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NASA CASE NO. LAR 14734-1-SB

PRINT FIG. 1

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LaRC

PATENT APPLICATION

(NASA-Case-LAR-14734-1-SB) TEMPERATURE REGULATOR FOR ACTIVELY COOLED STRUCTURES (NASA. Langley Research Center) 13 p

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TEMPERATURE REGULATOR FOR ACTIVELY COOLED STRUCTURES

<u>Awards Abstract</u>

NASA Case No. LAR 14734-1-SB

Structures may undergo significant heating while operating under normal conditions. Hypersonic vehicles, for example are subject to significant heating as a result of friction between the vehicle and the surrounding air. One method of reducing the temperature of a heated structure is the circulation of a coolant through the structure to remove excess heat. This may be achieved by use of a plurality of small coolant passages fed from a common manifold.

In practice, a given area of the structure will often have a time varying heat load applied to it as a result of changes in operating parameters. In the case of hypersonic vehicles these changes include changes in speed, attitude, vehicle maneuvers and impingement of shock waves. Thus, coolant passages are currently designed to allow flow of sufficient coolant to meet peak demand for a given portion of the structure. Thus, the majority of the time the structure is overcooled and coolant is wasted. In the case of gaseous coolants, highly heated coolant gas becomes more viscous, leading to a pressure drop in the heated coolant passage, further contributing to the overheating problem.

In other applications of flow control, present devices for reducing the flow of coolant in a passage often rely on a cylinder of wax which when melted increases its volume, pushing on a piston that activates a valve. This type of device is not easily miniaturized for use in the large number of very small coolant passages that are used in active cooling.

The present invention makes use of a shape memory alloy flap to passively control flow rates. The SMA reacts to an increase in temperature by moving to increase the flow of coolant in the overheated passage. This maintains a more even temperature distribution in the structure. Other embodiments make use of thermal expansion to passively control the flow of coolant.

The novelty of the present invention lies in use of passive, temperature reactive methods to control coolant flow in an active cooling system. The passive features may be more easily miniturized than mechanical valve systems.

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TEMPERATURE REGULATOR FOR ACTIVELY COOLED STRUCTURES

Origin of the Invention

The invention described herein was jointly made by an employee of the United States Government and a contract employee during the performance of work under NASA Contract No. NAS-1-19317. In accordance with 35 U.S.C. 202, the contractor elected not to retain title.

Background of the Invention

1. Technical Field of the Invention

The present invention relates generally to passive control of active cooling of structures which undergo uneven heating. More particularly the invention pertains to structures in which cooling is actively effected through the circulation of a coolant through passages within the structure.

2. Discussion of the Related Art

Structures may undergo significant heating while operating under normal conditions. Hypersonic vehicles, for example are subject to significant heating as a result of friction between the vehicle and the surrounding air. One method of reducing the temperature of a heated structure is the circulation of a coolant through the structure to remove excess heat. This may be achieved by use of a plurality of small coolant passages fed from a common manifold.

In practice, a given area of the structure will often have a time varying heat load applied to it as a result of changes in operating parameters. In the case of hypersonic vehicles these changes include changes in speed, attitude, vehicle maneuvers and impingement of shock waves. Thus, coolant passages are currently designed to allow flow of sufficient coolant to meet peak demand for a given portion of the structure. Thus, the majority of the time the structure is overcooled and coolant is wasted. In the case of gaseous coolants, highly heated coolant gas becomes more viscous, leading to a pressure drop in the heated coolant passage, further contributing to the overheating problem.

In other applications of flow control, present devices for reducing the flow of coolant in a passage often rely on a cylinder of wax which when melted increases its volume, pushing on a piston that activates a valve. This type of device is not easily miniaturized for use in the large number of very small coolant passages that are used in active cooling.

Summary of the Invention

It is therefore an object of the present invention to provide a system for distribution of coolant to various portions of a structure.

It is a further object of the present invention to provide variable coolant flow through coolant passages so that varying heat loads may be met without overcooling.

It is a further object of the present invention to provide for changes in flow through use of devices that may be easily miniaturized for use in narrow coolant passages.

It is a further object of the present invention to accomplish the flow control in a passive manner, responsive to a change in temperature.

Additional objects and advantages of the present invention are apparent from the drawings and specification which follow.

To achieve the forgoing objects devices are presented that make use of passages wherein a portion of the passage has a variable area for restricting flow of coolant. The variation of area is automatic and is related to the operating temperature of each individual coolant passage. Four examples of devices capable of achieving an automatic, temperature controlled variation in flow area follow.

The flow of coolant is restricted by use of inserts which alter their characteristics when subjected to a temperature change. A flap made of shape memory alloy (SMA) is placed in the passage. When the SMA is at a temperature below its transition temperature it will be flexible, allowing the flow of coolant to push it into a closed, operating position, reducing coolant flow in the passage. When above its transition temperature, it will return to an open position allowing increased coolant flow.

A bi-material flap is employed in a similar fashion. When cool, the flap is in a closed position, as the flap heats up it flexes due to differing coefficients of thermal expansion of the two materials. The flap flexes out of the way of coolant flow by this flexing allowing increased coolant flow.

A bi-material spring is used to rotate a movable disk which is aligned with a fixed disk. The two disks have openings which allow coolant flow when aligned but when the alignment changes coolant flow is reduced. As the temperature of the bi-material spring changes it rotates, changing the alignment of the movable disk with the fixed disk, thereby reducing coolant flow.

By use of a covering plate over the exit of each coolant passage the rate of flow may be controlled. An opening is provided in the cover plate to allow a minimum coolant flow, the opening being larger than that necessary to allow minimum flow but not being aligned fully with the exit of the passage. As the passage heats up the covering plate undergoes thermal expansion, pushing the opening into alignment with the exit thereby allowing increased coolant flow.

In all cases the closed position should allow some coolant flow. The closed position is the normal operating position, and should be capable of meeting expected heating loads. As the devices react to increased temperature by moving to an open position, they allow an increased flow. The increased flow allows increased cooling of the portion of the structure that is undergoing excessive heating. This helps to keep all portions of the structure at a more uniform temperature.

It is beneficial to position the flap towards the end of the coolant passage. This allows for more uniform pressures to develop in the passages. Additionally this provides a flap that is sensitive to the integrated heating load along the entire passage.

Brief Description of the Drawings

Fig. 1 is a drawing of a coolant passage with a shape memory alloy flap showing the position of the flap when the passage is cold and the position of the flap when the passage is hot;

Fig. 2 is a drawing of a coolant passage with a bi-material flap showing the position of the flap when the passage is cold and the position of the flap when the passage is hot;

Fig. 3 is a drawing of a coolant passage having an exit hole, a covering made of a second material partially blocks the exit hole, the drawing shows the position of the covering when the passage is cold; and

Fig. 4 is a drawing of a coolant passage having a helical spring which actuates a rotating disk with holes. The rotating disk is aligned with a fixed disk also having holes for allowing coolant flow.

Description of Preferred Embodiments

Examples of the present invention follow making reference to Figs. 1, 2, 3 and 4. One embodiment of the present invention as shown in Fig. 1 makes use of a shape memory alloy (SMA) flap **12** positioned in each of the coolant passages **10**. The SMA flap is designed so that when above its transition temperature it has a shape that allows coolant to flow freely through the passage. In its normal operating condition, the flap is below the transition temperature of the SMA, thus it has low stiffness and the flowing coolant pushes the flap into a closed position **12a**, restricting the flow of coolant to its operating level. At temperatures above the transition temperature of the SMA, the flap returns to its shape as designed, i.e., the open position. Above the transition temperature the SMA is relatively stiff and will remain in the open position **12b**, allowing coolant to flow freely through the passage. It is desirable to design the flap with an opening **14** so that in the closed position some operating level of coolant flow is maintained.

The SMA must be chosen to provide a transition temperature that is appropriate to the application. Nickel-Titanium alloys, for example, can be produced that will have a transition temperature of between 0 and 200 °F by variation of other alloying elements.

Another embodiment, shown in Fig. 2, makes use of a bi-material flap **22** in place of the SMA flap. By choosing the two materials of the bi-material flap to have differing coefficients of thermal expansion, the flap is designed to bend out of the way of flowing coolant when temperature rises above a preselected operating temperature. When the passage **10** is operating at low temperature the flap is in a closed position **22a** so that flow of coolant through the passage is reduced. As the temperature of the flap increases, one side of the flap expands faster than the other causing the flap to bend up and out of the path of the coolant flow to an open position **22b**, increasing coolant flow through the passage. As with the SMA flap it is desirable to design flap geometry with an opening **24** such that there will be some minimum flow even when the flap is in the closed position.

Another embodiment of the present invention, shown in Fig. 3, makes use of a covering plate **32** to adjust the flow through the coolant passage **10** by restricting flow through the passage's exit **36**. The covering plate has an opening **34** that, when in the closed position, is partially aligned with the exit hole of the coolant passage. This opening allows a minimum flow of coolant when operating at a temperature below the preselected operating temperature. The covering plate is made of a material having a different coefficient of thermal expansion from the coolant passage. As the temperature increases the covering plate expands, altering the alignment of the opening in the covering plate with respect to the passage exit. This allows increased flow of coolant through the passage exit, thereby increasing the coolant flow through the passage.

Another embodiment of the present invention, shown in Fig. 4, makes use of a bi-material spring **42** to rotate a movable disk **44**. The spring is anchored to the passage **10** and movable disk at attachment points **50**. The movable disk has openings **48** which partially align with openings in a fixed disk **46** which is adjacent to the movable disk. When the disks are partially aligned, a minimum flow is allowed through the coolant passage. As the temperature in the passage rises the bi-material spring rotates the movable disk altering the alignment of the openings in the two disks. The openings are designed such that the alignment of the openings increases as the spring rotates in reaction to an increase in temperature. This allows an increased flow of coolant in response to a temperature increase.

In each embodiment, the reaction to an increase in temperature in the passage is an increase in coolant flow through that passage. This helps to maintain the temperature of each passage at a more uniform level than would be maintained in a system lacking reactive elements. The uniformity of temperature of the coolant passages further allows for a more uniform temperature distribution in the structure being cooled.

In each embodiment it is beneficial to position the flap towards the end of the coolant passage. This allows for more uniform pressures to develop in the passages. Additionally this provides a flap that is sensitive to the integrated heating load along the entire passage.

Other variations will be readily apparent to those of skill in the art. The forgoing is not intended to be an exhaustive list of modifications but rather is given by way of example. It is understood that it is in no way limited to the above embodiments, but is capable of numerous modifications within the scope of the following claims.

TEMPERATURE REGULATOR FOR ACTIVELY COOLED STRUCTURES

Abstract of the Disclosure

In active cooling of a structure it is beneficial to use a plurality of passages for conducting coolant to various portions of the structure. Since most structures do not undergo isotropic thermal loads it is desirable to allow for variation in coolant flow to each area of the structure. The present invention allows for variable flow by a variation of the area of a portion of each of the coolant passages. Shape memory alloys and bi-material springs are used to produce passages that change flow area as a function of temperature.

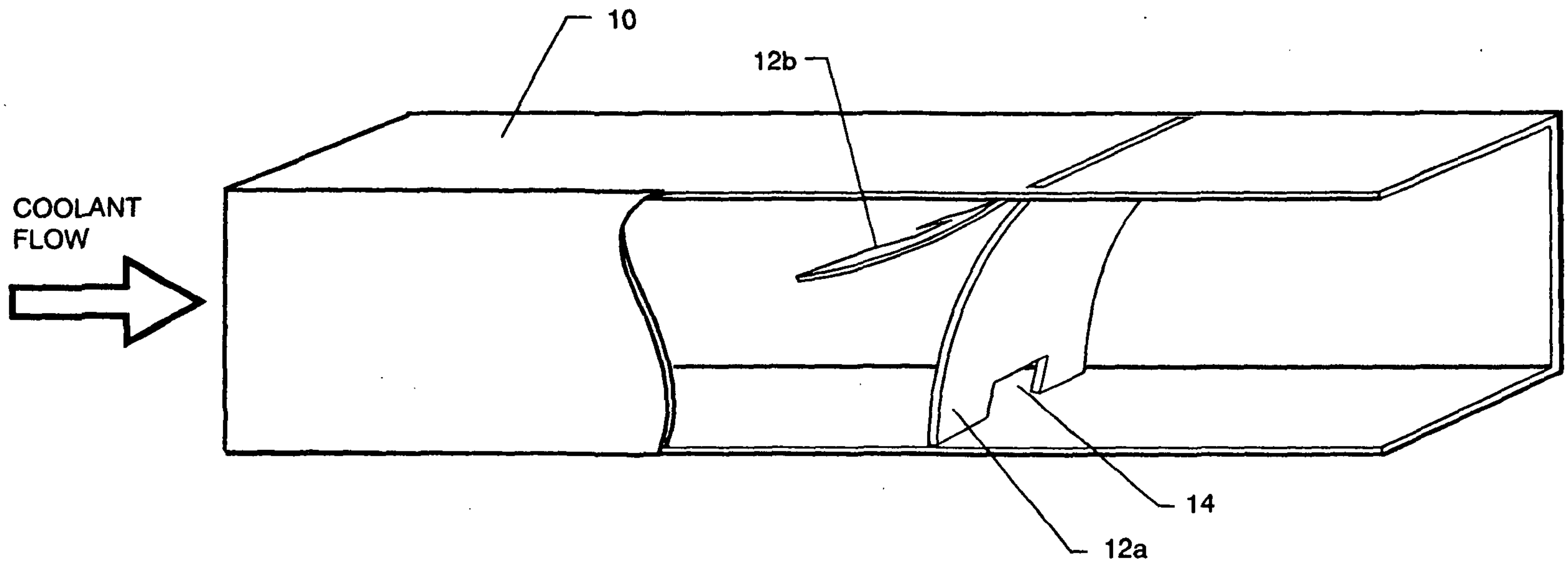

FIG 1

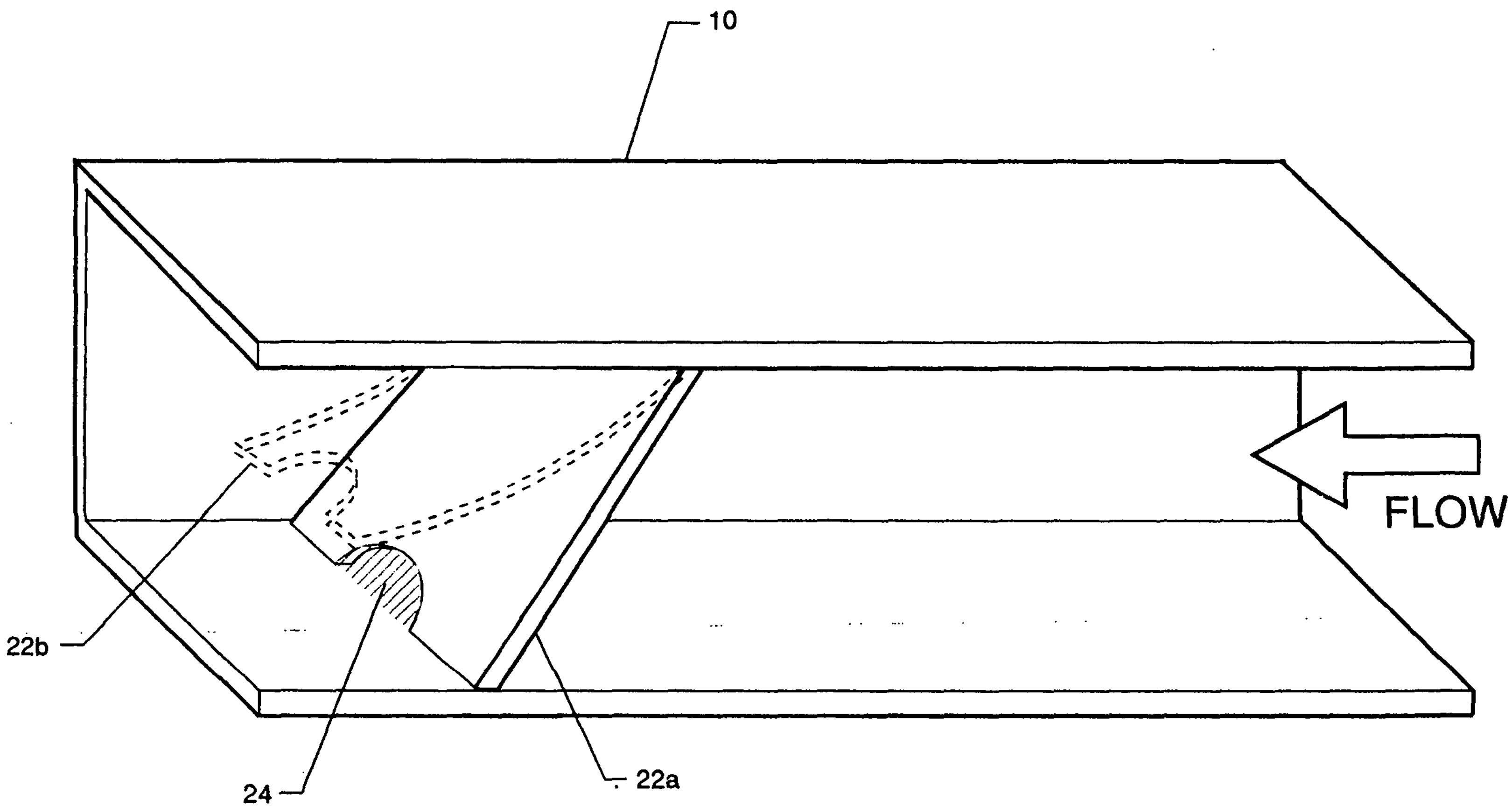

FIG 2

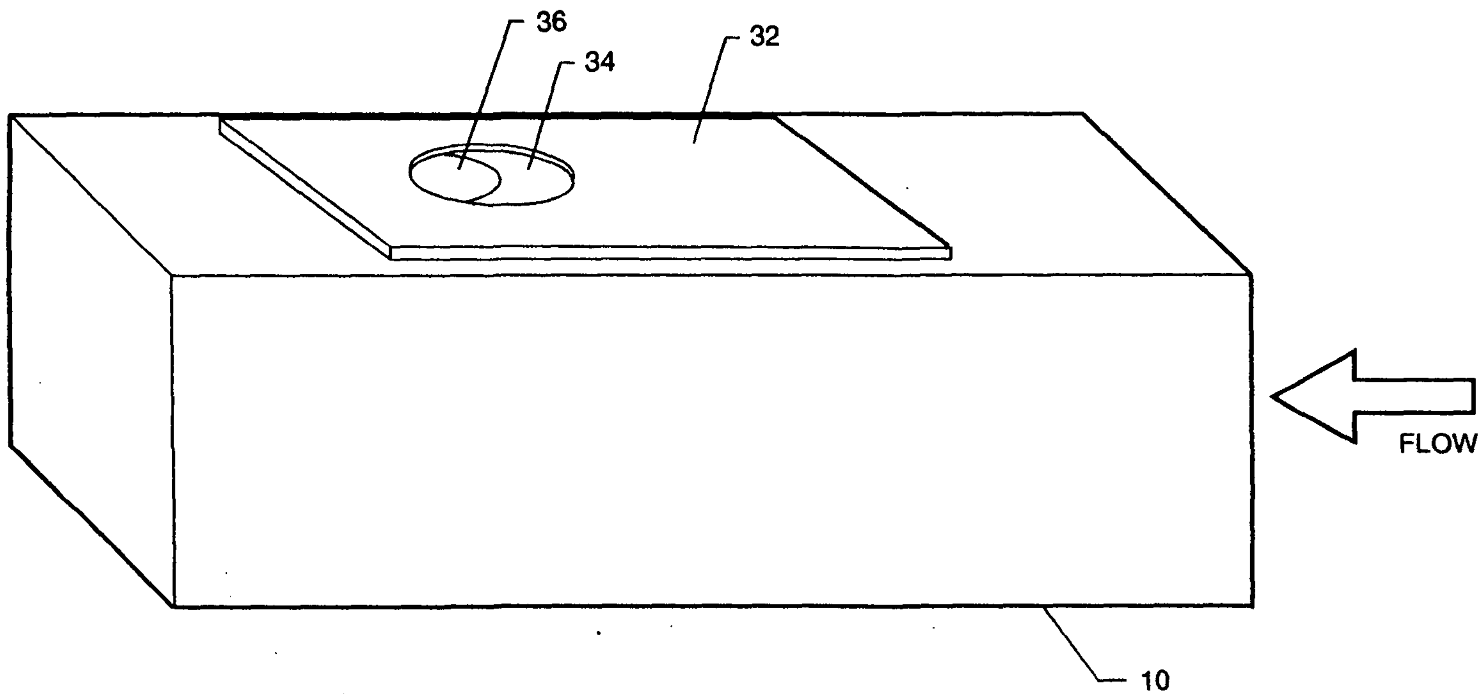

FIG 3

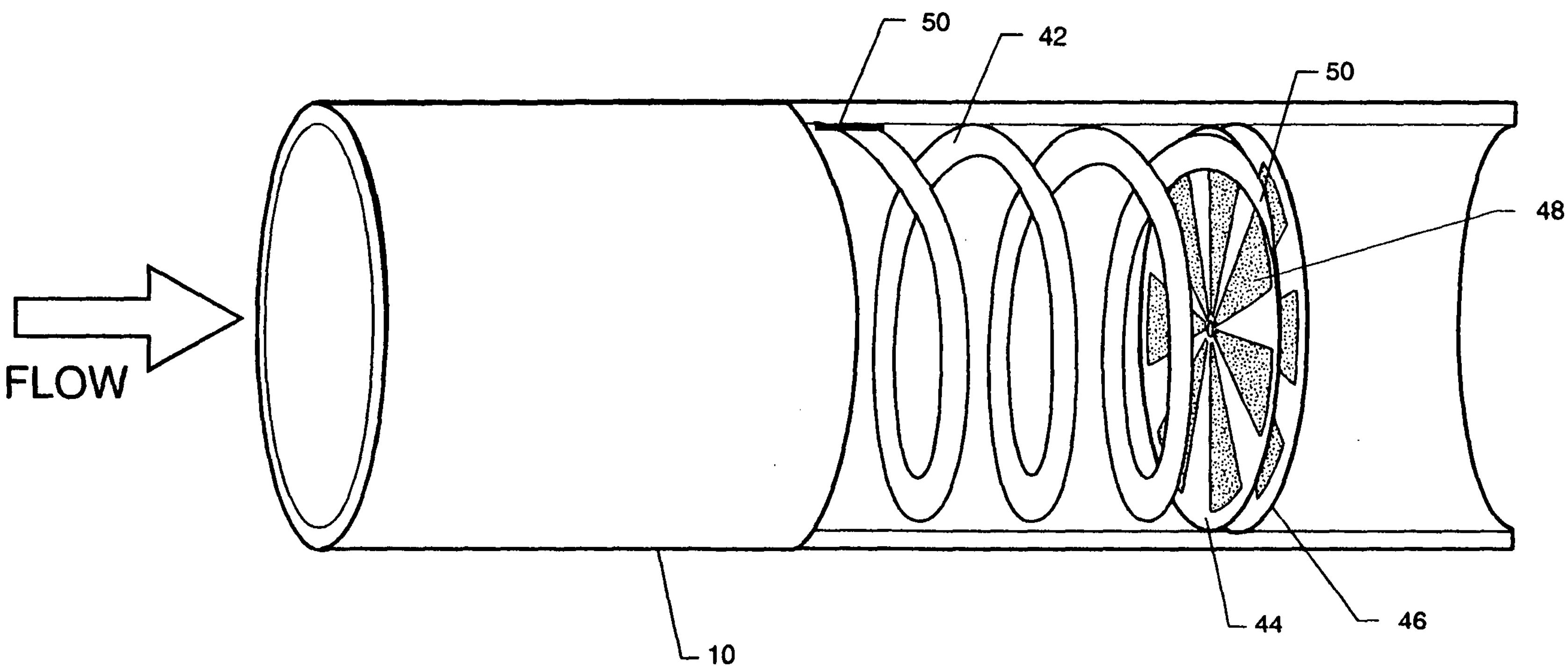

FIG 4