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COMPENSATING HAIRSPRING

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4 Claims. (Cl. 75—123)

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The alloys of iron and nickel that have been investigated by numerous research workers, particularly by Guillaume, Hanson and Hanson, Peschard, Honda and Miura, Merz, Kase, Scheil, Jette and Foote, Chevenard, are divided into two groups, the irreversible ferro-nickels and the reversible ferro-nickels, according to the percentage of nickel, the limit being between 27 and 28 per cent.

For clearance of exposition the limit indicated by Professor Chevenard, namely 27.3% of nickel, will be adopted.

It is moreover well known, since the scientific works of Dr. Guillaume, that the thermo-elastic anomaly that is characteristic of these alloys utilised in chronometry for making compensating hair-springs of the elinvar type is to be found between the limits of 27.5 and 44 per cent.

Made without addition, these alloys have a constant elastic force at 27.5 and 44 per cent, whereas the thermo-elastic coefficient is positive in the intervening range, exhibiting a maximum in the neighbourhood of 36 per cent. Beyond and below these limits the thermo-elastic coefficient becomes negative, and the hairsprings compensate only partially, and the more imperfectly as they move farther away from the limits indicated.

Below 27.5% the thermo-elastic coefficient is negative, without however reaching the value of that of steel. Hairsprings made of alloys in this category can therefore already effect a partial compensation, without however attaining accurate compensation, which can only be realised above 27.5%. Without auxiliary additions these alloys are very soft, and for this reason practically unutilisable (see Swiss Patent No. 15527).

The alloy at 27.5 is still very soft. In order to harden it Dr. Guillaume incorporates therein additions of chromium, tungsten, molybdenum or other hardening agents.

These additions diminish the breadth of the thermo-elastic anomaly. Compensating hairsprings rendered more elastic by this means require to have a nickel content of between 27.5 and 42%, and the proportioning is effected in such a way that the positive anomaly is diminished down to zero by the effect of the hardening additions, correcting or not correcting the secondary error (Swiss Patents Nos. 54,876, 89,576 and 82,081).

The hairsprings manufactured on the basis of Swiss Patents Nos. 160,798 and 196,408 utilise the same process, except for the difference that while still employing the hardening additions mentioned by Guillaume they include an addition of beryllium.

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The culminating point of this technique has been attained by the researches carried out by the Société des Fabriques de Spiraux Réunies with the Société anonyme de Commentry Fourchambault Decazeville, while the structural hardening process has been added to the hardening effect of the additions (Swiss Patents Nos. 217,548 and 217,814).

As is explicitly mentioned in Swiss Patents Nos. 217,548 and 217,814, all the alloys hitherto utilised, and mentioned in the present exposition, are reversible ferro-nickels, that is to say, austenitic solutions containing iron in the gamma state.

For an alloy having a grade higher than 27.3% of nickel, the austenitic state is determined solely by the nickel content (zone of the reversible ferro-nickels).

For the alloys containing less than 27.3% of nickel, and being in the irreversible zone, the gamma allotropic state of the iron is imposed by the temperature of fixing (the last manufacturing operation, in the course of which the hairsprings are passed through a furnace in order to give them the final form), which is above 550° C. (see Swiss Patent No. 196,408). This temperature implies the passage into the gamma state of all the irreversible alloys containing more than 25% of nickel. By cooling down to the surrounding temperature, the return to the alpha state never takes place when the alloys contain the hardening additions mentioned in all the patents cited, with the sole exception of Swiss Patent No. 15,527.

This latter patent describes a hairspring the compensating power of which is insufficient, as Dr. Guillaume has indicated in the patents taken out subsequently, and its characteristic as a soft alloy, expressly mentioned in the patent, is a determining feature as regards its austenitic structure.

In spite of all the hardening additions incorporated in large percentages, sometimes going as far as 30%, and far exceeding the percentages ordinarily employed in metallurgy, these austenitic solutions have never been able to attain the elastic limit of tempered hairsprings.

This elastic limit is measured, amongst hairspring-manufacturers, with the aid of a small appliance which maintains fixed the extremity of the outer turn of a standard hairspring (size 72, utilised for 45-millimetre chronometers), while the extremity of a rod is embedded at the centre of the hairspring. The length of the penetration before deformation intervenes character-

ises the elastic limit, which is thus measured in millimetres.

Hairsprings realising excellent compensations support elongations of 75 to 100 millimetres, and in exceptional cases 110 to 115 millimetres, without appreciable deformation, while tempered steel hairsprings easily go as far as 150 millimetres.

On the other hand, on account of the high temperature at which they have to be fixed, which may be in the neighbourhood of 700° C., but are more generally above that, the hairsprings become tarnished by oxidation on passing through the fire, the turns stick together and become very difficult to disengage, and the operation often proves impossible without deformation, owing to their low elastic limit. These deformations, which render the hairsprings useless, constitute in fact the principal difficulty of this industry.

The present invention obviates all these disadvantages, not by incorporating in the alloy new and bulky additions, as has been the practice hitherto, but by modifying the basic structure in such a way that in the finished hairspring the iron is in the alpha allotropic state rather than in the gamma state.

Whereas all the research-workers who have occupied themselves with this problem have believed that only gamma austenitic solutions permitted perfect compensation to be realised, the author of the present invention has discovered that such compensation can be perfectly realised by utilising a ferritic alloy containing iron in the alpha state, but that then the proportions of nickel utilised should no longer vary between 27.5 and 43% but only within the narrow limits of 24.5 to 27%, 27.3% being the limit at which the alloy becomes reversible and austenitic, as mentioned above. When the compensating element is thus constituted within these limits by the alpha-iron-nickel complex rather than by the gamma-iron-nickel complex, the hairsprings reveal an elastic limit which now not only rigorously attains the elastic limit of tempered hairsprings but even surpasses it in a proportion of 10 to 20%, since the standard test on hairsprings size 72 permits elongations without deformation going as far as 170 millimetres instead of 150 millimetres for tempered hairsprings and 75 to 100 millimetres for the usual compensating hairsprings.

The maintenance of the structure of the iron in the alpha state requires a fixing temperature below the alpha-gamma transformation point of the irreversible alloys containing from 24 to 27% of nickel, that is to say, below 550° C. In practice it should not exceed 500° C. This low temperature eliminates all the manufacturing troubles mentioned above, such as stains, and turns adhering to one another in fixing, with subsequent deformation at the time of disengagement.

To succeed in fixing the hairsprings at such a low temperature the author of the present invention has discovered that it is necessary to abandon the incorporation of the large additions at present utilised in alloys for compensating hairsprings, to return to the additions of 5 to 6% that are usual in metallurgy.

Suppressing any addition of chromium, tungsten, vanadium, beryllium, etc., the present invention shows that columbium incorporated in the alloy with a content of from 1 to 5% enables the desired result to be attained.

A slight addition of carbon of from 0.20 to 0.70% likewise facilitates the operation.

In certain cases the carbon may be omitted, and the columbium replaced partially by an addition of aluminium, but in a percentage always lower than ¼ of the columbium addition. Furthermore, an addition of manganese of from 0.5 to 1% remains necessary because it facilitates forging without exerting any other special influence.

Besides the defects already mentioned, austenitic compensating hairsprings are often unstable; without having to wait a very long time, this instability may reveal itself by an instantaneous going test, such as can be carried out with the modern quartz-oscillator machines. The test consists in verifying the going of the watch at the moment when the regulating has just been completed, and repeating it one hour later. The variation in going is a characteristic indication of the instability of the hairspring.

While austenitic hairsprings reveal variations which in the best results are from 11 to 12 seconds, in which in certain cases reach 80 to 100 seconds or more, the hairsprings of alpha-iron structure forming the subject of the present invention have disclosed variations of going lower than 3 seconds, and often even no change at all has been ascertainable. Such a result had never hitherto been attained, even with tempered hairsprings.

An alloy comprising the following percentages:

	Per cent
Nickel	24 to 27
Carbon	0.20 to 0.7
Columbium	1 to 5
Manganese	0.5 to 1

Iron, the remainder.

renders it possible to manufacture strictly compensating hairsprings of an elasticity not merely equal to but even greater than that of tempered hairsprings, and such that tests of variation of running carried out just after the termination of the regulating give promise of extraordinary stability.

This alloy further eliminates enormous difficulties in manufacture, on account of the fixing temperature being lower than 550° C.

In the annealed state, this irreversible alloy is austenitic. The alpha allotropic state of iron, which is characteristic of the present invention, is obtained slowly by intense drawing in a cold state at the time of manufacturing the wire, and then at the time of rolling the latter into a strip constituting the turns of the hairsprings. Any fixing above 550° destroys both the structure and the adjustment of the correct compensating properties.

By way of indication, a hairspring made with this alloy may reveal a thermal coefficient not exceeding 0.05 of a second, if it is coupled to an ordinary balance-wheel of the uncut nickel type, whereas if the fixing is effected at a temperature of 600° the same alloy will pass to the austenitic state, it will immediately become very soft, the advantages of stability will likewise disappear, and the compensating power will be greatly reduced, the thermal coefficient becoming modified as far as 7'' per degree, while a coefficient of 11 to 12 seconds corresponds to the complete absence of compensation when the same balance-wheel is coupled to a steel hairspring.

What I claim is:

1. A compensating hairspring of an elasticity at least equal to that of tempered steel hairsprings, and constituted by an alloy such that the

strict compensation obtained by association with a mono-metallic balance-wheel of the uncut nickel type is ensured by the aid of the alpha-iron-nickel complex, the nickel being in a proportion of 24 to 27 per cent., with auxiliary additions composed in such a way that the temperature permitting perfect fixing to be obtained is at the maximum 550 degrees centigrade, constituted by an alloy the composition of which is included between the following limits:

	Per cent
Nickel	24 to 27
Carbon	0.20 to 0.7
Columbium	1 to 5
Manganese	0.5 to 1

Iron, the remainder.

2. A compensating hairspring of an elasticity at least equal to that of tempered steel hairsprings, and constituted by an alloy such that the strict compensation obtained by association with a monometallic balance-wheel of the uncut nickel type is ensured by the aid of the alpha-iron-nickel complex, the nickel being in a proportion of 24 to 27 per cent., with auxiliary additions composed in such a way that the temperature permitting perfect fixing to be obtained is at the maximum 550 degrees centigrade, constituted by an alloy the composition of which is included between the following limits:

	Per cent
Nickel	24 to 27
Columbium	1 to 5
Manganese	0.5 to 1

Iron, the remainder.

3. A compensating hairspring of an elasticity at least equal to that of tempered steel hairsprings, and constituted by an alloy such that the strict compensation obtained by association with a monometallic balance-wheel of the uncut nickel type is ensured by the aid of the alpha-iron-nickel complex, the nickel being in a proportion of 24 to 27 per cent., with auxiliary additions composed in such a way that the temperature permitting perfect fixing to be obtained is at the maximum 550 degrees centigrade, constituted by an alloy the composition of which is included between the following limits:

	Per cent
Nickel	24 to 27
Carbon	0.20 to 0.7
Manganese	0.5 to 1
Columbium and aluminium together, the proportion of aluminium not exceeding ¼ of the quantity of columbium	0.1 to 5

Iron, the remainder.

4. A compensating hairspring of an elasticity at least equal to that of tempered steel hairsprings, and constituted by an alloy such that the strict compensation obtained by association with a monometallic balance-wheel of the uncut nickel type is ensured by the aid of the alpha-iron-nickel complex, the nickel being in a proportion of 24 to 27 per cent., with auxiliary additions composed in such a way that the temperature permitting perfect fixing to be obtained is at the maximum 550 degrees centigrade, constituted by an alloy the composition of which is included between the following limits:

	Per cent
Nickel	24 to 27
Manganese	0.5 to 1
Columbium and aluminium together, the proportion of aluminum not exceeding ¼ of that of columbium	0.1 to 5

Iron, the remainder.

ERNEST DUBOIS.

REFERENCES CITED

The following references are of record in the file of this patent:

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Number	Name	Date
2,507,698	Dubois	May 16, 1950

FOREIGN PATENTS

Number	Country	Date
15,527	Switzerland	Apr. 21, 1898