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(54) **THERMAL WICK COOLING FOR VIBROACOUSTIC TRANSDUCERS**

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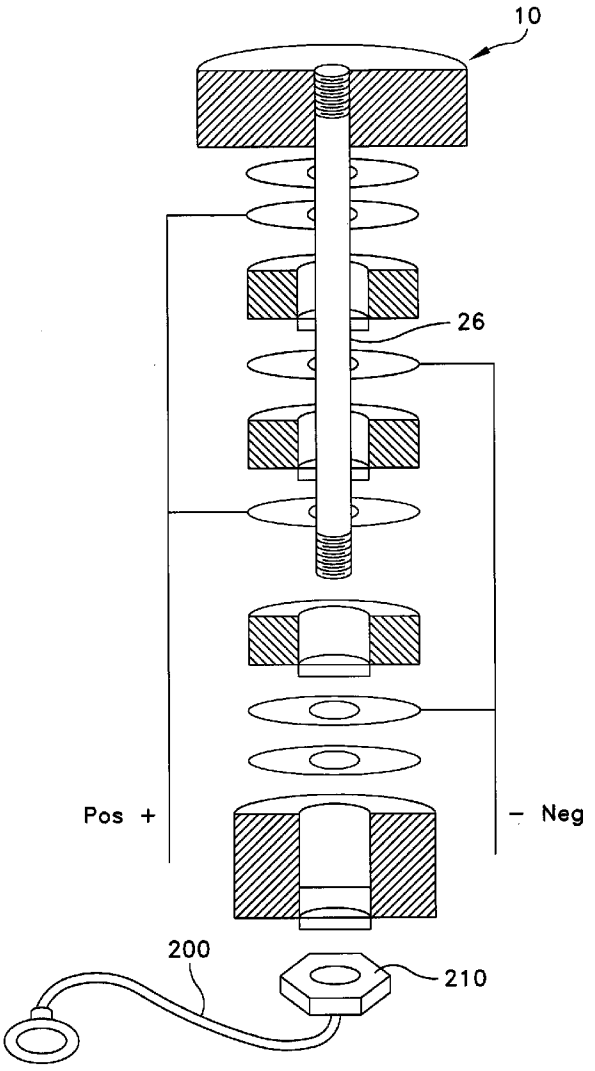
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(57) **ABSTRACT**

A soft thermally-conductive wick is provided to be connected between the metallic components on a transducer and onto a thermal sink. Beryllia ceramic is provided to improve heat flux within the transducer while maintaining electrical insulation. The wick provides adequate heat flux and such that the mass and stiffness of the wick do not adversely affect the vibroacoustic properties of the transducer in the frequency band of interest. The mass of the wick attachment is considered in the transducer design with the location and direction of the wick attachment designed so as to not introduce rocking modes or other adverse affects in the frequency band of interest. The wick may be strung, coiled, folded or configured in many ways between the transducer and the thermal sink to ensure that no acoustic or vibrational energy is transmitted down the length of the wick.



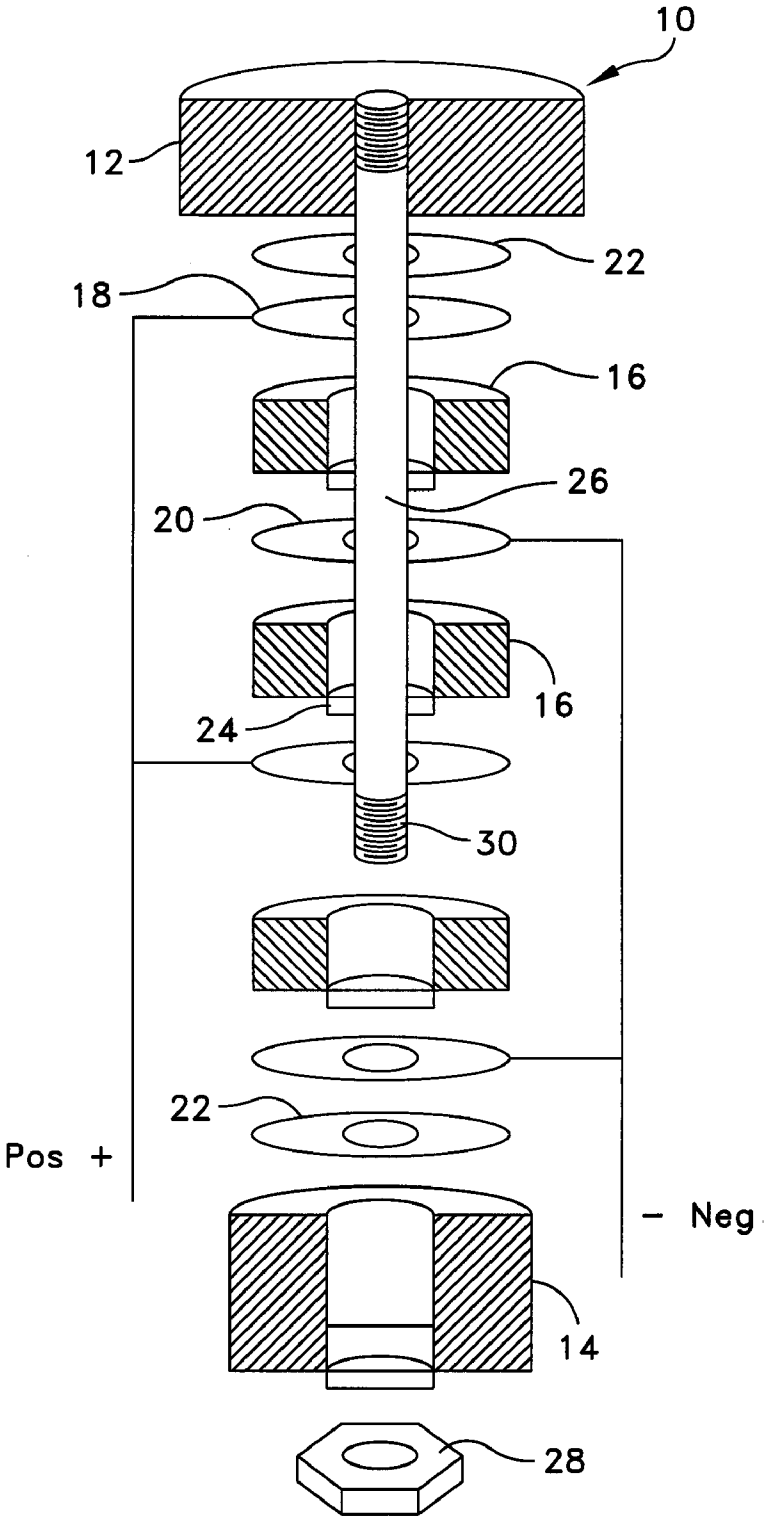


FIG. 1
(PRIOR ART)

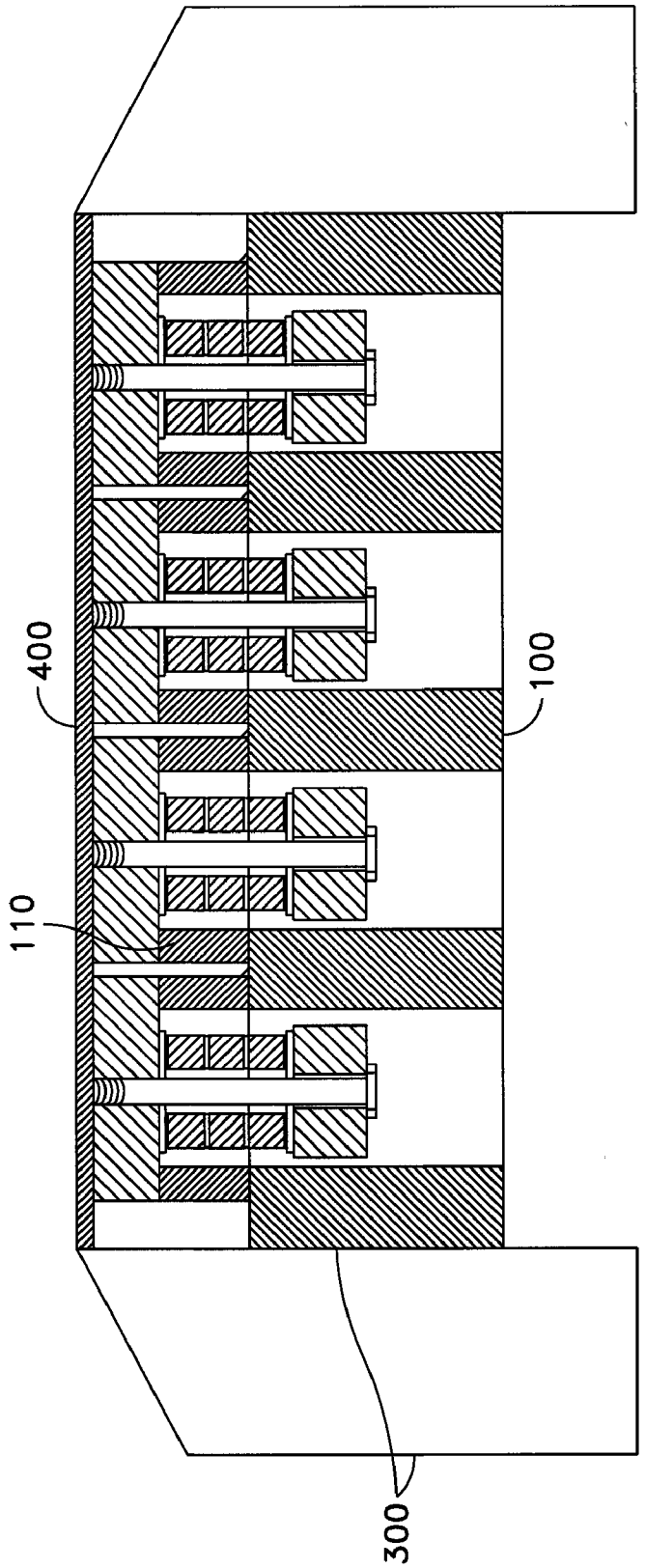


FIG. 2
(PRIOR ART)

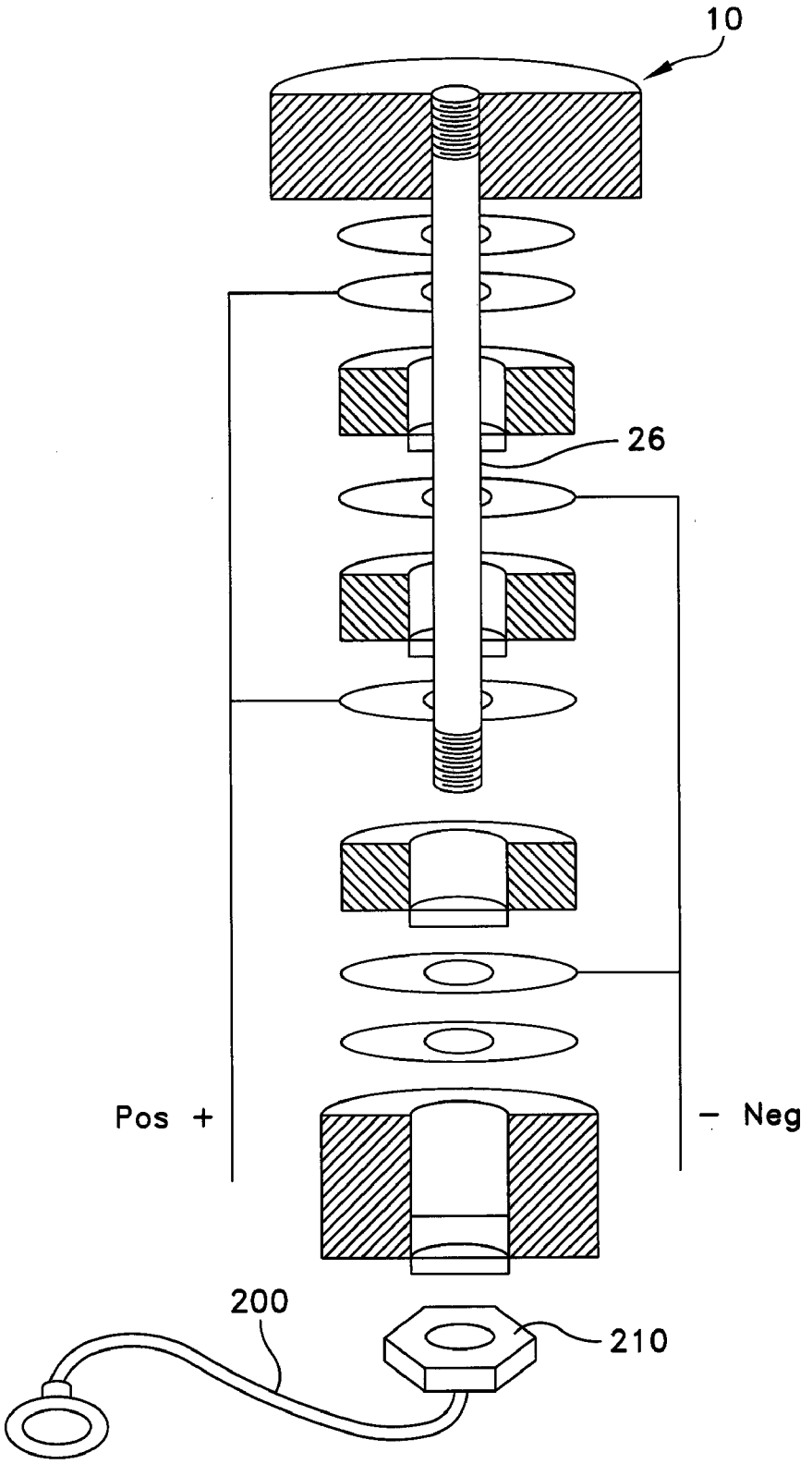


FIG. 3

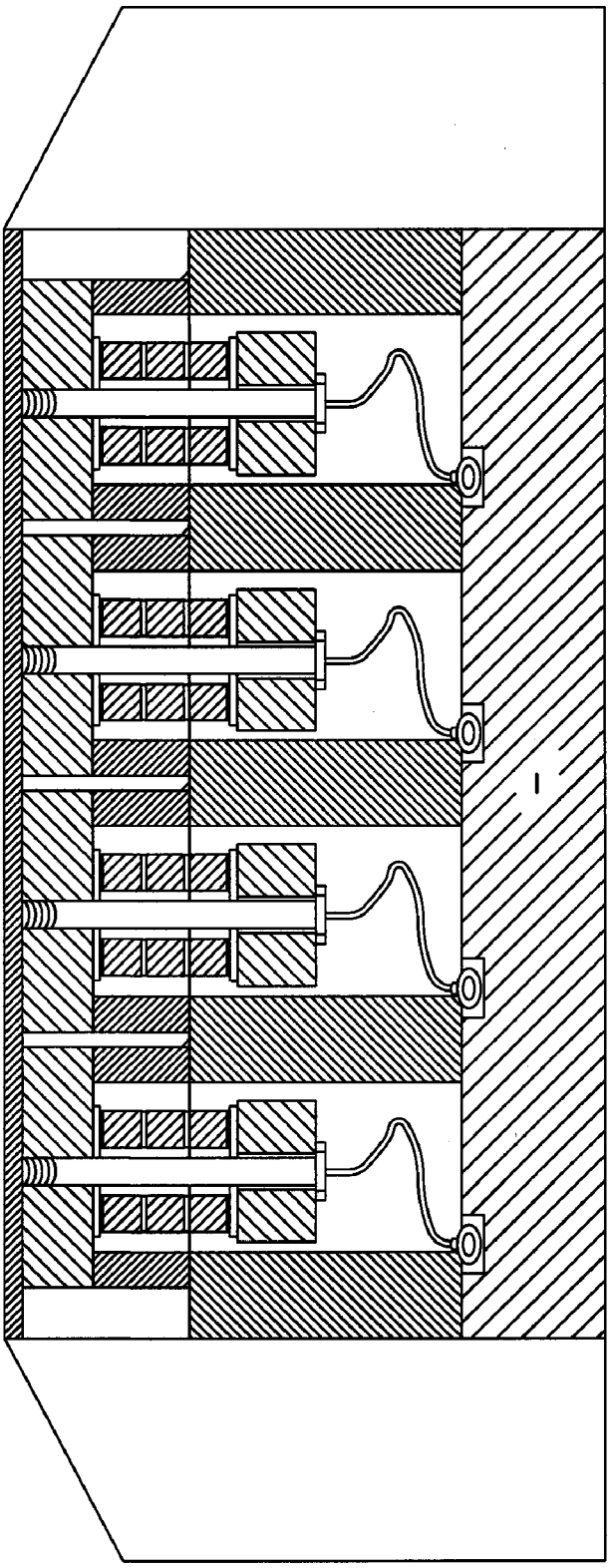


FIG. 4

THERMAL WICK COOLING FOR VIBROACOUSTIC TRANSDUCERS

STATEMENT OF GOVERNMENT INTEREST

[0001] The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefore.

CROSS REFERENCE TO OTHER PATENT APPLICATIONS

[0002] None.

BACKGROUND OF THE INVENTION

[0003] (1) Field of the Invention

[0004] The present invention provides a device for cooling a vibroacoustic transducer without adversely affecting vibrational characteristics of the transducer.

[0005] (2) Description of the Prior Art

[0006] Vibroacoustic transducers, such as piezoceramic tonpilz sonar array elements, generate heat as a byproduct of operation. These transducers are mounted in such a manner (gas-backed, syntactic foam mounted) as to have limited heat flux to their foundations or array plates. Therefore, as the drive levels and duty cycles increase, output power becomes heat-limited. Furthermore, as the frequency bandwidth of operation increases, these devices are driven further from their efficient resonant points, again increasing heat generation. During some operations, failure modes such as syntactic foam mount melting and acoustic window debond and melting have been observed.

[0007] Consider the section view of a typical prior art vibroacoustic transducer **10**—shown in FIG. **1**. In operation, acoustic energy is radiated from a headmass **12** as the headmass oscillates out of phase with a tailmass **14** when driven by a stack of piezoceramic wafers **16**. The piezoceramic wafers **16** exhibit a mechanical strain proportional and parallel to an alternating electrical voltage provided by oppositely-charged electrode discs **18**, **20**. The piezoceramic wafers **16** generate heat in this excitation process. Heat is conducted to the tailmass **14** and headmass **12**. The headmass **12** and tailmass **14** may be electrically insulated from the electrodes by insulating wafers **22**.

[0008] The piezoceramic wafers **16** may also be insulated electrically by core insulating collars **24** or more typically by air gaps around a central stress rod **26**. With a pre-defined load, the stress rod **26** clamps the stack of piezoceramic wafers **16**, electrodes and insulators between the headmass **12** and the tailmass **14**. The clamping operation is typically tuned by tightening a binding nut **28** or by using a screw thread **30** in the tailmass **14** if a nut is not used. This assembly is typically mounted to a foundation or to an array plate **100** by a syntactic foam mounting ring **110** as shown in FIG. **2**.

[0009] The mounting ring **110** may have resonant characteristics to provide mechanical isolation. Generally, the mounting ring **110** is a poor thermal conductor. An acoustically-transparent elastomeric window is often cast over the headmass **12**, thereby providing a hydrodynamic surface. Heat is also generated in the window material as the window is vibrated by the headmass **12**.

[0010] Generally, the elastomer properties of the window are a poor heat conductor. This heat may be conducted or convected from the outer surface by presence or flow of a surrounding fluid, such as seawater in the case of an underwater application. Excessive heat generated in the window may also be conducted back to the headmass **12**; thereby, increasing element heating.

[0011] As such a need still exists for alternative transducer cooling and the prior art includes numerous references that attempt to provide such cooling. In Krempl (U.S. Pat. No. 4,169,387), a transducer is disclosed for mechanical measured variables having a heat pipe system that is connected on one side to the thermally high stressed parts of the transducer and on the other side to parts that not exposed to heat or cold. The sensor element of the transducer is cooled through heat transport by means of an alternatively vaporizing and condensing working fluid within the heat pipe system.

[0012] In Boeglin et al. (U.S. Pat. No. 5,291,461), an elastomer support for a sonar transducer includes a ceramic stack electromechanical driver, a pair of rigid support members and a pair of elastomer layers disposed between the ceramic stack electromechanical driver and the support members. The elastomer support provides effective mechanical stress reduction in the ceramic stack driver, as well as, a simple reliable heat dissipation means for the transducer.

[0013] In Sliwa, Jr et al. (U.S. Pat. No. 5,560,362), an ultrasound transducer is provided as an assembly having a housing, a transducer array mounted in the housing, and an active cooling mechanism positioned adjacent to the transducer array for actively removing heat generated by the array by transport of energy from the affected site. The active cooling mechanism may comprise a heat exchanger including a closed loop circulating coolant system circulating coolant or a single-pass flowed coolant, passing through the heat exchanger, a heat pipe, a thermoelectric cooler, an evaporative/condenser system and/or a phase change material. One or more heat exchangers may be used having gas or liquid coolants flowing there through. The heat exchangers and coolant pumps may be located in various components of the transducer assembly, including the array housing, the connector assemblies or the ultrasound console.

[0014] In Drumheller (U.S. Pat. No. 5,703,836), an acoustic transducer is disclosed that has a one-piece hollow mandrel into the outer surface of which is formed a recess with sides perpendicular to the central axis of the mandrel and separated by a first distance and with a bottom parallel to the central axis and within which recess are a plurality of washer-shaped discs of piezoelectric material and at least one disc of a temperature-compensating material with the discs being captured between the sides of the recess in a pre-stressed interface fit.

[0015] In Nilsson et al (U.S. Pat. No. 5,955,823), a method is provided to improve the output characteristics of an ultrasonic transducer by urging a cooling gas to flow through the transducer, thereby passing a cooling member between each adjacent pair of piezoelectric elements.

[0016] In Wildes et al. (U.S. Pat. No. 7,105,986), a composite structure of a backing material with enhanced conductivity for use in a transducer is presented. The composite material includes a plurality of layers of backing material alternatively arranged with a plurality of thermal conductive elements, wherein the plurality of thermal conductive elements are configured to transfer heat from a center of the transducer to a plurality of points on the composite structure of backing material.

SUMMARY OF THE INVENTION

[0017] Accordingly, it is a primary object and general purpose of the present invention to provide a device for cooling

a vibroacoustic transducer without adversely affecting vibrational characteristics of the transducer.

[0018] It is a further object of the present invention to provide a device for cooling a vibroacoustic transducer which allows higher drive levels to be achieved for longer duty cycles and broader frequency bandwidths.

[0019] It is a still further object of the present invention to provide an inexpensive method of conducting waste heat from the transducer to any location—such as a heat sink.

[0020] In order to attain the objects described, the present invention provides a soft thermally-conductive wick connected between the metallic components on a transducer and onto a thermal sink. The wick provides adequate heat flux and such that the mass and stiffness of the wick do not adversely affect the vibroacoustic properties of the transducer in the frequency band of interest. The mass of the wick attachment is considered in the transducer design with the location and direction of the wick attachment designed so as to not introduce rocking modes or other adverse affects in the frequency band of interest. In operation, heat is conducted from the transducer via the wick to the thermal sink.

[0021] Improved heat transfer by beryllia insulators is also claimed for transducers requiring electrical isolation of metallic components. The wick may be strung, coiled, folded or configured in many ways between the transducer and the thermal sink to ensure that no acoustic or vibrational energy is transmitted down the length of the wick.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] A more complete understanding of the invention and many of the attendant advantages thereto will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein like reference numerals and symbols designate identical or corresponding parts throughout the several views and wherein:

[0023] FIG. **1** depicts an exploded view of a prior art transducer;

[0024] FIG. **2** depicts a prior art transducer mounted on an array plate;

[0025] FIG. **3** depicts a prior art transducer connected with thermal wick assembly of the present invention; and

[0026] FIG. **4** depicts a prior art transducer with thermal wick assembly of the present invention mounted on an array plate.

DETAILED DESCRIPTION OF THE INVENTION

[0027] As shown in FIG. **3**, a soft, tactile and pliable thermally-conductive wick **200** is connected between the metallic components on the transducer **10** and onto a thermal sink (not shown). This wick **200** may be a loosely-braided length of thermally conductive material such as copper or silver. An example of a suitable conductor for the role of the wick **200** is the copper de-soldering wick used in printed circuit board manufacturing. The assembly of the wick **200**, a lug **210** and tailmass **14** is designed and configured such that the wick **200** is of sufficient total material cross-section and of appropriate metal alloy to conduct the required thermal energy from the hot transducer to the cooler surrounding masses which serve as heat sinks **300**. For harsh duty cycles, the conduction equation is solved conservatively to determine this required wick cross section, using the allowable maximum temperature for the transducer element and the maximum expected temperature for the heat sink **300**, in order to minimize the available temperature differential. The contact area of the lug **210** on the tailmass **14** and stress rod **26** also allows thermal conduction at a rate not less than the heat flux required in the wick **200**.

[0028] The total cross-sectional area of the wick is determined by the cross-section of the strands of the wick, the tightness of the weave and the constitutive properties of the alloy from which the wick is made. These strand parameters are selected by consideration of the thermal conduction requirements as derived above and the mechanical requirement that the resulting stiffness of the wick does not adversely affect the vibroacoustic properties of the transducer in the frequency band of interest.

[0029] The wick **200** is connected to the metallic components of the transducer **10** via means known to those ordinarily skilled in the art (such as the lug **210** or stud) or by directly soldering or brazing the wick to the appropriate metallic component (such as the tailmass **14**, headmass **16** or the stress rod **26**. The mass of the attachment is considered in the transducer design as follows. The vibroacoustic requirement of the transducer of prior art sets the total allowable mass of the tailmass **14** (and the nut **28** if the tail mass itself is not threaded and solder/brazing material.

[0030] The location and direction of the wick attachment are designed so as to not introduce rocking modes or other adverse affects in the frequency band of interest. Generally, the lug **210** is designed to be azisymmetric on the centerline of the stress rod **26**. Furthermore, the assembly can be designed using modal analysis such that the stiffness, aspect ratio, orientation of the wick and resonant modes of the tail assembly do not introduce unwanted response modes in the complete transducer assembly within the frequency range of operation.

[0031] Thermal conduction to the metallic components may be enhanced by the introduction of thermally conductive dielectric wafers in place of the end insulating wafers **22**. Another feature of the invention is the use of beryllia for these dielectric wafers **22**, which has the rare properties of high thermal conduction, high stiffness and is an electrical insulator. The use of this unique ceramic has not been demonstrated in the prior art in vibroacoustic transducers. As such, this embodiment is a novel and beneficial feature enhancing heat transfer in vibroacoustic transducers—independent of the incorporation of the wick **200**.

[0032] In operation, heat is conducted from the transducer **10** via the wick **200** to a thermal sink **300**. The thermal sink **300** may be the array foundation, or may be a remote structure such as a heat exchanger. The wick **200** may be connected to the thermal sink **300** in a variety of attachments known to those ordinarily skilled in the art (such as the lugs or studs previously discussed).

[0033] If electrical isolation of the transducer wick **200** is required, a washer made of thermally conductive dielectric such as beryllia may be introduced. The wick **200** may be strung, coiled, folded or configured in many ways between the transducer **10** and thermal sink **300** to ensure that no acoustic or vibrational energy is transmitted down the length of the wick.

[0034] The wick **200** is preferably composed of fine (thin) filaments in a loose cord or weave such that no appreciable mass is added to the transducer **10** and no appreciable acoustic energy or vibrational energy is transmitted down the

length of the wick. Lossy materials or masses may be added at discrete points along the length of the wick to mitigate acoustic energy transfer.

[0035] The foregoing description of the preferred embodiments of the invention has been presented for purposes of illustration and description only. It is not intended to be exhaustive nor to limit the invention to the precise form disclosed; and obviously many modifications and variations are possible in light of the above teaching. Such modifications and variations that may be apparent to a person skilled in the art are intended to be included within the scope of this invention as defined by the accompanying claims.

What is claimed is:

1. A device for cooling a vibroacoustic transducer, said device comprising:

a thermally-conductive and pliable wick connectable at a first end to a metal component of a transducer with a second end of said wick connectable to a thermal sink;

wherein said wick is capable of sufficient heat flux.

2. The device in accordance with claim **1**, said device further comprising a beryllia washer interposed between the first end of said wick and the metal component of the transducer.

3. The device in accordance with claim **2** wherein the material of said wick is copper.

4. The device in accordance with claim **2** wherein the material of said wick is silver.

5. The device in accordance with claim **1** wherein the material of said wick is copper.

6. The device in accordance with claim **1** wherein the material of said wick is silver.

7. A system for cooling a vibroacoustic transducer, said device comprising:

a pliable and thermally-conductive wick connectable at a first end to a metal component of a transducer with a second end of said wick connectable to a thermal sink wherein said wick is capable of sufficient heat flux; and

a component for thermal conduction interposed within the transducer.

8. The system in accordance with claim **7** wherein the material of said thermal conduction component is beryllia.

9. The system in accordance with claim **7** wherein said thermal conduction component is in the shape of a wafer.

10. The system in accordance with claim **9** wherein the material of said thermal conduction component is beryllia.

11. The system in accordance with claim **7** said system further comprising a beryllia washer interposed between the first end of said wick and the metal component of the transducer.

12. The system in accordance with claim **11** wherein the material of said thermal conduction component is beryllia.

13. The system in accordance with claim **12** wherein the material of said wick is copper.

14. The system in accordance with claim **12** wherein the material of said wick is silver.

15. The system in accordance with claim **11** wherein said thermal conduction component is in the shape of a wafer.

16. The system in accordance with claim **15** wherein the material of said thermal conduction component is beryllia.

17. The system in accordance with claim **16** wherein the material of said wick is copper.

18. The system in accordance with claim **16** wherein the material of said wick is silver.

19. The system in accordance with claim **16** wherein the material of said wick is gold.

20. The system in accordance with claim **16** wherein the material of said wick is lead.

* * * * *