United States Patent [19]

Boehm

[11] **3,901,522**

[45] **Aug. 26, 1975**

[54] **VIBRATION DAMPED SKI**

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[73] Assignee: **Olin Corporation**, New Haven, Conn.

[22] Filed: **Aug. 22, 1974**

[21] Appl. No.: **499,726**

Related U.S. Application Data

[63] Continuation of Ser. No. 380,308, July 18, 1973, abandoned.

[52] **U.S. Cl.** ..... **280/11.13 L**

[51] **Int. Cl.**[2] **A63C 5/12**

[58] **Field of Search** ..... 280/11.13 F, 11.13 L

[56] **References Cited**

UNITED STATES PATENTS

3,537,717	11/1970	Caldwell	280/11.13 F
3,612,556	10/1971	Seawell	280/11.13 L
3,635,482	1/1972	Holman	280/11.13 L
3,635,483	1/1972	Barriball et al.	280/11.13 L

FOREIGN PATENTS OR APPLICATIONS

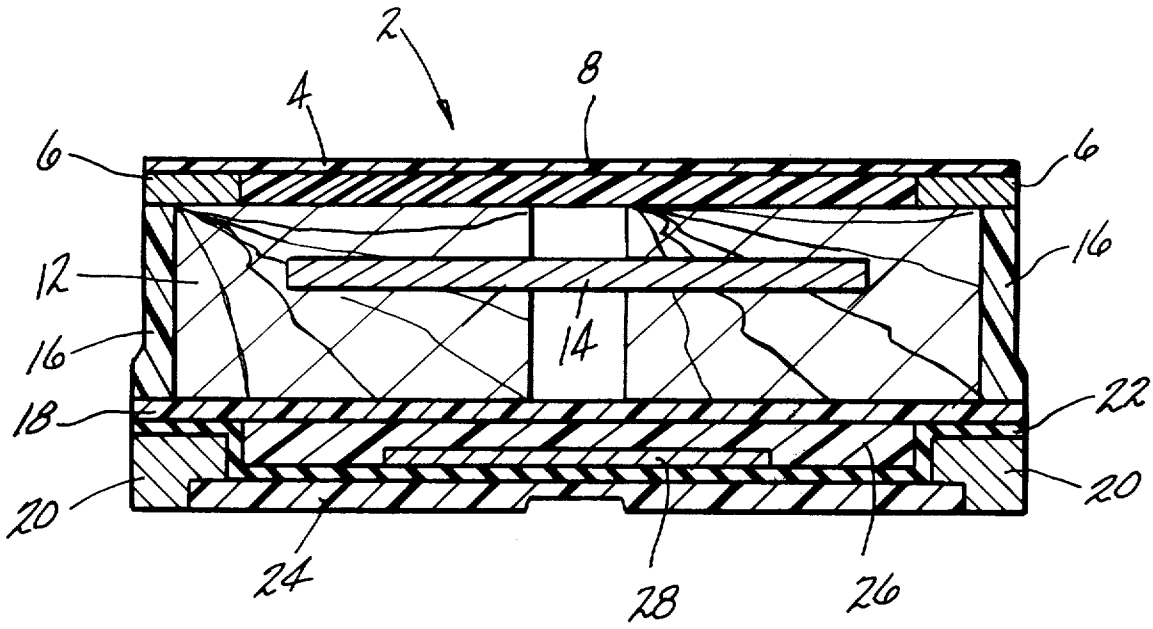
680,647	2/1964	Canada	280/11.13 L
466,980	2/1969	Switzerland	280/11.13 L
1,961,487	7/1970	Germany	280/11.13 L
1,304,880	8/1962	France	280/11.13 F
459,026	8/1968	Switzerland	280/11.13 F

Primary Examiner—Robert B. Reeves
Assistant Examiner—Charles A. Marmor
Attorney, Agent, or Firm—Donald R. Motsko; William W. Jones

[57] **ABSTRACT**

A ski structure of the multi-layer type having a core and one or more intermediate load-bearing layers between top and bottom surfaces of the ski, wherein at least one of the intermediate layers is a laminate comprising a layer of material having a relatively high modulus of elasticity with elastomeric material bonded to opposite faces of the high modulus of elasticity material, with at least a portion of the elastomeric material possessing pronounced viscoelastic properties and the remainder of the elastomeric material being rubber.

6 Claims, 4 Drawing Figures



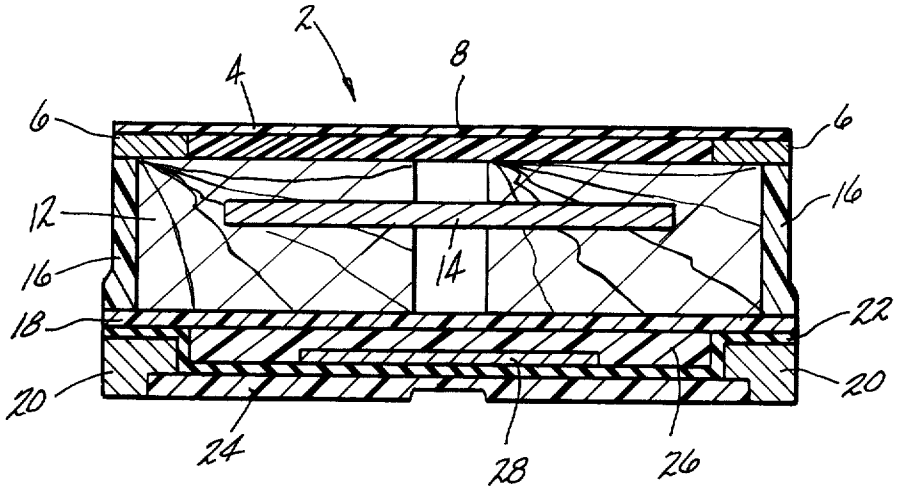


FIG-1

PRIOR ART

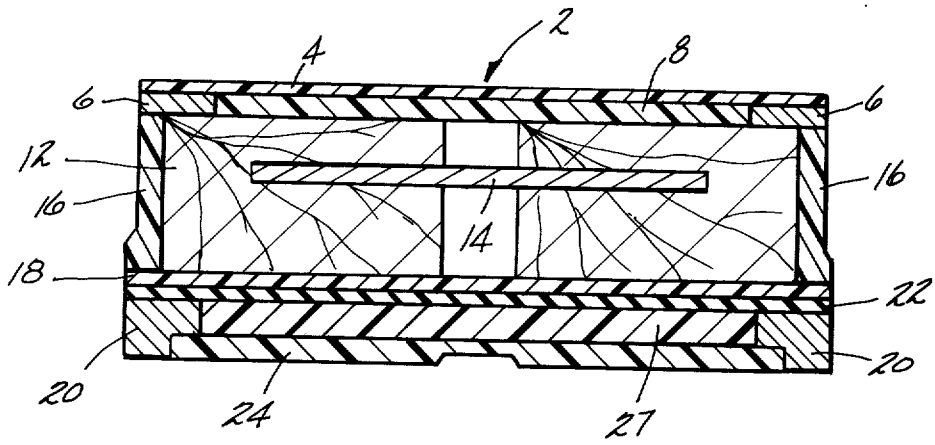


FIG-2

MODIFED PRIOR ART

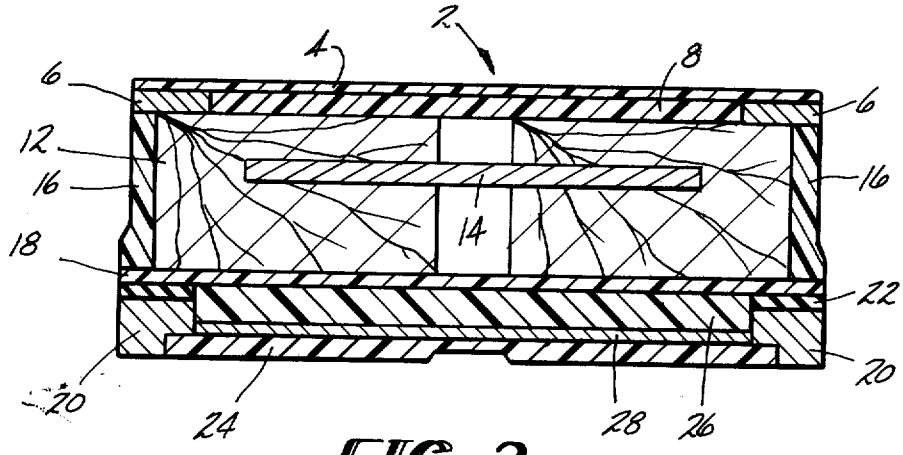


FIG-3

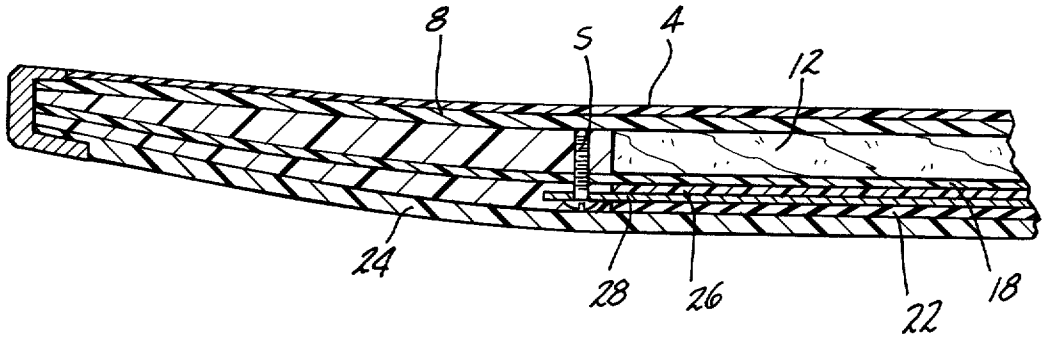


FIG-4

VIBRATION DAMPED SKI

This is a continuation of application Ser. No. 380,308 filed July 18, 1973, now abandoned.

This invention relates to a ski structure which is highly damped against vibration, and more particularly, to a ski structure utilizing viscoelastic material as the vibration damping agent, the viscoelastic material being disposed internally of the ski body.

The skier who favors a fast style and the racer who must control his skis at high speeds demand a ski that remains in steady contact with the slope even at high speeds and a ski that absorbs vibrations caused by uneven places in the terrain. A highly vibratory ski is not responsive for precise turns on icy slopes, this fact having been verified by many years of testing. To execute a proper carving or sliding turn, the steel edge of the ski must be in precise contact with the slope surface in such a way that the skier can balance his moment forces against the resistance forces of the slope. Not every ski meets these requirements. The metal ski's use under these conditions is precluded by its tendency to vibrate at high speeds. After an intensive investigation into the factors which influence the steadiness and vibration characteristics of the ski, it was recognized that there are two physical parameters that deserve attention: the vibrational frequency and the vibrational damping of the ski. Where vibration is not desired, a design with high shock absorbtion capabilities or vibration damping is necessary.

Having recognized the fact that a highly vibration damped ski has desirable characteristics, the prior art has made several attempts to provide this vibration damping feature to a ski. Most modern high performance skis are made up of a plurality of layers of various materials such as fiberglass, metal, wood, synthetic resins, and rubber which are bonded together to form the ski, the various materials being carefully selected for certain desirable characteristics which they contribute to the ski. Thus the search for a means to damp vibration of the ski has been concentrated or focussed upon the multilayer type of ski.

U.S. Pat. No. 2,995,379 issued Aug. 8, 1961 to H. Head and U.S. Pat. No. 3,194,572 issued July 13, 1965 to J. Fischer disclose the use of an internal layer of rubber which is utilized to damp vibtation of the ski imparted thereto during use. While rubber does contribute a vibration damping function to a multilayer ski, the amount or degree of vibration damping imparted to the ski by rubber is minimal, and for example, it is not enough to damp a metal ski sufficiently so that it may be used at high speeds on hard, icy slopes.

Other efforts have been made to modify multi-layer ski construction to improve vibration damping and have provided adequate damping, but have included other drawbacks not related to vibration damping. For example, hardwood cores have been used to improve vibration damping of a ski, but hardwood cores are heavy and expensive, thus adding to the cost of the ski and undesirably increasing the weight of the ski. Glass reinforced polyester resins have been used in place of epoxy resin, to increase internal friction, but polyester resin is not durable enough thus resulting in a low fatigue life for the ski. Plastic top edges rather than metal top edges have been used, but plastic top edges are softer than metal top edges thus giving inferior edge protection. Cracked steel running edges rather than continuous steel running edges have been used, however, cracked steel running edges are extremely expensive, thus undesirably adding to the cost of the ski.

Still another means for damping the vibration of a ski is disclosed in U.S. Pat. No. 3,537,717 issued Nov. 3, 1970 to D. B. Caldwell. A conventional ski is damped according to the Caldwell patent by applying to the top surface of the ski a laminate of a layer of viscoelastic material and a stretch resistant constraining layer, such as metal, with the viscoelastic layer being sandwiched between the top surface of the ski and the constraining layer and serving to bond the constraining layer to the top surface of the ski. This method of damping the ski displayed superior results, however, it also featured some pronounced disadvantages. Specifically, the disadvantages to this method are: that the viscoelastic material and constraining layer are exposed to mechanical forces such as shocks or impact by the other ski, and weathering; the constraining layer is attached to the ski only by the viscoelastic material, thus resulting in poor durability; when applied to the top surface of an already engineered ski, the constraining layer influences other characteristics of the ski, such as overall stiffness, stiffness balance, frequency of the ski, and temperature balance; and the constraining layer must be relatively short when compared to the full length of the skis since the constraining layer, when placed on the top surface of the ski, must terminate at the binding area. Thus the damping system disclosed in U.S. Pat. No. 3,537,717 does improve the vibration damping characteristics of a ski, but has sufficient disadvantages to render it of little practical value for use on commercially produced skis.

It will be noted that the disadvantages of the structure shown in prior art viscoelastic vibration damping system arise chiefly from the fact that the vibration damping laminate is secured to the top surface of the ski. It will be readily apparent that these disadvantages could be eliminated by disposing the vibration damping laminate inside of the ski rather than on its top surface, however, it has been demonstrated that a simple transfer of the vibration damping laminate shown in U.S. Pat. No. 3,537,717 from a location on the top surface of the ski to a location internally of the ski in fact may produce a ski whose vibration damping characteristics are actually worsened. Test results demonstrating this worsening of vibration damping characteristics are presented hereinafter in Table I.

The vibration damping characteristics of a ski can be greatly improved by incorporating a constrained viscoelastic damping laminate into the interior of a multilayer ski as a part of the overall ski structure without encountering the problems attendant with the prior art viscoelastic vibration damping system. The internally incorporated constrained viscoelastic laminate includes a constraining member of a material of relatively high modulus of elasticity, such as aluminum, steel, fiberglass, or the like, wherein the constraining member is substantially completely surrounded by viscoelastic material. This latter-most discovery is disclosed in U.S. patent application Ser. No. 380,309, filed July 18, 1973 now U.S. Pat. No. 3,844,576 to Hermann Schultes.

I have discovered that similar improved vibration damping can be achieved by an internal vibration damping laminate comprising a constraining member of a high modulus of elasticity material, such as aluminum, steel, fiberglass, or the like, which constraining member is isolated over its major portion from the re-

maining components of the ski by a layer of viscoelastic material on one side of the constraining member, and a layer of rubber on the other side of the constraining member. By utilizing both viscoelastic material and rubber to isolate the constraining member from the rest of the ski, a cost savings and a toughening of the vibration damping laminate are accomplished as compared to encasing the constraining member in viscoelastic material. In order to operate properly, the viscoelastic material must be interposed between the constraining member and a vertically adjacent load-bearing component of the ski. The constraining member can, if desired, be secured directly to the remainder of the ski at one point, preferably spaced as far as possible away from the shovel area of the ski, with the securement being in the form of an adhesive, screws, or the like, however, the remaining surfaces of the constraining member must be isolated from the remainder of the ski structure by the viscoelastic material or the rubber. In order to maximize the vibration damping performance of the internal constrained viscoelastic and rubber laminate, it should be positioned as far as possible away from the neutral axis of the ski, preferably below the neutral axis of the ski so as to be free from contact with binding screws conventionally embedded in the ski at the binding area.

By utilizing a constrained viscoelastic and rubber laminate as an internal component of a multi-layer ski, the vibration damping laminate can be properly designed in conjunction with the remaining ski components to accurately control proper ski flexibility, frequency, and the like. The vibration damping laminate is protected against delamination, impact, weathering and other adverse influences. The viscoelastic material is protected and reinforced by other stronger components of the ski. Internally positioning the vibration damping laminate permits the designer to use a constrained laminate substantially equal in length to the length of the ski which doubles the maximum shear strain in the laminate as compared to the system disclosed in U.S. Pat. No. 3,537,717. When the constraining member is attached directly to the tail end of the ski, it can be shown that the maximum shear strain is about 4 times that of the system disclosed in U.S. Pat. No. 3,537,717.

It is, therefore, an object of this invention to provide a damped ski having a constrained viscoelastic and rubber vibration damping laminate incorporated into the interior portion of the ski.

It is yet another object of this invention to provide a ski of the character described wherein the constraining member of the vibration damping laminate is substantially completely isolated from the remaining components of the ski by an elastomeric material, at least a portion of which possesses pronounced viscoelastic properties and the remainder of which is rubber.

It is a further object of this invention to provide a ski of the character described wherein the constrained viscoelastic and rubber laminate is protected from adverse effects by the remaining components of the ski.

These and other objects and advantages of the ski of this invention will become more readily apparent from the following detailed description of an embodiment of a ski formed in accordance with the invention taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a sectional view of a preferred embodiment of a ski made in accordance with the invention;

FIG. 2 is a sectional view of a prior art ski;

FIG. 3 is a sectional view of a modified prior art ski; and

FIG. 4 is a vertical sectional view of the tail end of a modified embodiment of a ski formed in accordance with this invention.

Referring to the drawings, a multi-layer laminated fiberglass ski **2** is shown in FIG. **1.** The top layer **4** is an ABS decorative layer. Beneath the top layer **4** are disposed top protective edges **6** of metal such as aluminum or steel. A load-bearing layer of fiberglass **8** is positioned below the top layer **4** and between the top edges **6** respectively and above a wood core **12.** A binding plate **14** may be embedded in the wood core **12** for strengthening the binding area of the ski. Sidewall layers **16** of phenolic resin extend from the top edges **6** to a further load bearing fiberglass layer **18** beneath the core **12.** Steel running edges **20** are bonded to the fiberglass layer **18** by means of an intermediate rubber layer **22.** The bottom running surface of the ski is a polyethylene layer **24** sold under the trademark P-Tex. Sandwiched between the running surface layer **24** and the lower fiberglass layer **18** is the vibration damping laminate which comprises a layer **26** of highly viscoelastic material preferably juxtaposed to the top and side surfaces of a constraining member **28** of a material having a high modulus of elasticity, such as aluminum, steel, fiberglass, or the like. The viscoelastic material layer **26** is elastomeric and inherently adhesive so as to bond itself to the constraining member **28** and the fiberglass layer **18** and the rubber layer **22,** however, this bond may be strengthened by proper application of epoxy resin which is used to bond the remaining layers together to form the ski.

It will be noted that the rubber layer **22** passes between the running edges **20** and the fiberglass layer **18,** thence downwardly between the viscoelastic material **26** and the running edges **20,** and thence across the ski between the constraining member **28** and the running surface layer **24.** Thus the rubber layer **22** isolates the bottom surface of the constraining member **28** from the running surface layer **24.** The rubber layer **22** is secured to the constraining member **28** and other adjacent layers by adhesive. It will further be noted that the viscoelastic material **26** isolates the constraining member **28** from the next vertically adjacent load-bearing member, the fiberglass layer **18.** Preferably the damping laminate extends for substantially the entire length of the ski. The constraining member **28** may be completely surrounded by viscoelastic material and rubber layer **22,** or the constraining member may be permitted to project beyond the viscoelastic material and rubber isolating material at its rear terminal at the rear end of the ski so that the projecting portion of the constraining member can be directly secured to the remaining layers of the ski with a screw S, as shown in FIG. **4,** adhesive, or the like. In any event, the major portion of the constraining member should be isolated from the rest of the ski layers by the viscoelastic material and rubber for best performance.

It will be noted that the particular ski structure illustrated in FIG. **1** is only one of many possible ski structures of the multi-layer type with which the invention may be used to improve vibration damping characteristics. While the load-bearing members of the ski struc-

ture of FIG. 1 are referred to as being fiber glass, they could also be made of metal or other conventional load-bearing material without departing from the spirit of the invention. Similarly, the core structure need not be wood, but could instead be made from a rigid plastic foam, a metal honeycomb, or any other conventional and known material utilized for cores of skis.

It is noted that most materials exhibit some degree of viscoelasticity, an elastic material being defined as a material whose stress is proportional to strain, and a viscous material being defined as a material whose stress is proportional to strain rate. A viscoelastic material is a material whose behaviour is a mixture of these two simple cases. In order to be useful in providing vibration damping in accordance with this invention, the elastomeric material used must possess pronounced viscoelastic properties. By pronounced viscoelastic properties, it is meant that the loss tangent of the viscoelastic material must be greater than about 0.8. When a viscoelastic material is subjected to a sinusoidal strain, the resultant stress is approximated by a sine wave which leads the strain by the phase angle β. The relationship between the components of the tension or compression modulus of any specimen is defined by the equation:

$$E^* = E' + i\,E''$$

where:

E^* is the complex modulus of elasticity:

E' is the storage modulus of elasticity;

E'' is the loss modulus; and

i is the square root of -1.

The loss tangent is the tangent of the phase angle β which equals E''/E'. As previously noted, the loss tangent of the viscoelastic material must be greater than about 0.8 to be useful in vibration damping in accordance with this invention.

The constraining member which forms a part of the vibration damping laminate must be of a material having a relatively high modulus of elasticity, such as steel, aluminum, fiberglass, or the like.

Several measurements which may be made to determine the amount of vibration damping present in a ski include: the Log Decrement which is defined as the natural logarithm of the ratio of any two successive vibration amplitudes wherein:

$$\text{Log Decrement} = \ln A_2$$

it being noted that the greater the value of the Log Decrement, the better vibration damping characteristic of the ski; and

The Half Life Time which is defined as the time period required for the vibration amplitude to decay to one-half of its initial value, it being noted that the shorter the Half Life Time, the better vibration damping characteristic of the ski.

Generally, when determining the vibration damping characteristics of a ski, the Frequency is also determined, the Frequency being defined as the number of complete vibration cycles, or cycles of motion in a unit of time, wherein by international convention, 1 cycle per second equals 1 Hertz.

Tests showing the vibration damping ability of the structure shown in FIG. 1 were conducted with comparisons being made between this structure and the structures shown in FIG. 2 and FIG. 3 which are respectively a commercially available prior art ski and a ski structure similar thereto but incorporating as an internal component, the prior art viscoelastic vibration damping composite shown in U.S. Pat. No. 3,537,717, noted above, referred to hereinafter as the "Modified Prior Art" ski. The prior art ski used in comparison tests was of the same construction shown in FIG. 2, it being noted that the rubber layer **22** extends in a straight line laterally across the full width of the ski. The space between the rubber layer **22** and running base **24** was filled with a viscoelastic clear polyethylene material **27.** The Modified Prior Art ski used in the comparison test was of the same construction shown in FIG. 3. It will be noted that the constraining member **28** is not surrounded with viscoelastic material and rubber. The viscoelastic material is sandwiched only between the constraining member **28** and the fiberglass layer **18,** the side surfaces of the constraining member **28** are adjacent the running edges **20** and the bottom surface of the constraining member is adjacent the running surface layer **24.**

Other numerals in FIGS. 2 and 3 denote structural members similar to those described in connection with FIG. 1.

The vibration damping characteristics of both the shovel and the entire forebody area of the skis were measured with the results thereof being set forth in Table I below. In measuring the vibration damping characteristics of the shovel area, the skis were clamped approximately midway between the shovel and binding areas and the shovel end of the ski was deflected and released to vibrate. In measuring the vibration damping characteristics of the forebody, the skis were clamped at the binding area and the shovel end of the ski was deflected and released to vibrate. The viscoelastic material used in the skis was made generally in accordance with the disclosure of Kalleberg and Turner U.S. Pat. No. 3,062,683 except that the glass fibers were omitted from the viscoelastic material and the viscoelastic material was carried on a plastic skrim cloth.

TABLE I

SKI	SHOVEL LOG DECREMENT	HALF LIFE(sec)	FREQUENCY (Hertz)	FOREBODY LOG DECREMENT	HALF LIFE(sec)	FREQUENCY (Hertz)
1. Prior Art	.052	.45	28.4	.064	.75	14.0
2. Modified Prior Art	.050	.48	30.5	.056	.84	14.6
3. FIG. 1 Ski Completely Isolated	.127	.18	27.0	.102	.55	13.0

As will be noted from the above results shown in Table I, the vibration damping characteristics of the ski

construction shown in FIG. 1 was vastly superior to the vibration damping characteristics of either the prior art ski construction or the Modified prior art ski construction wherein the vibration damping laminate of U.S. Pat. No. 3,537,717 was incorporated into the ski as an internal component thereof.

In fact it will be noted, contrary to what one might expect, the vibration damping characteristics of the Modified Prior Art ski tested were shown to be inferior to vibration damping characteristics of the prior art ski as evidenced by the decrease in Log Decrement and the increase in vibration Half Life Time. The Modified Prior Art ski displayed the poorest vibration damping characteristics of the three skis tested. The poor vibration damping characteristics of the Modified Prior Art ski is the result of the failure to isolate the constraining member **28** from the remainder of the ski with elastomeric material. The Log Decrement of the ski made in accordance with this invention increased by more than 100% in the shovel area test and by more than 80% in the forebody area test. Furthermore, the vibration Half Life for both the shovel and forebody portions of the ski was dramatically decreased. In the test specimens having an internal constraining member, e.g. Specimens **2** and **3**, the internal constraining member extended for substantially the entire length of the ski. Specimen **3** had the constraining member completely isolated by viscoelastic material and rubber.

It will be readily apparent to those skilled in the art that the vibration damping technique disclosed herein will result in much quieter and more skiable skis. This invention allows the ski designer to put as little or as much damping in a ski as required. Also, the other characteristics of the ski can be designed at optimum values. By varying five factors set forth below which control the amount of damping obtained from the constrained viscoelastic laminate, the ski designer can tune the ski to obtain optimum damping. The five factors are:

1. The loss tangent of the viscoelastic material (should be greater than about 0.8).
2. The thickness of the viscoelastic material.
3. The volume of the viscoelastic material.
4. The magnitude of the shear strain in the viscoelastic material.
5. The modulus of elasticity and cross-sectional area of the constraining member.

It should be noted that while the constraining member shown in the embodiment of the invention specifically disclosed above is in the form of a sheet-like member, the constraining member could also be in the form of a rod, tube, wire, or other such form without departing from the spirit of the invention.

Since many changes and variations of the disclosed embodiment of the invention may be made without departing from the inventive concept, it is not intended to limit the invention otherwise than as required by the appended claims.

What is claimed is:

1. A laminated ski structure of the type comprising a top surface, a bottom surface, and a plurality of intermediate layers disposed between said top and bottom surfaces, the improvement comprising at least one of said intermediate layers being a vibration damping laminate comprising a high modulus of elasticity member substantially completely surrounded by elastomeric material a portion of said elastomeric material possessing pronounced viscoelastic properties and having a loss tangent greater than about 0.8 and the remainder of said elastomeric material being rubber, said material possessing pronounced viscoelastic properties being insulated from external environment by outwardly adjacent material possessing substantially lower viscoelastic properties.

2. The ski structure of claim **1**, wherein said vibration damping laminate extends for substantially the entire length of the ski.

3. The ski structure of claim **1**, wherein said vibration damping laminate is offset downwardly from the neutral axis of the ski.

4. The ski structure of claim **1**, wherein said high modulus member includes a rearward portion projecting from said elastomeric material, and further comprising means for securing said rearward portion to a tail end portion of the ski.

5. The ski structure of claim **1**, wherein said elastomeric material possessing pronounced viscoelastic properties is sandwiched between said high modulus member and a vertically adjacent load-bearing member.

6. A laminated ski structure comprising a top surface, a bottom surface and one or more interbonded intermediate layers disposed between said top and bottom surfaces, at least one of said intermediate layers being a vibration damping laminate comprising a layer of material having a relatively high modulus of elasticity, a layer of material having pronounced viscoelastic properties and having a loss tangent greater than about 0.8 bonded to one surface of said high modulus layer, and a layer of rubber bonded to an opposite surface of said high modulus layer, said viscoelastic layer and said rubber layer serving to substantially completely isolate said high modulus layer from the remainder of the ski, and said viscoelastic layer being insulated from external environment by outwardly adjacent material possessing substantially lower viscoelastic properties.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,901,522 Dated August 26, 1975

Inventor(s) H. C. Boehm

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In Column 5, line 49, the equation "Log Decrement = ln A_2" should be deleted and the equation "Log Decrement = ln A_1/A_2" inserted.

Signed and Sealed this

twenty-third Day of *December 1975*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks