N70-35587

NASA CASE NO. FRC-10053

PRINT FIG. 1

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Application S/N 33,398
Filed: 04/30/70
Contractor: Boeing Co.
Contract: NAS4-1403

AWARDS ABSTRACT

Inventors: Darrell R. Harting NASA Case FRC-10053
Richard L. Egger
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STRAIN GAGE

This invention is directed to an improved strain gage particularly suited for use in detecting and measuring mechanical strain induced in thermally strained specimens.

The present invention utilizes a compensating link rigidly fixed to the surface of a test specimen in a manner such that relative displacement operatively is achieved as the specimen is mechanically strained. The link is adapted to be thermally strained but is isolated from mechanical strain. Preferably the link is fabricated from a material similar to that of the specimen so that the specimen and the compensating link possess similar thermal expansion characteristics. Since ambient heat imparts thermal strain to the compensating link as it imparts thermal strain to the specimen, and therefore any relative motion which is achieved between the specimen and the compensating link results from strain inducing stress mechanically applied to the specimen. Through a determination of the amplitude of the achieved relative motion, the induced mechanical strain is detected and measured.

By employing a compensating link having known thermal expansion characteristics, it is possible to detect and measure mechanical strain induced in a thermally strained specimen in a manner such that effects of thermal strain imparted to the specimen are negated.

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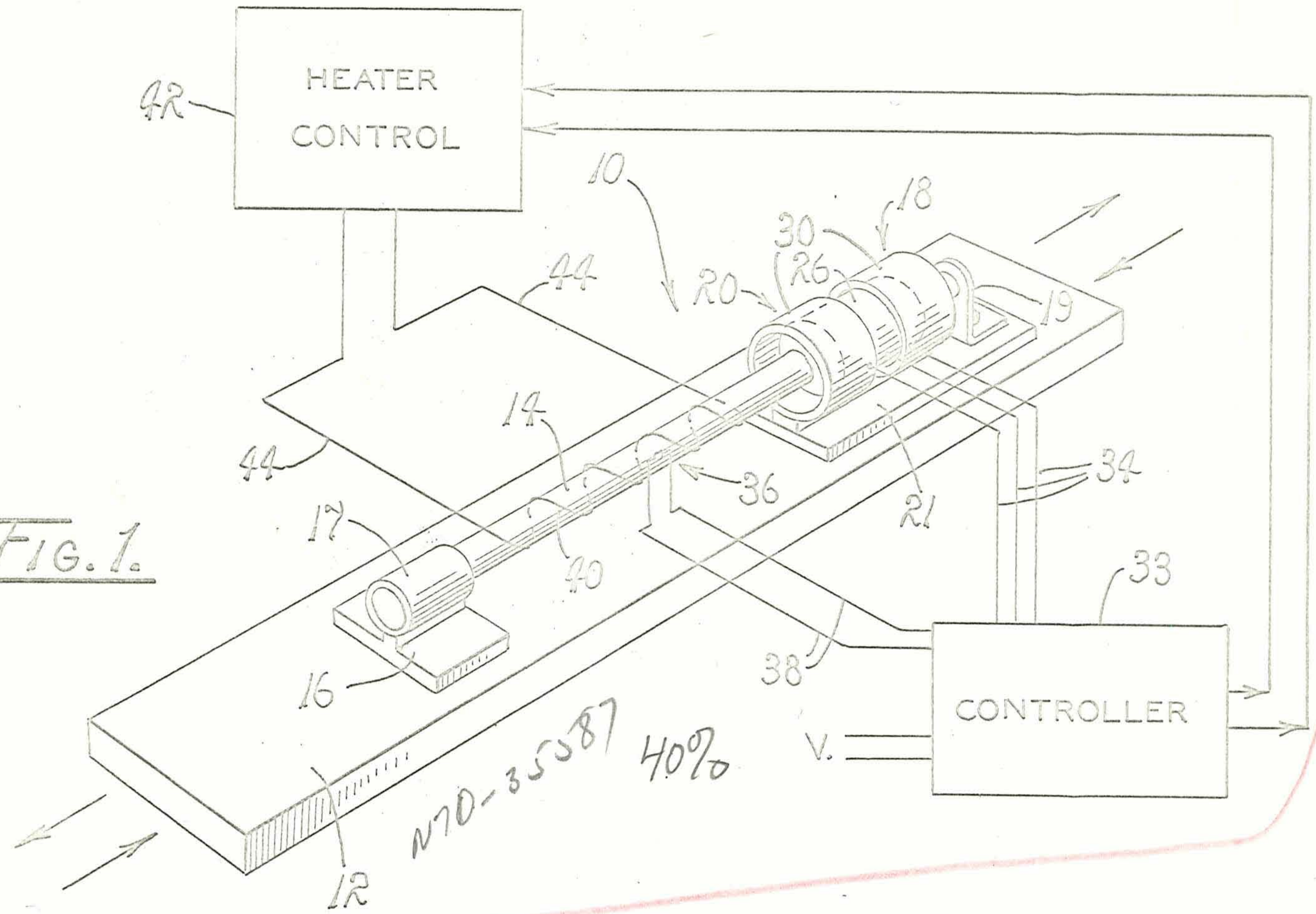

FIG. 1.

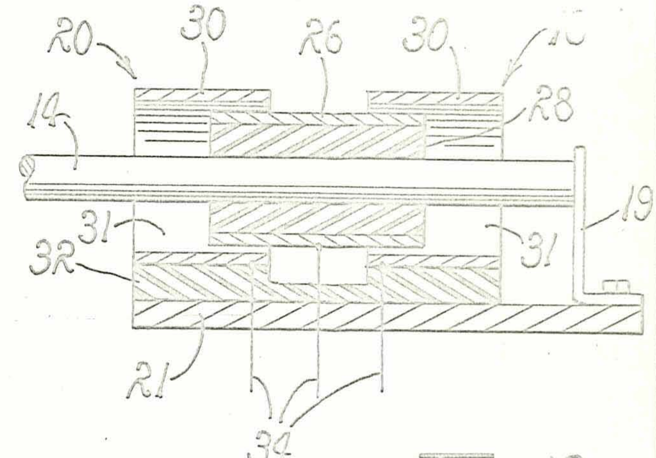

FIG. 2.

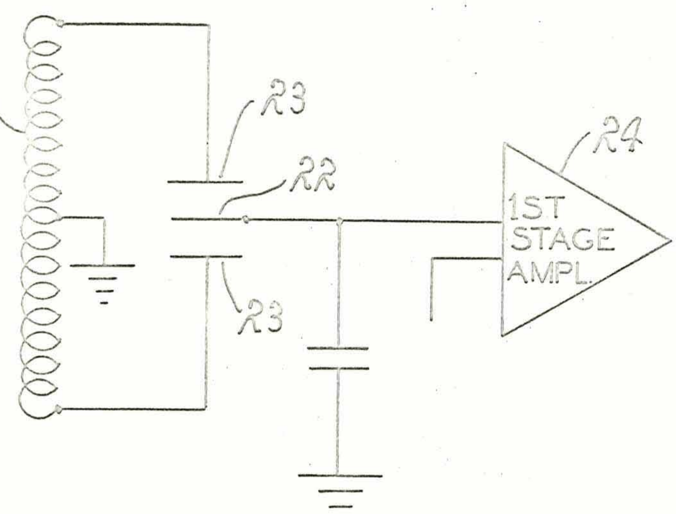

FIG. 8.

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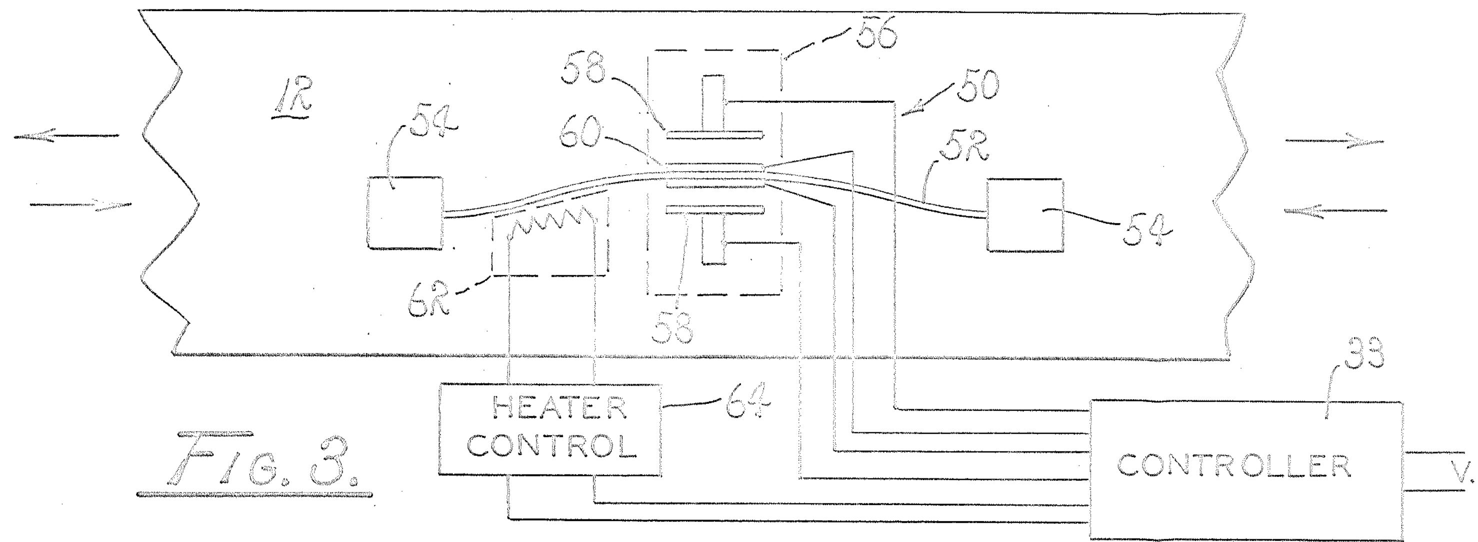

FIG. 3.

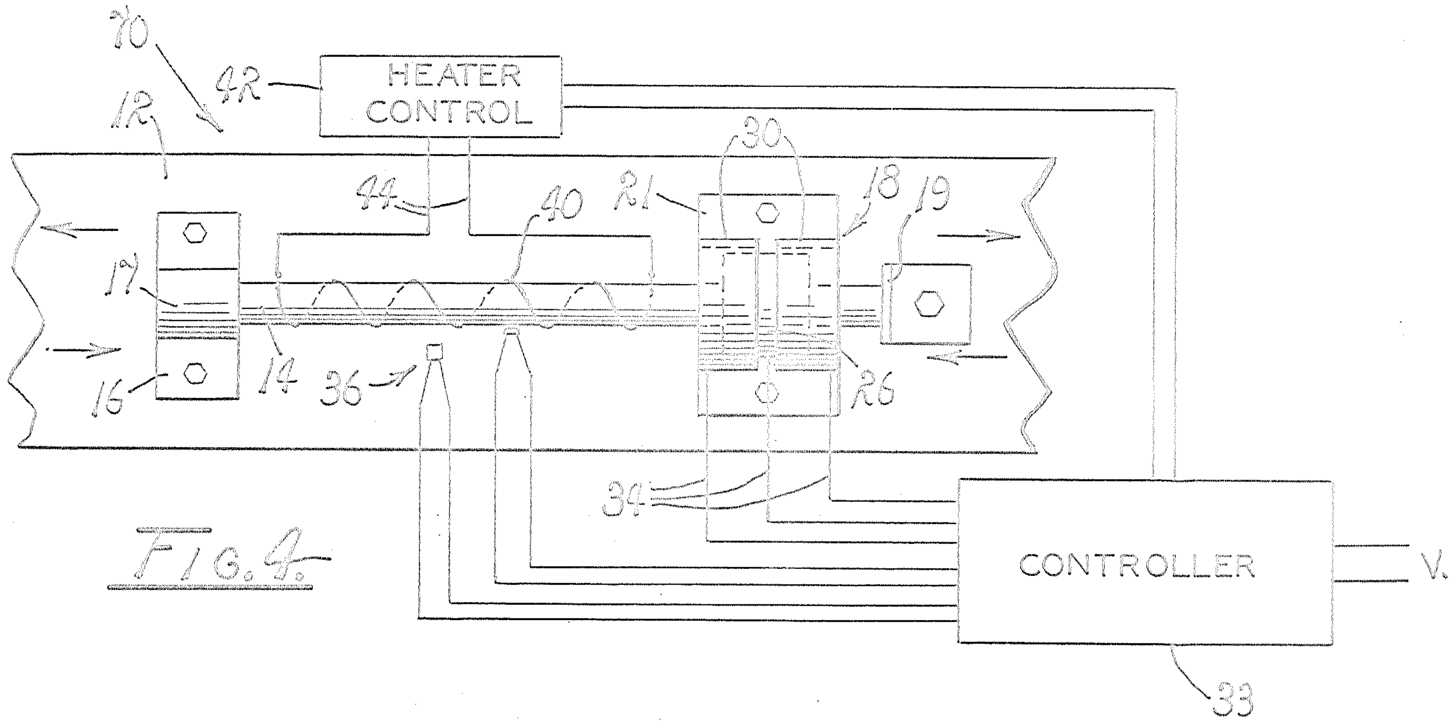

FIG. 4.

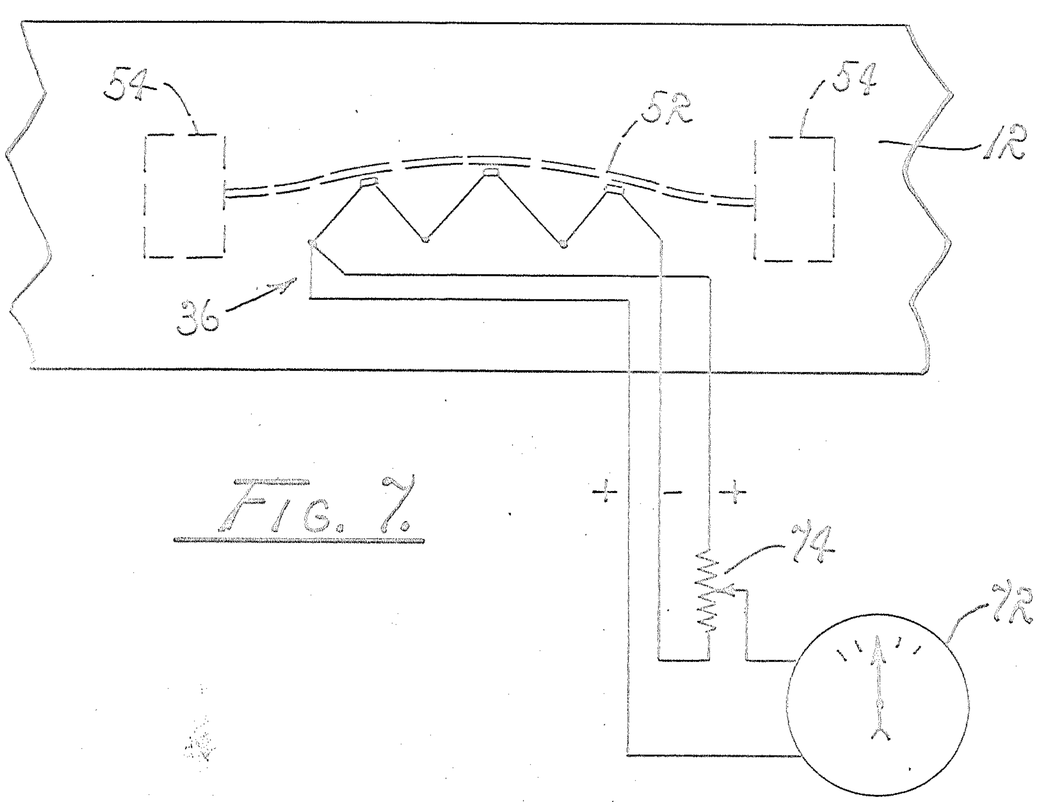

FIG. 7.

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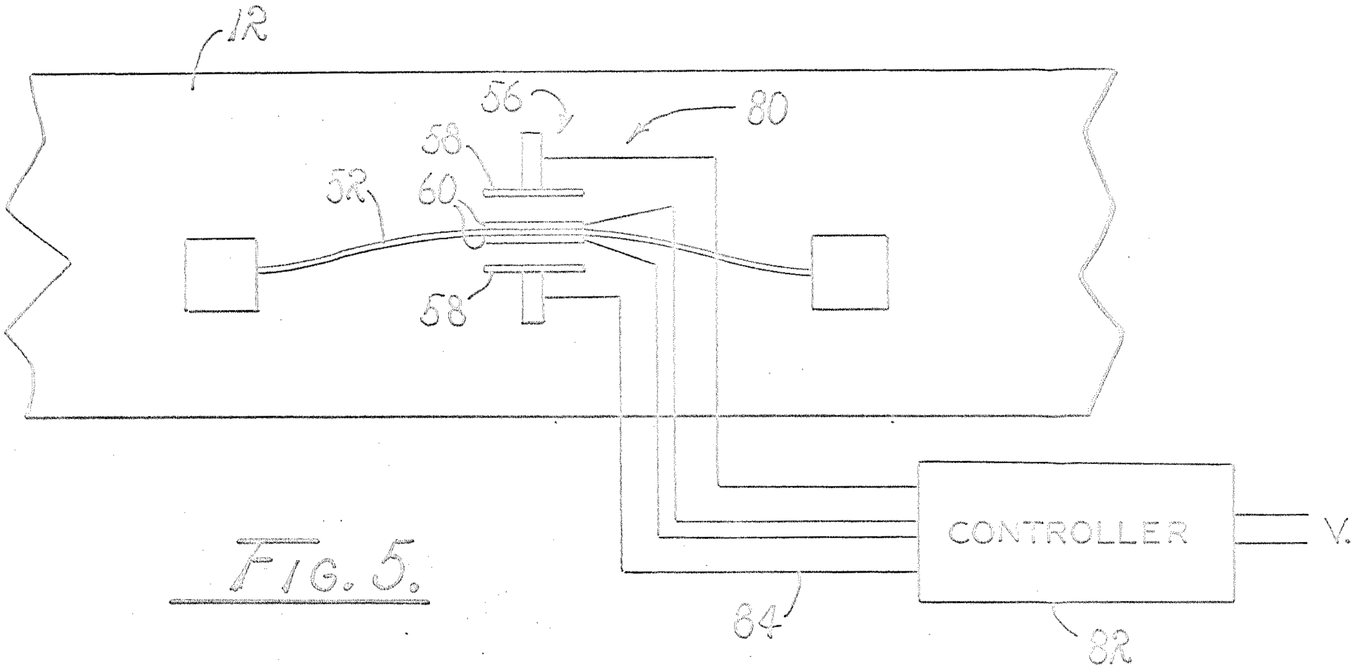

FIG. 5.

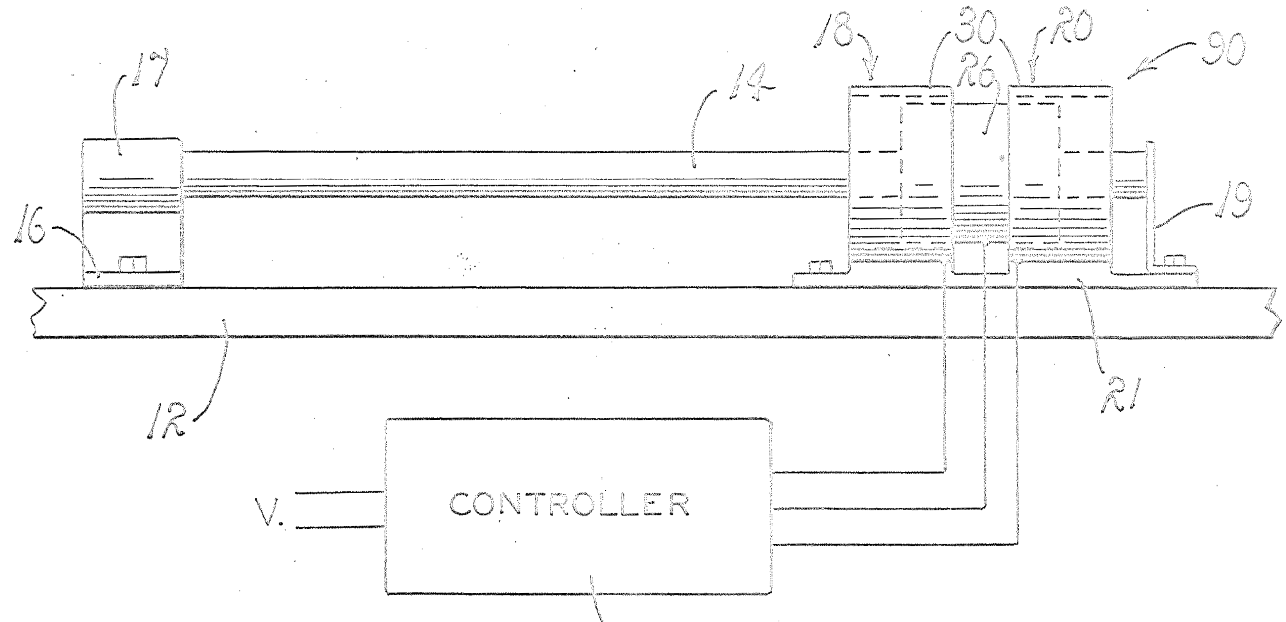

FIG. 6.

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S P E C I F I C A T I O N

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT DARRELL R. HARTING, a citizen of the United States of America, residing at Seattle, in the County of King, State of Washington, and RICHARD L. EGGER, a citizen of the United States of America, residing at Bellevue, in the County of King, State of Washington, have invented a new and useful

STRAIN GAGE

of which the following is a specification:

ABSTRACT OF THE DISCLOSURE

A strain gage particularly suited for use in detecting and measuring mechanically induced strain in thermally strained specimens including an elongated link, adapted to be fixedly secured to the surface of a specimen, having thermal expansion characteristics matched with those of the specimen, and characterized by a differential capacitor employed for detecting strain induced motion as such motion is effected between the link and the surface of the specimen.

ORIGIN OF INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 U.S.C. 2457).

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The invention relates to strain gages and more particularly to strain gages adapted to be employed in an environment wherein elevated temperatures operatively are encountered.

2. Description of the Prior Art:

The prior art is replete with strain gages for measuring strain resulting from mechanical stress. Attempts have been made to employ various types of known strain gages in measuring mechanical strain imparted to specimens while the specimens are maintained at elevated temperatures, and accordingly are subjected to thermal stress. However, such attempts have not always met with success as various impediments normally are encountered. For example, where optical techniques are employed in measuring mechanically imparted strain, in samples subjected to thermal stress, an attendant inability to effectively cancel thermal strain persists. Where the techniques being employed require the use of devices based on a change in capacitance, an attendant change in dielectric constant and an inability to adequately cancel the effects of the source of thermal energy have impeded the use of such devices. Where devices, such as the device disclosed in United States Letters Patent No. 3,293,909, are employed, such devices fail to totally satisfy existing needs since these devices do not readily accommodate real-time observation of performance.

OBJECTS AND SUMMARY OF THE INVENTION

This invention overcomes many of the aforementioned difficulties through the use of a simplified gage which employs a differential capacitor, and a displaceable link coupled with the specimen as the specimen is subjected to both mechanical and thermal stresses.

Accordingly, it is an object of the instant invention to provide an improved strain gage which utilizes thermal strain induced in a compensating link for acquiring intelligence indicative of induced mechanical strain.

It is another object of the instant invention to provide an improved strain gage particularly suited for use in detecting mechanical strain induced in thermally stressed specimens.

It is another object of the instant invention to provide a strain gage capable of being employed in an environment wherein elevated temperatures ranging between room temperature and 1500° F. are encountered.

It is another object of the instant invention to provide an improved strain gage which is adapted for use in an environment wherein a specimen simultaneously is subjected to both thermal and mechanical loading for inducing both mechanical and thermal strain.

These and other objects and advantages of the instant invention are achieved by providing a strain gage for use in detecting and measuring mechanically induced strain in given specimens simultaneously subjected to mechanical and thermal stresses, including a compensating link mounted on a specimen and formed of a material having thermal expansion characteristics consistent therewith, and a differential capacitor for detecting mechanical strain as the effects of thermal strain are compensated for through the use of the compensating link.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective, diagrammatic view of a first embodiment of the instant invention which employs a differential capacitor.

Fig. 2 is a partially sectioned side elevation of the differential capacitor employed by the embodiment of the invention illustrated in Fig. 1.

Fig. 3 is a top plan view of a second embodiment of the instant invention.

Fig. 4 is a top plan view of a third embodiment of the instant invention.

Fig. 5 is a diagrammatic view of a fourth embodiment of the instant invention.

Fig. 6 is a side elevation of a fifth embodiment of the instant invention.

Fig. 7 illustrates a coupling of a thermopile with an associated meter, as employed in detecting temperature differentials.

Fig. 8 is a diagrammatic view of a differential capacitor which typifies the capacitors employed in the embodiments illustrated in Figs. 1 and 3 through 6.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

Referring now to the drawings wherein like reference characters designate like or corresponding parts throughout the several views, there is shown in Fig. 1 a strain gage 10, which is a first embodiment of the instant invention, attached to a surface of a specimen 12. This gage is, in effect, a thermal-null strain gage. Consequentially, the effects of thermally induced expansion or contraction, commonly called thermal strain, are canceled and strain is not detected, so long as the specimen 12 is not mechanically stressed. Preferably, this condition prevails for a wide range of temperatures, between, for example, room temperature and 1500° F.

As illustrated in Fig. 1, the strain gage 10 is mounted on the specimen 12 and is employed in either compression or tension and at elevated temperatures. For purposes of describing the invention, it will be assumed that the specimen 12 is in an environment wherein it is subjected to tensile stress at elevated temperatures and, consequently, experiences elongation due to thermal stress as well as mechanical stress which results from a mechanical loading thereof.

Mounted along one surface of the specimen 12 there is an elongated bar or link 14, preferably of a tubular configuration, formed of a material having thermal characteristics matched with the thermal characteristics of material of the specimen 12. Preferably, the material from which the bar 14 is fabricated is that of the specimen 12. It may, however, differ so long as the relationship of the characteristics of the materials, over the operating range, is a known factor. The link 14 rigidly is secured at one end thereof to the surface of the specimen 12 through a suitable bracket 16. The bracket is fixed to the surface of the specimen 12, through any convenient means, including commercially available high temperature epoxy resins, welds and the like. The bracket 16 includes a unitary sleeve 17 which, in effect, serves as a receptacle for receiving therein in a telescoping relationship, one end of the link 14 which rigidly is coupled with the sleeve 17 and therefore rigidly is secured to the specimen 12.

Adjacent the opposite end of the link 14 there is a motion detector 18 also fixedly secured to the surface of the specimen 12. The purpose of the detector 18 is to detect relative displacement, occurring between the link 14 and the surface of the specimen 12 as either is strained. The particular type of detector employed determines the manner in which the end of the link 14 is mounted adjacent to the detector.

As illustrated, particularly in Figs. 1 and 2, the means employed in mounting the end of the bar 14 adjacent to the position detector 18 includes a vertically disposed flexible leaf 19. This leaf is coupled to the end surface of the link 14 and supports the end of the link adjacent to a differential capacitor 20 which functions as a motion detector. The differential capacitor 20 and the leaf 19 are mounted on the surface of the specimen 12 by means of a suitable bracket 21 fixed to the surface of the specimen in a manner similar to that in which the bracket 16 is fixed to the surface of the specimen 12. It is to be understood that the leaf 19 is, in operation, flexed in order to accommodate axial displacement of the end of the link 14 relative to the surface of the specimen 12.

While the principles of a differential capacitor are well known, it is to be understood that the differential capacitor 20, as employed by the various embodiments of the instant invention, includes a plurality of capacitor plates between which the capacitance is varied as displacement of the link 14, relative to the surface of the specimen 12, is achieved. A typical differential capacitor is illustrated in Fig. 8.

The differential capacitor illustrated in Fig. 8 includes a movable capacitor plate 22, disposed between a pair of fixed capacitor plates 23. The capacitor plates 23, in turn, are coupled to the opposite ends of a center-tapped secondary winding 24 of a carrier transformer. The capacitor plates 23 are fixed in a mutually spaced relationship, while the capacitor plate 22 is displaceable therebetween for varying the capacitance established between the movable plate and the fixed plates. Hence, as the distance between the moving capacitor plate 22 and the fixed capacitor plates 23 is varied, a varying output signal is delivered from the capacitor to a first stage amplifier 24, whereupon the resulting signal can be delivered to a suitable filter and phase correction network, not shown, for further processing and utilization in a manner consistent with known capacitance detecting techniques. Since the signal processing circuits utilized in processing output signals of differential capacitors are well known, a detailed description of the circuits here employed is omitted in the interest of brevity.

As a practical matter, the differential capacitor 20, Fig. 2, is so formed as to include a metallic cylinder 26 mounted on, and insulated from the link 14. Mounting of the cylinder 26 is achieved through the use of suitable ceramic oxides, designated 28, so that the cylinder 26, in effect, serves as a moving capacitor plate as the link 14 experiences axial strain.

Disposed in coaxial relationship with the cylinder 26, and concentrically disposed about the link 14, is a pair of spaced tubular blocks 30. These blocks, in effect, function as the fixed capacitor plates and are provided with coaxially related bores 31 having a diameter slightly larger than the outside diameter of the cylinder 26. The blocks 30 are so positioned, relative to the cylinder 26, that the cylinder simultaneously is telescopingly displaced relative to each of the bores 31 as relative displacement is achieved between the link 14 and the specimen 12. This telescoping displacement serves simultaneously to vary the effective area of the external surface of the metallic cylinder 26 relative to the surface of the bores 31 of the blocks 30 so that the capacitance established between the external surface of the metallic cylinder 26 and the surface of each of the bores 31 is varied as telescoping displacement is imposed on the link 14. The tubular blocks 30 are supported in any suitable manner, however, it is preferred that the bracket 21 also serves to support the blocks through a mount 32 formed of ceramic oxides, similar to the ceramic oxides employed in mounting the metallic cylinder 26 on the link 14.

A capacitor circuit, including a first stage amplifier 24, is coupled with the cylinder 26 and blocks 30, which function in a manner similar to capacitor plates 22 and 23, Fig. 8, and is included within a controller circuit, generally designated 33, Fig. 1. The controller 33 is coupled with the differential capacitor 20, through suitable leads 34. The controller 33 also is connected with a thermopile, generally designated 36, through leads 38, and a resistance heater coil 40, through a current controller 42 and leads 44.

Since the design and function of thermopiles are well known, a detailed description is omitted in the interest of brevity. However, it is to be understood that the thermopile 36, as employed, includes a series of thermocouples having alternate terminals connected to the link 14 and the surface of the specimen 12 and is employed in detecting a temperature differential as it is established between the link 14 and the specimen 12 through an energization of the heater coil 40.

As illustrated, the heater coil 40 is wound about the link 14, however, it could be concentrically disposed within the link 40. Current through this coil is controlled through the heater controller 42, which, as a practical matter, is coupled with a suitable source of electrical energy, not shown. The current controller circuit 42 is of any suitable design and, in operation, is controlled by signals delivered from the controller circuit 33 so that the flow of current through the coil 40 is, in effect, dictated by the output of the controller 33. The circuit which is employed in the heater current controller is of any suitable design, and therefore a detailed description thereof is omitted.

Operation Of The First Embodiment

The operation of the thermal-null strain gage 10 can readily be understood when it is appreciated that the resistance heater coil 40 is employed to impart to the link 14 thermal strain which is equal to the mechanical strain imposed on the specimen 12 and that the detector 18 serves to detect the relative position of the link 14 as it thermally is strained in response to a current flowing through the coil 40. Since the link 14 and the specimen 12 possess similar thermal expansion characteristics, ambient or environmental temperature tends to induce a similar strain in the link as in the specimen.

Hence, it is to be understood that the link 14 is mounted on the surface of a specimen 12 employing the brackets 16 and 21, and that the specimen 12 operatively is subjected to a mechanical load for thus imposing mechanical strain thereon. As strain occurs, relative displacement between the link 14 and the surface of the specimen 12 is experienced. This displacement, in turn, repositions the metallic cylinder 26 relative to the surfaces of the bores 31 of the tubular blocks 30, for thus varying the capacitance of the differential capacitor 20. The initiated change in capacitance is detected within the controller circuit 33, whereupon a control signal is delivered through the leads 44 to the heater current controller circuit 42 for causing the heater coil 40 to be energized and heated sufficiently for imparting thermal strain to the link 14. As the link thermally is strained, the cylinder 26 is repositioned relative to the bores of the blocks 30, whereupon the initial capacitance of the differential capacitor 20 is re-established. As repositioning of the metallic cylinder 26 is achieved, the thermopile 36 continuously detects the temperature differential, as it is established between the link 14 and the specimen 12, so that at the instant the cylinder 26 is repositioned, for re-establishing the capacitance, the temperature differential is a known value. Since the thermal characteristics of the link 14 are known, and preferably matched with those of the specimen, the extent of thermal strain imposed upon the link 14 is a known value. Since the thermal strain thus imposed on the link 14 is equal to the mechanical strain imposed on the specimen 12, in repositioning the cylinder 26, the mechanical strain imposed on the specimen 12, through mechanical loading, becomes a known value.

Second Embodiment

A second embodiment of the invention is illustrated in Fig. 3. This embodiment is a strain gage, designated 50, which is quite similar in function to the embodiment illustrated in Fig. 1. The embodiment of Fig. 3 is particularly useful in instances wherein mechanical strain imposed on a specimen 12 involves minimal motion and therefore requires amplification of the resulting motion.

The strain gage 50 includes a flexible link 52 rigidly supported at its opposite ends by suitable mounting posts 54. These posts are fixed to the surface of a specimen 12 in a mutually spaced relationship, in a manner similar to that in which the brackets 16 and 21 are mounted. The link 52, however, is a thin, elongated member which is fabricated from a given material, preferably the material of the specimen 12. Hence, the link 52 also possesses thermal expansion characteristics which substantially match those of the specimen. In practice, the link 52 mechanically is loaded or bowed, as it is secured to the surface of the specimen 12 by the mounting post 54. Of course, as can be appreciated, where desired the mounting post 54 can be fabricated as a unitary portion of the link 52 so that the link, in effect, is configured to conform to an inverted U-shaped configuration.

The link 52 is deflected in lateral directions as the specimen 12 is axially strained. This laterally directed deflection acts to amplify the resulting motion as strain is imposed on the specimen 12. This motion then is detected through a differential capacitor 56, which possesses a mode of operation also conforming to that of the differential capacitor, illustrated in Fig. 8.

It is important to note that the capacitor 56 is so fabricated as to include a pair of fixed capacitor plates, designated 58, mounted in a manner such that the spacing established therebetween remains constant in dimension. A pair of movable plates, designated 60, is fixedly mounted on the link 52, at opposite sides thereof, so that the pair of movable plates is oppositely and simultaneously displaced relative to the adjacent fixed plates 58 as lateral deflection is imparted to the link 52. Thus, the capacitor 56 serves to provide an output signal indicative of changes in its established capacitance for purposes of indicating the relative motion achieved by the link 52 as the link is flexed, or deflected, due to mechanical strain imposed on the specimen 12.

As schematically illustrated, the strain gage 50 also includes a heater unit 62 coupled with a heater control circuit 64. This circuit is similar to the circuit 42 coupled with the heater coil 40 and functions to achieve a similar result. The unit 62 preferably is a heater coil wound about the link 52, however, the unit 62 can be of any suitable configuration.

It is important to note that the link 52 possesses thermal expansion characteristics which match those of the specimen 12. Therefore, ambient heat serves similarly to impose thermal strain on both the specimen 12 and the link 52 so that the variation which occurs in the spacing of the plates 58 and 60 is a function of the mechanical strain imposed on the specimen 12. Hence, as the specimen 12 mechanically is loaded for imposing thereon mechanical strain, detectable thermal strain can be imposed on the link 52 in order that the extent of the imposed mechanical strain can be determined. This determination is made simply by driving the heater unit 62 to a temperature sufficient for thermally straining the link 52 until the link is strained for again centering the pair of moving plates 60 relative to the fixed plates 58.

A differential temperature sensor, similar to the thermopile 36 is employed in detecting the established temperature differential required in repositioning the plates of the capacitor 56. It is preferred that the current through the heater 62 be detected, through a suitable ammeter, not shown, for purposes of determining the temperatures at which thermal strain sufficient for repositioning the plates is achieved.

Operation Of The Second Embodiment

The mode of operation of the embodiment illustrated in Fig. 3 is quite similar to that of the embodiment shown in Fig. 1. It is, however, to be understood that the link 52 is a flexible member rigidly mounted at its opposite ends on a surface of the specimen 12 and that the link is, in operation, laterally deflected from an initial position as an axially directed mechanical load is imposed on the specimen 12. The imposed lateral deflection is, in effect, a magnification of axially directed, relative motion established between the link and the specimen, as a consequence of mechanical loading. As deflection of the link 52 thus occurs, a variation in the spacing between the moving plates 60 and the adjacent fixed capacitor plates 58 is achieved. Repositioning of the moving plates 60 is effected through thermal strain imposed on the link 52 and this strain is a function of the temperature of the link. The imposed thermal strain is proportional to the strain mechanically imposed on the specimen 12 and is therefore indicative of the mechanical strain imposed on the specimen.

Third Embodiment

Turning now to Fig. 4, therein is illustrated a strain gage 70 which is a third embodiment of the instant invention. The structure of this device is quite similar, in many respects, to the device illustrated in Fig. 1. However, the mode of operation of this embodiment substantially is different.

It should be noted that the embodiment illustrated in Fig. 1 employs a detected temperature differential for purposes of providing an electrical signal indicative of thermal strain achieved by the link 14. This signal then is converted into intelligence indicative of the mechanical strain imposed on the specimen at the instant the link 14 has been thermally strained to achieve the length commensurate with the mechanically strained specimen 12. Conversely, the embodiment of the invention, as illustrated in Fig. 4, attempts to maintain a constant temperature differential between the link 14 and the specimen 12. The initiated change in capacitance of the differential capacitor 20, therefore, is employed to provide a signal which is indicative of mechanical strain.

The embodiment depicted in Fig. 4 particularly is suited for use in instances wherein the test specimen 12 is subjected to changes in temperature. When changing temperatures are encountered, the specimen 12 necessarily experiences a change in its dimensions, due to changing thermal effects. Should the test specimen 12 simultaneously be thermally and mechanically loaded, it necessarily is subjected to mechanical stress as well as thermal stress. Where a simultaneous mechanical and thermal stressing of the specimen 12 is encountered, it is imperative that the effects of thermal strain be nullified in order to obtain an accurate measurement of the mechanical strain. Therefore, the heater coil 40 is utilized for initiating changes in the temperature of the link 14 in a manner such that the temperature of the link is caused to follow the temperature of the specimen 12.

It, therefore, is important to understand that the thermopile 36, as illustrated in Fig. 4, is employed in detecting thermal differentials established between the link 14 and the specimen 12, which, in the simplest case, is a zero differential. This condition is achieved simply by energizing the heater coil 40 sufficiently for causing the temperature of the link 14 to follow the temperature of the specimen 12. Consequently, the thermal strain of the link 14 always matches the thermal strain of the specimen 12. Any change in position, as detected by the differential capacitor 20, then is indicative of the mechanical strain imposed upon the specimen 12.

Operation Of The Third Embodiment

The operation of the third embodiment of the invention illustrated in Fig. 4, is similar to the operation of the embodiment illustrated in Fig. 1, with one important exception. This exception is typified by the particular use of the heating coil 40. Instead of heating the link 14 in order to establish a temperature differential between the link and the specimen 12, sufficient to impart a greater thermal strain to the link 14, the heater coil 40 is driven in a manner such as to establish a zero temperature differential between the link and the specimen.

It is to be understood, of course, that due to the various combinations of masses, orientation of the gage relative to external sources of heat, and for various similar reasons, it is possible to employ a preselected temperature differential, which is not zero, for achieving a desired matched thermal expansion of the link 14 and the specimen 12.

Referring for a moment particularly to Fig. 7, therein is illustrated one manner in which the thermopile 36 can be coupled with a suitable voltage drive meter 72 for providing gage read-outs over large temperature ranges. In order to maintain the voltage level of the output signal of the thermopile 36 within a usable range for use with the meter 72, the links between the opposite ends of the thermopile can be coupled through a potentiometer 72 so that a continuous sampling of total specimen temperature is, in effect, applied proportionally at both sides of the meter 72 for reducing the effect of the large temperature changes encountered as the temperature of the specimen is increased throughout the total operative range. This manner of coupling can be employed with any of the gages hereinbefore described.

Fourth Embodiment

Referring now to Fig. 5, there is illustrated a fourth embodiment of the invention. This embodiment is a gage 80, quite similar in design and function to the gage 50 illustrated in Fig. 3.

The gage 80 includes a flexible link 52 and a differential capacitor 56 mounted on the surface of a specimen 12. The link 52 and differential capacitor 56 function in the manner hereinbefore described. However, the output signal developed by the differential capacitor 56 is delivered to a controller circuit 82, through suitable leads 84 and acts to drive a recorder, not shown, which serves to record detected changes in capacitance initiated as the specimen 12 is strained, as hereinbefore described.

The gage 80 preferably is employed in an operative environment wherein the gage is heated by environmental sources of heat, not shown. Hence, the link 52 operatively is maintained at a temperature such that the instantaneous temperature differential existing between the specimen 12 and the link is a constant value. It is important here to note that the embodiment illustrated in Fig. 5 does not include a heating element, as it is heated, in its entirety, by energy derived from the environmental source of heat. Due to the fact that the gage 80 can be calibrated, the recorded output of changes in capacitance of the differential capacitor 56 is suitable for use in detecting and determining mechanical strain as it is imparted to the specimen 12.

Operation Of The Fourth Embodiment

In operation, the gage shown in Fig. 5 is mounted on the surface of a specimen 12 and the specimen is loaded in either compression or tension. As the specimen 12 responsively is strained, resulting motion imparted to the specimen 12 is amplified as lateral deflection of the link 52 is experienced. This deflection serves to vary the capacitance established between the fixed plates 58 and 60 of the differential capacitor 56. This capacitance differential is detected at the controller circuit 82 and the resulting signal is applied to a recorder. The recorded signal then is employed in determining the extent of mechanical strain.

Thermal strain imposed on the specimen can be ignored since the link 52 and the specimen 12 have substantially matched thermal expansion characteristics and the gage is heated by the same source which serves to heat the specimen 12.

Fifth Embodiment

The embodiment of the invention as illustrated in Fig. 6 is a gage 90. This gage is quite similar in design and function to the gage 10, illustrated in Fig. 1, the gage 70, illustrated in Fig. 4, and the gage 80, depicted in Fig. 5. However, it is important to note that the gages 10 and 70 employ heating coils 40 for purposes of heating the link 14. While, as is the case with the embodiment illustrated in Fig. 5, the gage 90 does not employ a heating element. Otherwise the structure of the gage 90 is similar in design and function to the structure shown in Fig. 1. Therefore, a detailed description of the structure is here omitted.

Operation Of The Fifth Embodiment

In practice, the link 14 is supportingly mounted on the surface of the specimen 12, employing brackets 16 and 19, as illustrated in Fig. 1. The differential capacitor 20 is employed in providing an output signal to a controller 92 which serves to drive a recorder, in a manner quite similar to that in which the controller 82 drives a similar recorder. Since the link 14 and the specimen 12 are provided with matched thermal expansion characteristics, the temperature of the environment serves to initiate an elongation, or contraction, such that the thermal strain of the link 14 is commensurate with that of the specimen 12 as the link and the specimen simultaneously are thermally stressed. Since the gage 90 and the specimen 12 are heated from the same source of heat achieved, relative displacement initiated between the mechanically loaded specimen 12 and the link 14 is a function of mechanical strain and therefore changes detected in the capacitance of the differential capacitor are initiated as a consequence of mechanically imposed strain. By detecting the changes in capacitance of the differential capacitor 20 the extent of the mechanical strain imposed on the specimen 12 is detected and can be determined through an empirical calibration of the gage.

In view of the foregoing, it is to be understood that the various embodiments of the instant invention have utility in detecting mechanically induced strain through the use of capacitors. Such utility is particularly significant in instances wherein the specimen being tested operatively is subjected to extreme temperatures. Furthermore, the various embodiments are readily adaptable for use where the specimen is to be subjected to compression as well as to tension.

The specific embodiment employed in measuring strain for any given specimen is somewhat dependent upon the particular environment of the specimen. For example, where ambient temperature remains constant, the embodiment illustrated in Fig. 1 serves quite satisfactorily, particularly where the imposed mechanical strain is significant. Of course, in the event the resulting motion induced by the mechanical strain is minimal, a motion magnification may be required. In such instances, the embodiment illustrated in Fig. 3 can readily be employed.

In employing the device of Fig. 1, a linear output can be expected, whereas when employing the invention embodied in the device of Fig. 3, the resulting output may require an empirical determination or calibration of the gage 50 in order that the derived intelligence be rendered useful. In instances wherein a gage being employed is subjected to rapidly changing temperatures, such as may be encountered upon the leading edge of aircraft or wind-tunnel models, the embodiment of Fig. 4 preferably is employed. In such instances, changing thermal conditions continuously are monitored and effects thereof are neutralized by driving the temperature of the link 14 in a manner such that it follows closely the temperature of the specimen 12. Hence, any relative motion achieved between the link 14 and the surface of the specimen 12 is a function of a mechanical strain.

Conversely, where the temperature differential operatively established between the link and the specimen is zero, the heating coils or units are eliminated and the output signal derived from the differential capacitor is employed in determining the quantity of mechanical strain imposed on the specimen.

Hence, the present invention provides a suitable solution to a perplexing problem, while yet providing a strain gage which functions accurately and efficiently at excessively high temperatures over increased ranges.

Although the invention has been herein shown and described in what are conceived to be the most practical and preferred embodiments, it is recognized that departures may be made therefrom within the scope of the invention, which is not to be limited to the illustrative details disclosed.