bow, having essentially inorganic tension and compression elements, characterized when stressed by an elongation of the tension element at least equal to or greater than the shortening of the compression element.

From the standpoint of optimum distribution of the shear stresses within the core of the bow, the elongation and the shortening should be substantially equal. From the standpoint of the safety of the archer, in case the bow should break at full draw, and for the unforeseen and surprising reason of the obtained substantial improvement in cast, it is desirable that the compression element should shorten at full draw less than the tension element elongates and that the compression element should yield but not break when and if the tension element fails.

In order to achieve an outstanding improvement in cast and at the same time to obtain the desired margin of safety for the archer, it has been found advantageous—as part of this invention—to compromise in favor of safety to the archer as against optimum distribution of internal stresses.

This advantageous compromise has been effected through the novel combination in a bow of a tension element comprising a thin layer of resilient material having a modulus of elasticity greater than wood, spaced apart by a wooden core from a thin sheet-metal compression element such as spring steel, beryllium bronze or a hard aluminum alloy.

The effect of so doing has been to produce for the first time bows in which the elongation of the tension element at full draw is greater than the shortening of the compression element up to the order of 35% but preferably in the neighborhood of 5% to 10%.

Over the normal range of ambient temperatures and relative humidities in which bows are commonly used, the bows of this invention show substantially no change in draw-weight or cast, which is an advantage heretofore enjoyed by all-metal bows only.

According to the present invention the bow comprises limbs which are wider than thick, each limb comprising a tension element on the back side, a compression element on the face side and an intermediate core element, the elements being interconnected throughout their interfaces with adhesive, and the outer surfaces of the tension and compression element being approximately parallel at any cross-section throughout substantially the active length of the limb, characterized in that the tension element comprises a thin layer of resilient material having a modulus of elasticity higher than wood, preferably glass threads extending lengthwise of the limb, either with or without cross threads interwoven therewith, the core member comprises wood, preferably maple, and the compression element comprises a thin ribbon of resilient metal having an elastic yield factor which approaches but does not substantially exceed that of the tension element, the elastic yield factor being the change in the length of the element in drawing the bow, the tension element temporarily increasing in length and the compression element temporarily decreasing in length. Intermediate the metal compression element and the wood core is a sub-facing which preferably comprises a thin strip of maple or the like which is impregnated on its opposite sides with two different thermoplastic adhesives respectively, a relatively high temperature adhesive for adhesion to the metal and a relatively low temperature adhesive for adhesion to the wood core. The sub-facing is attached to the metal compression element first at a temperature higher than that which the wood core could safely withstand, and then the combined compression element and sub-facing are joined to the wood core at a lower temperature which the wood core can safely withstand.

In a more specific aspect the bow comprises a riser having dips which meet the back of the riser substantially asymptotically at the ends of the riser, the compression element and sub-facing extending along the face of each limb of the bow to the riser and thence along the dip to the inner end of the dip, terminating substantially at the grip intermediate the two dips. A portion of the core element may also extend along the dip to the junction between the grip and dip. Preferably the core of each limp comprises two layers which extend in juxtaposition from the free end of the limb to the end of the riser and thence along the face and back side of the riser, the face layer terminating substantially at the inner end of the dip. This construction eliminates nodal virbation and therefore minimizes fatigue in the metal of the compression element.

In still another aspect of the invention the wood core comprises laminations extending in planes parallel to the plane defined by the longitudinal axis of the bow, the grain of each of the laminations extending obliquely with respect to the face of the bow and the grain in alternate laminae extending transversely of each other. In the preferred embodiment the core comprises two layers and the grain of each lamination of each layer extend at an angle of approximately 45° with respect to the face of the bow and the grain in alternate laminae of each layer extend at approximately right angles to each other. This construction avoids the danger of the aforesaid dog's legs by eliminating local weak spots sometimes occurring in normal core woods and substantially increases the resistance of the core to the greatly increased tension-shear stresses put upon it by the high modulus of elasticity of both the compression and tension elements.

In a further aspect of the invention the tension element comprises a plurality of strata, the outer stratum being longitudinally compressed when the element is attached to the core so that as the bow is flexed in bracing the compression is reduced. Preferably the different strata comprise different layers adhesively joined together. In the preferred embodiment the outer stratum is not only longitudinally compressed but the inner stratum is longitudinally tensioned when the element is attached to the core. The preferred degree of compression and tension in the outer and inner strata is such that at three-quarters of full draw the inner and outer strata are subjected to approximately equal tension.

For the purpose of illustration a typical embodiment of the invention is shown in the accompanying drawings in which

Fig. 1 is a side elevation of a braced bow of the type having unbending ears at the free ends of the limbs;

Fig. 2 is a rear elevation with the upper end broken off;

Figs. 3 and 4 are longitudinal sections on lines **3—3** and **4—4** of Fig. 2;

Figs. 5, 6 and 7 are cross-sections on lines **5—5**, **6—6** and **7—7** of Fig. 1;

Fig. 8 is a longitudinal section through the end of a multi-layer tension element at the outer end of the element before it is applied to the core;

Fig. 9 is a similar section of a tension element for use in making a conventional type of bow which does not have unbending ears; and

Fig. 10 comprises force-draw curves.

The particular embodiment of the invention chosen for the purpose of illustration comprises a string **1**, a riser **2** having dips **3**, a grip **4** surrounding the central portion of the riser, a tension element **6** on the back side of the bow, a compression element **7** on the face or belly side of each limb of the bow, a core comprising two layers **8a** and **8b** intermediate the tension and compression elements, a sub-backing **11** between the tension element **6** and the core, a sub-facing **12** between the compression element and core and a finish layer **13** of wood or other decorative material over each compression element. The various layers are secured together with thermosetting adhesives appropriate to the materials at the different interfaces, the sub-backing **11** and the sub-facing **12** being joined to the tension and compression elements respectively at relatively high temperature before these two elements are joined to the wooden core at relatively low temperature. The compression elements may be formed of any one of several metals. When formed of spring steel they are preferably approximately 0.018 to 0.022 inch thick, when formed of beryllium bronze they are about 0.029 to 0.037 inch thick, and when formed of hard aluminum they are preferably about 0.051 to 0.064 inch thick. The sub-facing and sub-backing are preferably formed of thin strips of maple impregnated on opposite sides with high-temperature and low-temperature adhesives respectively. For the high-temperature adhesive best results have been obtained with phenolic resin or a combination of phenolic and polyvinyl resins. After the strips of maple have been impregnated part way through from one side and then dried, they are applied to the tension and compression elements at a temperature of about 325° F. with a pressure of about 150 pounds per square inch for about 30 minutes. Thereafter the sub-facing and sub-backing are impregnated part way through from their exposed sides with a low-temperature urea formaldehyde cement and then applied to opposite sides of the core and riser at a temperature of about 180° F. under a pressure of about 80 pounds per square inch for about 60 minutes.

As shown in Fig. 3 each dip **3** of the riser **2** meets the back of the riser asymptotically at one end of the riser, and both the compression element **7** and the sub-facing **12** extend along the face of the dip to the inner end of the dip adjacent the grip. The tension element **6** and the sub-backing **11** preferably extend continuously across the back of the riser. In the preferred embodiment the two layers of the core diverge from each other from the end of the riser to the grip, one layer extending along the back of the riser approximately to the middle point **14** of the riser and the other layer extending along the face of the dip to the inner end thereof.

As shown in Figs. 5 and 6 each layer of the core **8** comprises laminations whose interfaces lie in planes parallel to the plane containing the longitudinal axis of the bow. As shown by the marking in the longitudinal section of Fig. 4, the grain of each lamination of each layer extends at approximately 45° with respect to the face of the bow and the grain in alternate laminae of each layer extend in opposite directions so that the grain in alternate laminae of each layer extend approximately at right angles to each other.

As shown in Figs. 4 to 8 inclusive the tension element **6** comprises a plurality of layers, more than two and preferably five, cemented together. As shown in Fig. 8 the inner layers **6a** and **6b** terminate short of the other layers **6e** at the free ends of the limbs, and the layers are cemented together and to the sub-backing while curved more than the core so that the outer surface of the outer layer **6e** is convex and the inner surface of the inner layer **6a** is correspondingly concave. Then, when the tension element is joined to the core through the medium of the sub-backing **11**, it is flexed into parallelism with the core, thereby putting the outer layers under compression and the inner layers under tension. The longitudinal curvature of the layers is preferably the same as that of the bow limb at three-quarters full draw so that at three-quarters full draw both the inner and outer layers are subjected to tension in approximately the same degree. The tension element comprises layers of glass fabric having interwoven fibers extending both lengthwise and crosswise of the bow. However it may comprise only longitudinal fibers cemented together in the aforesaid curved formation so that, after the tension element is attached to the core, the outside strata are under compression and the inside strata are under tension.

As shown in Fig. 9 all of the layers of the tension element preferably extend to the end of each limb when the aforesaid unbending ears are not used on the ends of the limbs.

In Fig. 10 the curve O illustrates the objectionable upward curvature in the region of full draw characteristic of many types of prior laminated bows and the curve N shows the desirable straightness in the region of full draw characteristic of the present bow.

A salient feature of the present invention consists in that the tension and compression elements are so constituted and constructed that the elastic yield factor of the compression element approaches but does not substantially exceed that of the tension element. For most uniform distribution of internal stresses the elastic yield factors should be approximately equal so that at full draw the elongation of the tension element is about the same as the contraction of the compression element. However, to afford a higher degree of safety to the archer and yet obtain excellent cast, the elastic yield factor of the tension element is preferably 5% to 10% greater than that of the compression element.

Bows according to this invention exhibit substantially no hysteresis as demonstrated by the fact that the cast at a draw dwell of five seconds for aiming is the same as at a draw dwell of sixty seconds within the aforesaid precision of measurement.

Another advantage of the present bows is that they are substantially unaffected by changes in ambient temperature and relative humidity over the normal range encountered in ordinary use.

It should be understood that the present disclosure is for the purpose of illustration only and that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

I claim:

1. An archery bow comprising a riser having dips which meet the back of the riser substantially asymptotically at the ends of the riser, limbs which are wider than thick, each limb comprising a tension element on the back side, a compression element on the face side, an intermediate core element intermediate the compression and core elements, said compression element terminating substantially at the inner end of the dip, said elements being interconnected throughout their interfaces with adhesive, the outer surfaces of the tension and compression elements being approximately parallel at any cross-section throughout substantially the active length of the limb, the tension element comprising a thin layer of resilient material having a modulus of elasticity substantially higher than wood, the core member comprising wood, and the compression element comprising a thin ribbon of resilient material having an elastic yield factor which approximates that of the tension element.

2. An archery bow comprising a riser having dips which meet the back of the riser substantially asymptotically at the ends of the riser, limbs which are wider than thick, each limb comprising a tension element on the back side, a compression element on the face side, an intermediate core element and a sub-facing intermediate the compression and core elements, said compression element and sub-facing terminating

substantially at the inner end of the dip, said elements being interconnected throughout their interfaces with adhesive, the outer surfaces of the tension and compression elements being approximately parallel at any cross-section throughout substantially the active length of the limb, the tension element comprising a thin layer of resilient material having a modulus of elasticity substantially higher than wood, the core member comprising wood, and the compression element comprising a thin ribbon of resilient material having an elastic yield factor which approximates that of the tension element.

3. An archery bow comprising a riser having dips which meet the back of the riser substantially asymptotically at the ends of the riser, limbs which are wider than thick, each limb comprising a tension element on the back side, a compression element on the face side and an intermediate core element, each of said cores comprising two layers extending in cemented juxtaposition from the free end of the limb to the end of the riser and thence along the face and back side of the riser, said compression element and face layer terminating substantially at the inner end of the dip, said elements being interconnected throughout their interfaces with adhesive, the outer faces of the tension and compression elements being approximately parallel at any cross-section throughout substantially the active length of the limb, the tension element comprising a thin layer of resilient material having a modulus of elasticity substantially higher than wood, the core member comprising wood, and the compression element comprising a thin ribbon of resilient material having an elastic yield factor which approximates that of the tension element.

4. An archery bow comprising a riser having a grip and dips which meet the back of the riser substantially asymptotically at the ends of the riser, limbs which are wider than thick, each limb comprising a tension element on the back side, a compression element on the face side, an intermediate core element and a sub-facing intermediate the compression and core elements, each of said cores comprising face and back layers extending in cemented juxtaposition from the free end of the limb to the end of the riser and thence along the face and back side of the riser, said compression element and sub-facing and face layer terminating substantially at the inner end of the dip, said elements being interconnected throughout their interfaces with adhesive, the outer faces of the tension and compression elements being approximately parallel at any cross-section throughout substantially the active length of the limb, the tension element comprising a thin layer of resilient material having a modulus of elasticity substantially higher than wood, the core member comprising wood, and the compression element comprising a thin ribbon of resilient material having an elastic yield factor which approximates that of the tension element.

5. An archery bow comprising limbs which are wider than thick, each limb comprising a tension element on the back side, a compression element on the face side and an intermediate core element, the elements being interconnected throughout their interfaces with adhesive, the outer surfaces of the tension and compression element being approximately parallel at any cross-section throughout substantially the active length of the limb, the tension element comprising a thin layer of resilient material having a modulus of elasticity substantially higher than wood, the core member comprising wood, and the compression element comprising a thin ribbon of resilient material having an elastic yield factor which approximates but does not substantially exceed that of the tension element, said core comprising two layers cemented together, each layer comprising laminations extending in planes parallel to the plane defined by the longitudinal axis of the bow, the grain of each of said laminations extending obliquely with respect to the face of the bow, and the grain in alternate laminae of each layer extending transversely of each other.

6. An archery bow comprising limbs which are wider than thick, each limb comprising a tension element on the back side, a compression element on the face side and an intermediate core element, the elements being interconnected throughout their interfaces with adhesive, the outer surfaces of the tension and compression element being approximately parallel at any cross-section throughout substantially the active length of the limb, the tension element comprising a thin layer of resilient material having a modulus of elasticity substantially higher than wood, the core member comprising wood, and the compression element comprising a thin ribbon of resilient material having an elastic yield factor which approximates but does not substantially exceed that of the tension element, said core comprising two layers cemented together, each layer comprising laminations extending in planes parallel to the plane defined by the longitudinal axis of the bow, the grain of each of said laminations extending at an angle of approximately 45° with respect to the face of the bow, and the grain in alternate laminae of each layer extending at approximately right angles to each other.

7. An archery bow comprising limbs which are wider than thick, each limb comprising a tension element on the back side, a compression element on the face side and an intermediate core element, the elements being interconnected throughout their interfaces with adhesive, the outer surfaces of the tension and compression elements being approximately parallel at any cross-section throughout substantially the active length of the limb, the tension element comprising a thin layer of resilient material having a modulus of elasticity substantially higher than wood, the core member comprising wood, and the compression element comprising a thin ribbon of resilient material having an elastic yield factor which approximates but does not substantially exceed that of the tension element, said tension element comprising a plurality of strata, the outer stratum being longitudinally compressed throughout its thickness so that as the bow is flexed in bracing the compression is reduced.

8. An archery bow comprising limbs which are wider than thick, each limb comprising a tension element on the back side, a compression element on the face side and an intermediate core element, the elements being interconnected throughout their interfaces with adhesive, the outer surfaces of the tension and compression elements being approximately parallel at any cross-section throughout substantially the active length of the limb, the tension element comprising a thin layer of resilient material having a modulus of elasticity substantially higher than wood, the core member comprising wood, and the compression element comprising a thin ribbon of resilient material having an elastic yield factor which approximates but does not substan-

tially exceed that of the tension element, said tension element comprising a plurality of strata, the outer stratum being longitudinally compressed throughout its thickness and the inner stratum being longitudinally tensioned throughout its thickness so that as the bow is flexed in bracing the compression and tension are reduced.

9. An archery bow comprising limbs which are wider than thick, each limb comprising a tension element on the back side, a compression element on the face side and an intermediate core element, the elements being interconnected throughout their interfaces with adhesive, the outer surfaces of the tension and compression elements being approximately parallel at any cross-section throughout substantially the active length of the limb, the tension element comprising a thin layer of resilient material having a modulus of elasticity substantially higher than wood, the core member comprising wood, and the compression element comprising a thin ribbon of resilient material having an elastic yield factor which approximates but does not substantially exceed that of the tension element, said tension element comprising a plurality of strata, the outer stratum being longitudinally compressed throughout its thickness and the inner stratum being longitudinally tensioned throughout its thickness to such extent that at three-quarters of full draw the inner and outer strata are subjected to approximately equal tension.

10. In making a bow having a curved core, and a multi-layer tension element on the back side of the core, the method of manufacture which comprises adhering the layers of the tension element together while they are curved more than the core, partially straightening the tension element so that its inner layer which is to be joined to the core is under tension and its outer layer is under compression, and then adhering the tension element to the core.

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