March 30, 1954 L. G. BOSTWICK 2,673,482

VIBRATING REED DEVICE

Filed Oct. 19, 1950 2 Sheets-Sheet 1

FIG. 1

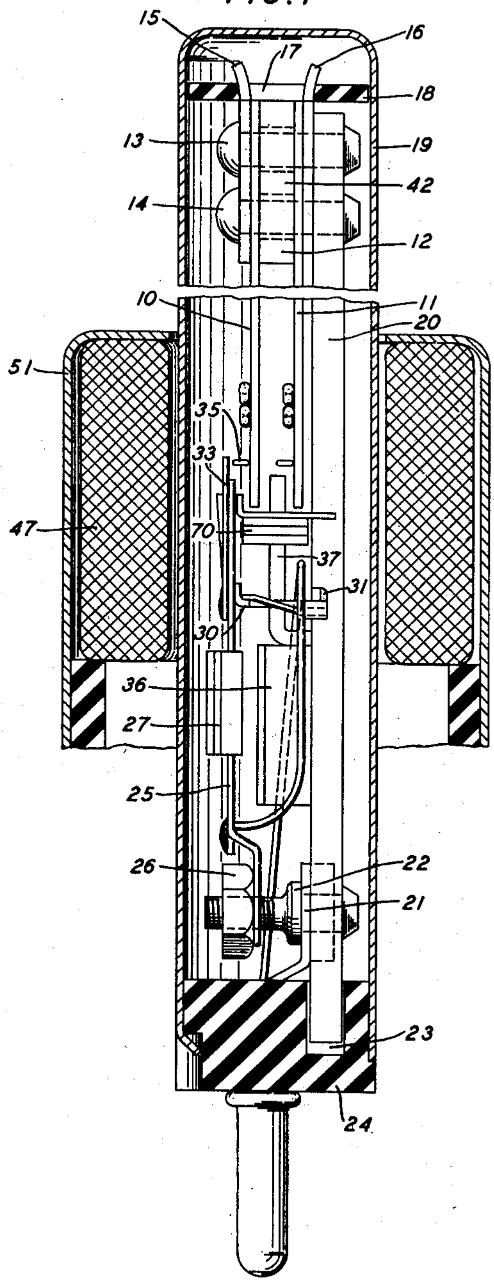
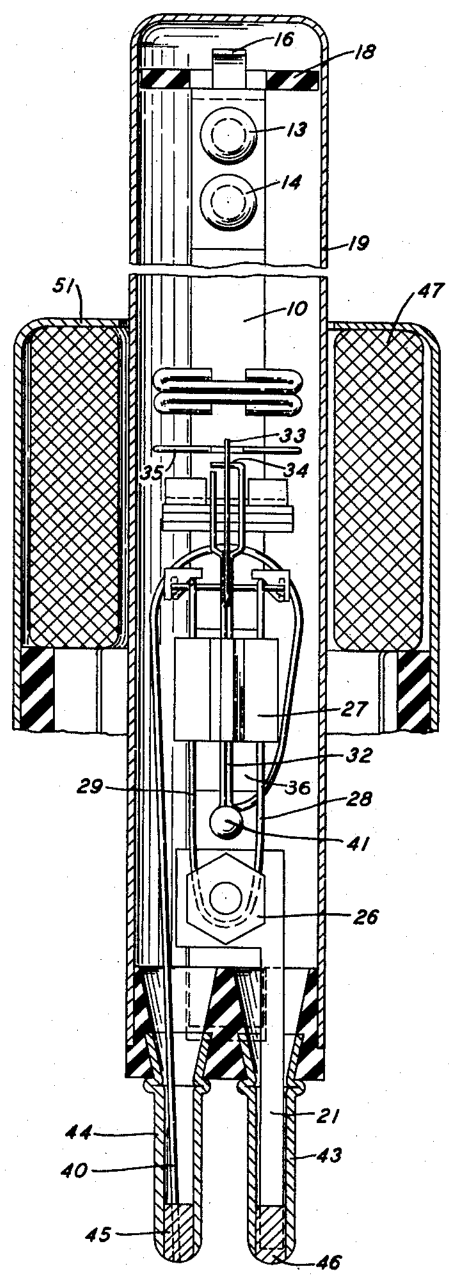


FIG. 2



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March 30, 1954 L. G. BOSTWICK 2,673,482

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Filed Oct. 19, 1950 2 Sheets-Sheet 2

FIG. 3

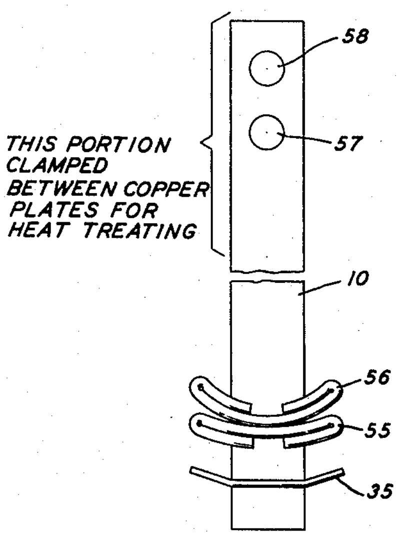


FIG. 4

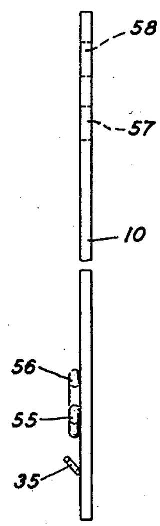
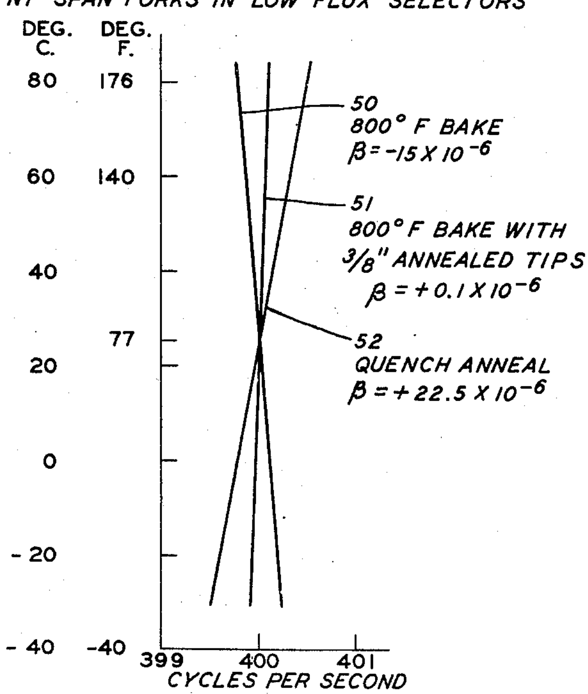


FIG. 5

FREQUENCY-TEMPERATURE CHARACTERISTICS OF 3483 NI-SPAN FORKS IN LOW FLUX SELECTORS



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Patented Mar. 30, 1954 **2,673,482**

UNITED STATES PATENT OFFICE

2,673,482

VIBRATING REED DEVICE

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Application October 19, 1950, Serial No. 191,027

4 Claims. (Cl. 84—456)

1

This invention relates to devices including magnetic vibrating reeds and more particularly to such devices wherein it is especially important that the resonance frequency of the reed or reeds remain substantially constant over a range of operating temperatures.

The resonance frequency of a vibrating reed or reeds such as clamped-free cantilevers, tuning forks or other forms is subject to variation with changes in temperature. This variation may be caused by several factors. First the dimensions of the reed are changed in accordance with the temperature coefficient of expansion of the reed material and this usually causes the resonance frequency to increase with rising temperatures. A temperature change also causes a change in the elastic modulus of the reed material, which enters into the frequency equation of the reed in a well-known manner. If the reed is electromagnetically driven, the resonance frequency may be materially altered by a change in the magnetic flux in the gap across which the driving force for the reed is developed. This gap flux change is caused by permeability and coercive force changes which in turn are caused by temperature changes in the reed material.

One object of this invention is to maintain the resonance frequency of the reed or reeds in vibrating reed devices substantially constant over a range of operating temperatures.

In accordance with one broad feature of this invention, the reed is constructed so that the effective thermoelastic coefficient of the reed as a whole is of a value to compensate for the effects of the temperature coefficient of expansion, specifically and for example is substantially equal and opposite in sign to the temperature coefficient of expansion.

In accordance with a more specific feature of the invention, the reed of a suitable alloy having a prescribed thermoelastic coefficient is first heat treated to relieve internal strains and stresses, at a temperature that does not appreciably alter its thermoelastic properties. A portion of the reed is then heated to a higher temperature and quenched without greatly heating the remaining portion of the reed. This is accomplished as by clamping the remaining portion of the reed between relatively massive blocks of a good heat conducting material, such as copper, and inserting the unclamped portion in an induction heating coil or in a locally applied gas flame. This higher temperature theatment anneals the treated portion of the reed, thereby increasing its magnetic permeability and reducing the coercive force so that these factors have less effect on the gap flux and frequency with temperature changes. The high temperature treatment also changes the thermoelastic coefficient of the material but only so much of the

2

reed is annealed that the thermoelastic coefficient of the treated portion of the reed results in an over-all effective thermoelastic coefficient of the reed as a whole substantially equal in magnitude, but opposite in sign, to the temperature coefficient of expansion of the reed material.

These and other objects and features of the invention will be more clearly understood from the following detailed description when read in conjunction with the drawing, in which:

Fig. 1 is an elevational view partly in section of a vibrating reed device, illustrative of one embodiment of this invention.

Fig. 2 is a view similar to Fig. 1 but taken at right angles thereto;

Fig. 3 is a front view of a reed or tine in the device of Fig. 1:

Fig. 4 is a side view of the reed; and

Fig. 5 is a graph showing the frequency characteristics of reeds given different heat treatments.

Referring now to Fig. 1 the tines **10** and **11** are mounted on either side of spacer **12** as by brazing. Secured to the tines **10** and **11** by rivets **13** and **14** are washers **15** and **16** which extend through an aperture **17** in insulating spacer **18**. This spacer has an outside diameter slightly less than the inside diameter of envelope **19**, thus allowing the tine assembly limited freedom of motion within the envelope **19**. This assembly is secured by the rivets **13** and **14** to one end of conducting bar **20** which in turn is secured near its other end by conducting element **21** positioned around stud **22**. The extreme lower end of conducting bar **20** sets into slot **23** of end plug **24**. It is to be noted that the cross-sectional area of slot **23** is larger than the cross-sectional area of conducting bar **20**, thus allowing the conducting bar **20** to move freely within slot **23**. It can thus be seen that the tine assembly is floatably mounted to prevent any bending or distortion of the assembly within the housing.

The contact support and spring assembly **25** is secured on the stud **22** by nut **26**. This assembly comprises an insulating spacer block **27**, spring wires **28** and **29** shown in Fig. 2, support spring **30** through which spring wires **28** and **29** are secured by suitable tension means. The spring **30** rests in a slot **31** in contact bar **20**. Supported by insulating block **27** is a double wire assembly **32** to which contact **33** is affixed as by soldering. One of the wires of the double wire assembly **32** is terminated with the end **34** thereof bent perpendicular to the contact **33**. The spring contact **33** extends just beyond the tuning bar **35** and is spaced a short distance therefrom. During vibration of the tine **10**, the tuning bar

35 which is fastened thereto will make contact with the spring contact 33.

A permanent magnet 36 is secured to bar 20. Adjacent the permanent magnet 36 is located pole-piece 37 which extends through electromagnetic damping members such as copper sleeves 70 to a position between the ends of the reeds or tines 10 and 11.

The reeds or tines are shown in detail in Fig. 3. Tuning bars 35, 55 and 56 are secured to the reed 10 as by spot welding, for example, and may be adjusted by bending to impart the desired frequency of vibration to the reed 10. Holes 57 and 58 provide means for mounting the reed.

The contact separation can be adjusted by the nut 26 which can be moved along the stud 22 thus causing a variation of the distance of spring contact 33 from tuning bar 35 by means of the lever action of double wire 32.

The tines or reeds 10 and 11 may be set in vibration by energization of a magnetic coil 47 mounted exterior of and extending around the envelope 15. Magnetic coil 47 is partially enclosed in a magnetic shell 51. The magnetic circuit of permanent magnet 36 extends through pole-piece 37, tines 10 and 11, through magnetic shell 51 and back to permanent magnet 36. Thus the portion of the pole-piece 37 positioned between the tines 10 and 11 has a definite polarity due to permanent magnet 36. Consequently, when the tines 10 and 11 are magnetized by external coil 47 they will either be attracted to the pole-piece 37 or will be repelled from the pole-piece 37 depending upon the polarity of magnetization of the tines.

When contact is made between spring contact 33 and tuning bar 35, an electrical circuit may be traced in Fig. 2 from conductor 40 through solder joint 41, double wire assembly 32, spring contact 33, tuning bar 35, tuning fork tine 10, metal spacer 42, metal washer 16, conducting bar 20, and element 21 which terminates in terminal pin 43. Terminal pins 44 and 43 are sealed as by solders 45 and 46 respectively which secure conductor 40 and conducting strip 21 respectively.

It is important in a number of applications of vibrating reed devices of the type described that the reeds be responsive substantially, only to energizing forces of a prescribed frequency or within a restricted frequency range. To this end, the reeds in such devices heretofore have been tuned mechanically at a preassigned frequency. However, as has been pointed out hereinabove, the resonance frequency of the reed is subject to variation with temperature. In accordance with this invention, such variation is minimized or substantially prevented. The manner in which this is effected will be understood from consideration of a specific embodiment.

The tines or reed 10 and 11 in this embodiment of the vibrating reed device described herein had a composition approximately as follows:

	Percent
Ti	2.1
Cr	6.0
Ni	41.93
C	.04
Fe	48.11
Mn	.57
Al	.61
Si	.55

The alloy used in the specific embodiment may be annealed, formed into metal tape, and cut into lengths to be used as the reeds or tines. The strip material initially is not sufficiently mechanically stable due to large residual internal stresses. To relieve these stresses, the material is heat treated, without deleteriously affecting its magnetic properties. In a specific case for example, it may be rolled and heated for three hours at a temperature of the order of 800° F. or at a temperature of the order of 600° F. for about twenty-four hours. As so processed, the material is mechanically stable, has a high yield strength, and is suitable mechanically for use in reeds. The thermoelastic coefficient, however, is not properly related to the expansion coefficient so as to maintain constant frequency with variations in temperature. Furthermore, the magnetic properties of these reeds are not favorable because the permeability is low and variable with temperature, and because the coercive force of the reeds is sufficiently large to materially alter the gap flux, and therefore the reed resonance frequency, when the reed strikes the pole-piece and becomes, to some extent, permanently magnetized.

To avoid these magnetic shortcomings of the reeds and to make their thermoelastic coefficient substantially equal to their expansion coefficient, one end of the tines is annealed to leave them in a soft state. This increases the permeability of the reeds several fold and reduces the coercive force to a small fraction of its previous value in the tip section of the reed where the magnetic properties are most important.

For the alloy treated as noted above, specifically when heated for about twenty-four hours or more at a temperature of 600° F. or about one hour or more at a temperature of about 800° F., to relieve internal stresses and strains, the alloy is found to have a thermoelastic coefficient of approximately -15×10^{-6}.

The alloy when heated to about 1800° F. and quenched, has a positive thermoelastic coefficient of approximately $+22.5\times10^{-6}$ per degree F. A coefficient for the reed as a whole between these two values is required because the temperature coefficient of expansion of the alloy is about $+4.5\times10^{-6}$ per degree F. and the over-all thermoelastic coefficient should be approximately equal to this and of opposite sign. To obtain the proper coefficient for the reed as a whole, the base end of the reed is clamped between good heat conducting plates, such as of copper, and the other end portion of the reed is annealed without affecting the remainder. Specifically, the other end is inserted in a coil of an induction heat furnace, brought to a temperature of about 1800° F. and then quenched in water. The copper blocks prevent the remainder of the reed from heating substantially. The annealed tips of the tines have a thermoelastic coefficient of about $+22.5\times10^{-6}$ which has the effect of reducing the thermoelastic coefficient of the reed as a whole and making it more nearly compensate for the effect of the temperature coefficient of expansion. Furthermore, the ends of the tines have a higher permeability due to the annealing and also have lower coercive force.

The magnitude and character of the effect of heat treating in a particular case are indicated in Fig. 5 which shows the frequency variation with temperature in a 400-cycle vibrating reed device, with the magnet strength reduced to a low level such that only elastic modulus effects are present. Three devices are represented as follows, for reeds of a length of about 1.5 inches:

1. Curve 50 shows frequency-temperature char-

acteristics of reeds rolled and heated three hours at 800° F.

2. Curve 51 shows frequency-temperature characteristics of similar reeds with ⅜" of the tips annealed at a temperature of 1800° F.
3. Curve 52 shows frequency-temperature characteristics of reeds quench annealed over the full length.

The effective themoelastic coefficient, β, for each case is indicated on the curves. From these curves the improvement realized by the treatment above described is evident. Although for the case illustrated in Fig. 5, exact compensation for the temperature coefficient of expansion is not realized, it has been found that for many practical purposes, compensation of the magnitude indicated is adequate. In typical devices constructed in accordance with this invention, the resonance frequency of the reeds is maintained constant within ± 0.05 per cent over an operating temperature range of $-40°$ F. to $+180°$ F.

It is to be understood that the embodiment of the invention herein described is but illustrative thereof and that various changes may be made therein without departing from the scope and spirit of the invention. For example, other materials such as nickel iron alloys containing small amounts of molybdenum may be used and different baking and annealing temperatures employed for these alloys. Also various lengths of the reeds may be treated, it being noted that by annealing a greater length the over-all thermoelastic coefficient is made more positive.

What is claimed is:

1. The method of processing a pressure formed reed having the composition substantially 48 per cent iron, 42 per cent nickel, 6 per cent chromium and 2 per cent titanium, which method comprises heating said reed at a temperature of about 800° F. for about three hours to relieve stresses and strains developed in the reed during the forming thereof, and treating one end portion of said reed to alter the thermoelastic coefficient of said portion such that the effective thermoelastic coefficient of said reed as a whole is substantially equal and of opposite sign to the temperature coefficient of expansion of said reed, said treating comprising heating said end portion to a temperature of about 1800° F. and quenching said portion.

2. The method of processing a pressure formed reed having a composition substantially 48 per cent iron, 42 per cent nickel, 6 per cent chromium and 2 per cent titanium, which comprises heating said reed at a temperature of about 800° F. for about three hours to relieve stresses and strains developed in the reed during the forming thereof, mounting said reed in a heat conducting body with a tip portion of said reed exposed, treating said tip portion to alter the thermoelastic coefficient of said portion such that the effective thermoelastic coefficient of said reed as a whole is substantially equal and of opposite sign to the temperature coefficient of expansion of said reed, and removing said reed from said heat conducting body, said treating comprising heating the tip portion only to a temperature of about 1800° F. and quenching said portion.

3. A reed for a vibrating reed device comprising a metallic strip having a composition of substantially 48 per cent iron, 42 per cent nickel, 6 per cent chromium and 2 per cent titanium, said strip having a pair of portions including a body portion having a negative thermoelastic coefficient and a tip portion having a positive thermoelastic coefficient, said coefficients being correlated to provide a thermoelastic coefficient for the entire reed of a preassigned value intermediate the thermoelastic coefficients of the body and tip portions.

4. A reed in accordance with claim 3 wherein said body portion has a thermoelastic coefficient of about -15×10^{-6}, said tip portion has a thermoelastic coefficient of about $+22.5\times10^{-6}$ and the composite thermoelastic coefficient for the entire reed is substantially equal and of opposite sign to the temperature coefficient of expansion of the reed.

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