Dec. 11, 1951 W. A. MUDGE 2,578,197

THERMOSTATIC DEVICE

Filed April 10, 1946

FIG. 1.

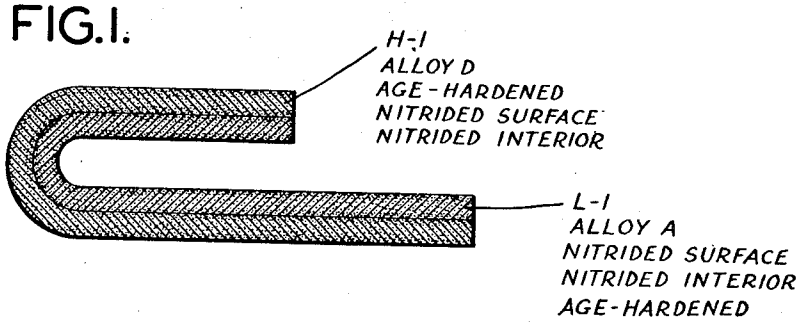
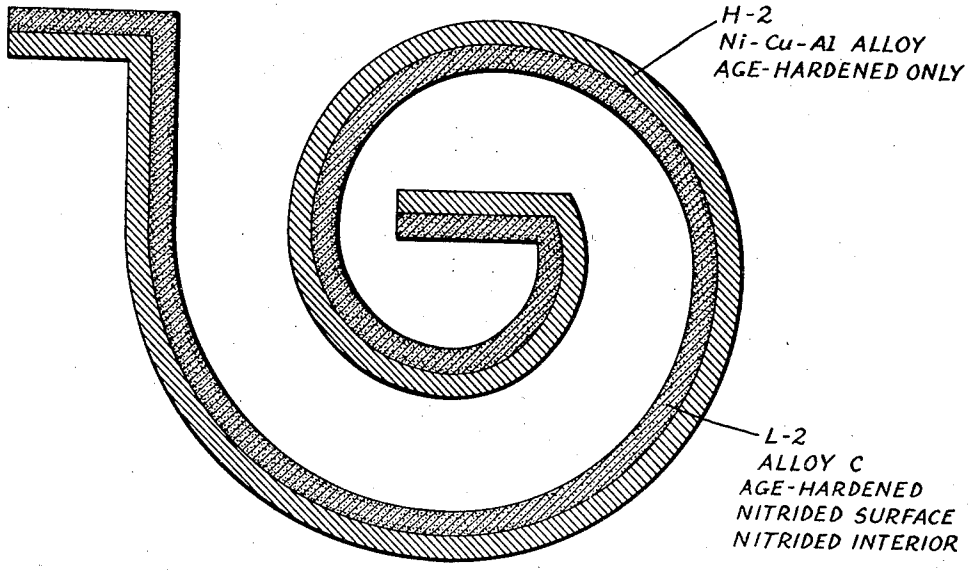


FIG. 2.



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THERMOSTATIC DEVICE

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The present invention relates to a composite metal temperature responsive device and more particularly to a thermostatic element to be used in a thermostat.

It is an object of the present invention to provide an improved composite metal thermostatic element.

It is another object of the invention to provide a bimetallic thermostatic element having improved strength.

It is still another object of the invention to provide a bimetallic thermostatic element having longer life.

It is a further object to provide a composite metal thermostatic element having improved flexing properties by reason of better fatigue resistance.

It is also an object to provide an improved temperature responsive device, such as a thermostat, comprised of the composite metal thermostatic elements provided by the invention.

Other objects and advantages of the invention will be apparent to those skilled in the art from the following description taken in conjunction with the drawing which depicts two views in section of two bimetallic thermostatic elements each embodying the present invention.

Broadly stated, the present invention provides a thermostatic element comprising a plurality of metallic members of dissimilar coefficients of thermal expansion secured together in face-to-face relationship by rivets, spot welds, diffusion bonding, or other known manner, and adapted to act as a unitary element, at least one of said members being made of an age-hardened alloy which is also nitrided throughout the cross section of the member. By "age-hardened" is meant that the member is in a hardened condition resulting from a solution treatment at high temperatures followed by a treatment at lower temperatures, the latter treatment producing the hardening effect. In the more common age-hardenable alloys, age-hardening is generally obtained by heating the alloy to a high temperature to place the precipitable phase in a solid solution, followed by rapid cooling to preserve the solid solution and treatment of the alloy at lower aging temperatures to precipitate the precipitable phase in a critical finely dispersed state to cause hardening. By "nitrided throughout the cross section" is meant that the member contains nitrogen diffused throughout the cross section of the member. The invention is not limited to the age-hardening and nitriding of only one member

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More than one member can be age-hardened and nitrided. Thus, if the thermostatic element consists of two members, both can be age-hardened and nitrided throughout their cross sections. Likewise, if the thermostatic element consists of three or more members, more than one member can be age-hardened and nitrided throughout the cross section.

Despite the fact that age-hardening markedly increases the hardness and lowers ductility accordingly, and that nitriding renders metals and alloys extremely hard, up to 1000 Vickers hardness number, with a tendency to be brittle, I have discovered that when a member of a thermostatic element is age-hardened and nitrided throughout the cross section, better flexing properties are obtained. In addition, the thermostatic element made of at least one age-hardened and nitrided member has a high "equivalent yield strength." The "equivalent yield strength" is considered by many in the art to be a very important property which gives a good indication of the load-carrying capacity which will evaluate service life. The "equivalent yield strength" is the stress which will give a composite metal thermostatic element a permanent set when the stress is removed. The degree of permanent set is considered by many in the art to be the Proof Stress set, e. g. — 0.01% permanent elongation. The art has employed severe cold working or cold deformation to raise the "equivalent yield strength." The age-hardened and nitrided members provided by the present invention have a higher "equivalent yield strength" than has been obtainable heretofore by cold working. The age-hardened and nitrided members also have greater strength, better flexing properties and longer life, by reason of improved fatigue resistance. As a result of the improved properties, the invention provides thinner thermostatic members, such as strip-like members, than has been available heretofore.

In carrying the invention into practice, it is preferred that the smaller cross sectional dimension of the age-hardened and nitrided member not exceed about 0.03 inch. In order that this member be nitridable, the sum total of the elements present which do not impart nitridability, e. g.—nickel, copper, chromium, molybdenum, tungsten, should not exceed approximately 80% of the whole composition. On the other hand, iron imparts nitridability to the member and is preferably present in the com-

ability, such as titanium, maganese, silicon, and aluminum act like iron in this respect. The greater the amount of those elements which are nitriding promoters, the more pronounced will be the effects of nitriding, with respect to both nitrogen concentration and rate of diffusion. The member to be age-hardened and nitrided is made of an alloy containing approximately 2% to 80% of one or more of those metallic elements which do not impart nitridability, e. g. — nickel, copper, chromium, molybdenum, tungsten; approximately 20% to 97% of these elements which are nitriding promoters, e. g. — titanium, maganese, silicon, aluminum, and particularly iron; and containing at least one age-hardening element, e. g.—titanium, aluminum, silicon, beryllium, and magnesium, and in the case of copper-base alloys, manganese, in an amount sufficient to impart age-hardenability and nitridability to the alloy.

This invention particularly contemplates age-hardened and nitrided members made of an iron-nickel-titanium or an iron-nickel-chromium-titanium alloy containing about 1% to 10% titanium up to about 25% chromium, about 2% to 80% nickel, the balance being substantially iron in an amount constituting at least 10% of the alloy, the sum of the nickel plus any chromium that may be present not exceeding approximately 80% of the whole composition, and the sum of the iron plus nickel contents being at least approximately 70% of the whole composition. An example of different types of alloys which also may be employed in accordance with this invention as an age-hardened and nitrided member of the thermostatic element are the copper-nickel-manganese alloys, e. g.—60% copper, 20% nickel, and 20% manganese, such as are disclosed in the Dean, United States patent, No. 2,234,552.

Illustrative examples of ranges of compositions which are preferably employed in accordance with the invention as the nitrided and age-hardened member of the thermostatic element are as follows:

	A	B	C	D	E
Per cent Ni	40.5–42.5	44.5–46.5	51.0–53.0	28.0–30.0	41.0–43.0
Per cent Ti	2.2– 2.8	2.2– 2.8	2.2– 2.8	2.2– 2.8	2.2– 2.8
Per cent Al	0.4– 0.8	0.4– 0.8	0.4– 0.8	0.4– 0.8	0.4– 0.8
Per cent Si	0.1– 0.8	0.1– 0.8	0.1– 0.8	0.1– 0.8	0.1– 0.8
Per cent Mn	0.3– 0.6	0.3– 0.6	0.3– 0.6	0.3– 0.6	0.3– 0.6
Per cent Cr				8.0– 9.0	4.5– 6.5
Per cent C	0.1 max.	0.1 max.	0.1 max.	0.1 max.	0.1 max.
Per cent Fe	Balance	Balance	Balance	Balance	Balance

When it is stated herein that the balance is iron or is substantially all iron, it is not intended to exclude small percentages of incidental elements and impurities such as cobalt, calcium, sulfur, phosphorus, etc. Thus, the compositions usually contain small amounts of sulfur and/or phosphorus, but it is preferred that the amounts of each of these, when present, not exceed about 0.04%. Likewise, cobalt may be present. Commercial nickel usually contains some cobalt in amounts up to about 1% or more. The presence of cobalt in the amounts of the order of 5% is often beneficial in low-expansion iron-nickel alloys such as set forth hereinabove. Small amounts of calcium of the order of about 0.05% are often desirable to impart forgeability.

Alloy compositions A, B, and C in the age-hardened and nitrided condition are particularly suitable as the low-expansion member of the thermostatic element, for example, members L–1 and L–2 in the drawing. Alloy composition D in the age-hardened and nitrided condition forms an excellent high-expansion member, for example, member H–1 in the drawing. Alloy composition E when age-hardened and nitrided throughout the cross section can be used either as the low-expansion member or the high-expansion member. Thus, when used in combination with an age-hardened and nitrided member of alloy composition A or B, any of the latter is the low-expansion member, and the member of composition E is the high-expansion member. When used in combination with a member made of alloy composition C or D, the latter is the high-expansion member, and the composition E member is the low-expansion member. In all the foregoing examples, both the low-expansion and the high-expansion member can be in the age-hardened and nitrided condition, or only one member need be in such a condition. Thus, one member could be in an age-hardened and nitrided condition while the other is in a non-nitrided but age-hardened condition. It is preferred that both members be in an age-hardened and nitrided condition provided the expansion and other required properties will so permit.

When only one member is made of an age-hardened and nitrided alloy, such as compositions A to E, the other member can be a non-nitridable material, such as non-ferrous alloys. Illustrative examples of suitable non-ferrous alloys include cupro-nickel, e. g., an alloy containing about 30% to 45% nickel and about 55% to 70% copper, and nickel-copper alloys sold under the trade-mark of "Monel" and containing about two-thirds nickel and one-third copper, e. g., about 26% to 33% copper and about 63% to 73% nickel. Small amounts of age-hardening elements, e. g., aluminum and/or titanium, may be present in the nickel-copper alloy, and such an alloy is sold under the trade-mark "K Monel." The non-nitrided member can be made of such an age-hardenable alloy composition. When cupro-nickel or nickel-copper alloys are employed as the non-nitrided member, that member is the high-expansion member when the other member is made of an age-hardened and nitrided alloy of compositions A, B, C, or E, and is the low-expansion member when the other member is made of an age-hardened nitrided alloy of composition D.

Illustrative examples of compositions suitable for use in strip-like or ribbon-like form as the age-hardened and nitrided members in the thermostatic elements, and temperature responsive devices comprised thereof, contemplated by the invention include the following:

	I	II	III	IV	V
Per cent Ni	42.0	45.0	52.0	29.0	42.0
Per cent Ti	2.4	2.4	2.4	2.4	2.4
Per cent Al	0.4	0.4	0.4	0.4	0.4
Per cent Si	0.3	0.3	0.3	0.5	0.5
Per cent Mn	0.4	0.4	0.4	0.4	0.4
Per cent Cr				8.5	5.4
Per cent C	0.06 max.	0.06 max.	0.06 max.	0.06 max.	0.06 max.
Per cent Fe	Bal.	Bal.	Bal.	Bal.	Bal.

Compositions I to V are illustrative of alloys within the ranges of compositions A to E, respectively, and are all age-hardenable and nitridable. Age-hardening can be obtained in all the compositions by treatment for at least twenty minutes, e. g., one-half to one and one-half hours, within the solution temperature range of about 1700° F. to 1850° F., followed by cooling the alloy to preserve the solid solution of the precipitable constituent, e. g., by a rapid cooling such as

quenching, and thereafter treating the compositions within the aging temperature range of about 1100° F. to 1350° F. to impart age-hardness, e. g., treating within said range for about three to forty-eight hours. The compositions can all be nitrided by treating them in an atmosphere of dissociated ammonia, e. g., about 24% to 40% dissociation, at nitriding temperatures between about 900° F. and 1200° F. for sufficient time to nitride the member throughout its cross section. Because the nitriding temperatures overlap the aging temperatures, it is possible to age-harden and nitride the member simultaneously, e. g., at temperatures of about 1100° F. to 1200° F. In other words, after treatment to dissolve the precipitable constituent and to preserve its solid solution, the member may be placed simultaneously in an age-hardened and nitrided condition throughout its cross section.

The age-hardened and nitrided member can advantageously be subjected to an additional shot-peening treatment to improve further the strength and performance of the thermostatic element. The shot-peening treatment can be accomplished by the usual methods, and its effect is superimposed on those derived from the age-hardening and nitriding treatment whereby new and improved characteristics are obtained in thermostatic elements.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such variations and modifications are considered to be within the purview and scope of the invention and the appended claims.

I claim:

1. As a new article of manufacture, a bimetallic thermostatic element comprising a low-expansion member made of an iron-nickel alloy containing about 40.5% to 53% nickel, about 2.2% to 2.8% titanium, about 0.4% to 0.8% aluminum, about 0.1% to 0.8% silicon, about 0.3% to 0.6% manganese, a small amount up to about 6.5% chromium, a small amount up to about 0.1% carbon and the balance substantially iron, and a high-expansion member made of an iron-nickel alloy containing about 28% to 30% nickel, about 2.2% to 2.8% titanium, about 0.4% to 0.8% aluminum, about 0.1% to 0.8% silicon, about 0.3% to 0.6% manganese, about 8% to 9% chromium, up to about 0.1% carbon and the balance substantially iron, said low-expansion member and said high-expansion member both being in an age-hardened and nitrided condition throughout the cross sections of said members.

2. In a bimetallic thermostat the improvement which comprises making the low-expansion member of said thermostat of an alloy containing about 40.5% to 53% nickel, about 2.2% to 2.8% titanium, about 0.4% to 0.8% aluminum, about 0.1% to 0.8% silicon, about 0.3% to 0.6% manganese, a small amount up to about 6.5% chromium, a small amount up to about 0.1% carbon and the balance substantially iron; said member having an age-hardened and nitrided structure throughout the cross section thereof.

3. In a bimetallic thermostat the improvement which comprises making the high-expansion member of said thermostat of an alloy containing about 28% to 30% nickel, about 2.2% to 2.8% titanium, about 0.4% to 0.8% aluminum, about 0.1% to 0.8% silicon, about 0.3% to 0.6% manganese, about 8% to 9% chromium, a small amount up to about 0.1% carbon and the balance substantially iron; said member having an age-hardened and nitrided structure throughout the cross section thereof.

4. In a thermostatic element having a plurality of members the improvement which comprises making at least one member of said thermostatic element of an alloy containing about 28% to 53% nickel, about 2.2% to 2.8% titanium, about 0.4% to 0.8% aluminum, about 0.1% to 0.8% silicon, about 0.3% to 0.6% manganese, a small amount up to about 9% chromium, a small amount up to about 0.1% carbon, and the balance substantially iron; said member having an age-hardened and nitrided structure throughout the cross section thereof.

5. In a thermostatic element having a plurality of members the improvement which comprises making at least one member of said thermostatic element of an alloy containing about 2% to 80% nickel, about 1% to 10% titanium, and the balance substantially iron, the sum of the titanium plus iron contents being at least 20% of the alloy composition; said member having an age-hardened and nitrided structure throughout the cross section thereof.

6. In a thermostatic element having a plurality of members the improvement which comprises making at least one member of said thermostatic element of an alloy containing about 2% to 80% nickel, about 1% to 10% titanium, a small amount up to about 25% chromium, and the balance substantially iron, the sum of the nickel plus chromium contents not exceeding approximately 80% of the alloy composition; said member having an age-hardened and nitrided structure throughout the cross section thereof.

7. In a thermostatic element having a plurality of members the improvement which comprises making at least one member of said thermostatic element of an alloy containing about 2% to 80% nickel, about 10% to 97% iron, about 1% to 10% titanium, the sum of the iron plus titanium contents being at least 20% of the alloy composition, the sum of the iron plus nickel contents being at least 70% of the alloy composition; said member having an age-hardened and nitrided structure throughout the cross section thereof.

8. In a thermostatic element having a plurality of members the improvement which comprises making at least one member of said thermostatic element of an alloy containing about 2% to 80% nickel, about 10% to 97% iron, a small amount up to about 25% chromium, about 1% to 10% titanium, the sum of the nickel plus chromium contents not exceeding approximately 80% of the alloy composition, the sum of the iron plus nickel contents being at least 70% of the alloy composition; said member having an age-hardened and nitrided structure throughout the cross section thereof.

9. In a thermostatic element having a plurality of members the improvement which comprises making at least one member of said thermostatic element of an alloy containing about 2% to 80% nickel, about 10% to 97% iron, and metal from the group consisting of aluminum and titanium in an amount within the range of about 1% to 10% sufficient to impart age-hardenability, the sum of the iron plus the metal from said group being at least 20% of the alloy composition, the sum of the iron plus nickel contents being at least 70% of the alloy composition; said member hav-

ing an age-hardened and nitrided structure throughout the cross section thereof.

10. In a thermostatic element having a plurality of members the improvement which comprises making at least one member of said thermostatic element of an alloy containing about 2% to 80% nickel, about 10% to 97% iron, a small amount up to about 25% chromium, and metal from the group consisting of aluminum and titanium in an amount within the range of about 1% to 10% sufficient to impart age-hardenability, the sum of the nickel plus chromium contents not exceeding 80% of the alloy composition, the sum of the iron plus nickel contents being at least 70% of the alloy composition; said member having an age-hardened and nitrided structure throughout the cross section thereof.

11. In the method of producing a thermostatic element having a plurality of strip members the improvement which comprises making at least one strip member of said thermostatic element of an alloy containing about 2% to 80% nickel, about 10% to 97% iron, and metal from the group consisting of aluminum and titanium in an amount within the range of about 1% to 10% sufficient to impart age-hardenability, the sum of the iron plus the metal from said group being at least 20% of the alloy composition, the sum of the iron plus nickel contents being at least 70% of the alloy composition; said member having an age-hardened and nitrided structure throughout the cross section thereof; and joining said strip member in face-to-face relationship with another strip member of said thermostatic element.

12. In the method of producing a thermostatic element having a plurality of strip members the improvement which comprises making at least one strip member of said thermostatic element of an alloy contaning about 2% to 80% nickel, about 10% to 97% iron, a small amount up to about 25% chromium, and metal from the group consisting of aluminum and titanium in an amount within the range of about 1% to 10% sufficient to impart age-hardenability, the sum of the nickel plus chromium contents not exceeding about 80% of the alloy composition, the sum of the iron plus nickel contents being at least 70% of the alloy composition; said member having an age-hardened and nitrided structure throughout the cross section thereof; and joining this strip member in face-to-face relationship with another strip member of said thermostatic element.

13. In a temperature-responsive device having a plurality of members the improvement which comprises making at least one member of said device of an alloy containing a small but effective amout up to about 80% of metal from the group consisting of nickel, chromium and copper, about 1 to about 10% of metal from the group consisting of titanium and aluminum and the balance consisting essentially of iron; said member having an age-hardened and nitrided structure throughout the cross section thereof.

14. In a temperature-responsive device having a plurality of members, the improvement which comprises making at least one member of said device of an alloy containing a small but effective amount up to about 80% of metal from the group consisting of nickel, chromium and copper, and the balance essentially metal from the group consisting of titanium, aluminum, manganese, silicon and iron; said member having an age-hardened and nitrided structure throughout the cross section thereof.

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