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WATCH MAINSPRING

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4 Claims. (Cl. 267—1)

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This invention relates to power springs, of which the mainspring of a watch is an example of practice presenting extreme problems in that space and probable life considerations in a watch demand the capability of being able to store a high amount of energy in a small space with assurance that repeated winding and unwinding during the life of the watch will represent the storage and release of substantially identical amounts of energy.

This application is a continuation-in-part of our copending application Serial No. 567,894, filed December 12, 1944, now abandoned.

A characteristic of such power springs is that, during their use, they are under continuous loaded conditions and, by design for economy, the load at the end of winding is close to the strength limits of the material, the least feasible factor of safety being allowed.

Prior to our invention, watch mainsprings have been customarily made of high-carbon spring steel as this is the only material which has been found to have the necessary combinations of high strength properties and toughness to store the required amounts of energy in the small space available. The spring steel currently used in watch mainsprings has a yield strength of around 232,000 p. s. i., and a modulus of elasticity of around 28,400,000 p. s. i.

Two defects of steel watch mainsprings have long been apparent. One of these is a tendency to corrosion in the presence of moisture. As watch springs are stressed near their ultimate of strength in use, only slight corrosion causes them to break.

A second defect is the tendency to take a permanent "set" which shortens the effective length of the springs and decreases the amount of energy which can be put into them. This defect results from the fact that spring steel has a proportional limit well below its yield strength. The proportional limit of ordinary watch spring steel is only about 177,000 p. s. i., so that any stressing over this amount leads to a permanent set and, at the least, has the effects of shortening the length of time the watch will run for a single complete winding, and of altering its accuracy due to reduction of average torque delivered to the train while unwinding and driving.

We have succeeded in overcoming both of these

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defects by providing a watch mainspring of a non-corrosive material which has a yield strength and modulus of elasticity as great as those of spring steel and has a proportional limit well above that of spring steel. Our new watch mainspring is made of a non-corrosive alloy which is solution-annealed to give it the relative softness and other properties necessary to permit cold-working. A yield strength and elasticity equal to those of spring steel and a porportional limit remarkably higher than that of spring steel are developed in this material by elongation by cold-working followed by heat-aging. The combination of these two steps has the effect of increasing the hardness and strength of the material and at the same time the effect of causing an increase of as much as 75 percent in the proportional limit of the material.

The alloy which is subjected to this treatment to produce the new spring consists principally of cobalt which gives it strength, and chromium which gives it strength and corrosion resistance, and a plasticizer including nickel which makes the alloy when in solution-annealed condition sufficiently plastic to be susceptible of a high percentage of elongation by cold-working. The solution-annealed alloy includes precipitatable components which during aging develop hardness and strength in the article. The steps of cold elongation and then aging at precipitation temperature result not only in hardening the alloy, but also in greatly increasing its tensile strength and proportional limit. The strength inherent in the matrix of cobalt and chromium, coupled with the increase of strength resulting from the cold elongation followed by aging, lead to the development of tensile strength as great as that of watch mainspring steel and a proportional limit materially greater than that of watch mainspring steel.

Thus, the new mainspring can have the identical cross-section and length of a steel mainspring, and the identical original spiral curvature; so that it forms an exact replacement therefor, in the same space, and will operate initially at least as well as the steel spring in each necessary respect, with the great advantage of being free of deterioration by corrosion or "set," and of being without response to magnetic fields.

Illustrative alloys useful for the present purposes are:

Table I

Alloy No.	Co	Cr+Mo	Cr	Mo	Ni+Fe+Mn[1]	Ni	Fe	Mn	C	Be
1	45.0	29.5	22.5	7.0	25.5	15.0	8.5	2.0	.09	-----
2	40.0	32.0	25.0	7.0	28.0	15.0	10.0	2.0	.16	.04
3	40.0	27.0	20.0	7.0	33.0	15.5	15.0	2.0	.11	-----
3A	40.0	27.0	20.0	7.0	33.0	15.5	15.0	2.0	-----	.02
4	35.0	32.0	25.0	7.0	33.0	20.0	11.5	1.5	.10	.03
4A	35.0	32.0	25.0	7.0	33.0	30.0	1.5	1.5	.13	.03
5	34.0	31.0	25.0	6.0	35.0	32.0	2.0	0.14	.08	-----
6	30.0	32.0	26.0	6.0	38.0	31.0	6.0	1.0	.23	.02
7	31.0	29.0	23.0	6.0	40.0	35.0	4.5	0.80	.09	-----
8	40.0	37.0	30.0	7.0	23.0	16.0	5.0	2.0	.13	-----
9	20.0	32.0	25.0	7.0	48.0	35.0	10.0	2.0	.06	.03
10	40.0	25.0	25.0	-----	35.0	22.0	10.0	2.0	.04	.03

[1] NOTE.—The numerals for Ni + Fe + Mn are herein set out for ternary diagram employment.

Of these, alloys Nos. 1–7, inclusive, have been found to give final articles highly satisfactory as mainsprings for watches and alloys Nos. 8 to 10, inclusive, are usable for such purpose. For comparison, the behavior of the following alloys, unsatisfactory for the purpose, will also be described:

Table IA

Alloy No.	Co	Cr+Mo	Cr	Mo	Ni+Fe Mn	Ni	Fe	Mn	C	Be
11	20.0	46.0	40.0	6.0	34.0	20.0	12.0	2.0	-----	.05
12	20.0	26.3	22.6	3.7	52.0	26.3	25.0	0.72	.06	-----
13	40.0	16.0	10.0	6.0	44.0	30.0	12.0	2.0	-----	.04
14	56.0	22.0	15.0	7.0	21.5	4.5	15.0	2.0	-----	.01
15	55.0	34.5	27.5	7.0	10.5	8.5	-----	2.0	-----	-----

In the above and other tables, the cobalt, chromium, nickel, molybdenum, iron and manganese are the computed amounts by weight (found closely accurate upon analysis), while the carbon is the analytic value.

Alloys Nos. 4 and 4A have the same "ternary" composition; in No. 4, there is 20% Ni with 11.5% Fe; in No. 4A there is 30% Ni with 1.5% Fe. Alloy No. 8 is usable but inferior to alloys Nos. 1 to 7, because of high Cr+Mo content with low Ni+Fe+Mn plasticizer. Alloy No. 9 has minimum Co with only 0.06% C. It is usable, but a modification by increasing the carbon content to 0.20% is desirable. Alloy No. 10 has no Mo, and is low in tensile strength.

Alloys are known, which are based upon cobalt and chromium and are employed as castings for dental work, for non-corrosive cutting tools, for parts which must retain shape and strength at elevated temperatures as in combustion engine valves, etc., the final shaping being by hot-forging or grinding.

Further, it is known to introduce other elements as ingredients in such basic alloys; for example, molybdenum has been introduced in such alloys which are used for dental parts, and tungsten has been used in such alloys which are used for cutting tools, valve facings, etc., to improve the hardness and wear resistance. It is recognized that such modified base alloys can demonstrate strengths and hardnesses almost as high as those of high-carbon heat-treated steels, but, so far as we are aware, none of them has been successfully employed as a substitute for springs of carbon steel.

We have found that by proper and correlated selections of conditions of composition, mechanical working and heat treatments, alloys which

have cobalt and chromium in proportions to confer original strength can be so worked and treated that their strength properties can be increased until the same are equal to or greater than those which can be developed with excellent watch mainspring steels; and in this fashion horological power springs can be made with original properties at least equal to those of a steel spring of the same size, and with capability of avoiding corrosion and "set" so that its probable life is far greater than that of the replaced steel spring.

It is preferred to melt the cobalt, nickel, and iron in a high-frequency induction furnace, and then add the chromium as ferrochromium and the molybdenum as ferromolybdenum. The manganese is preferably added as a ferroalloy containing about 80 percent of manganese. After melting and being brought to proper temperature, a small addition of aluminum and then a small addition of calcium-silicon alloy are made for deoxidation. Slag is skimmed, and the ingot cast. In practice, ingots from 5 to 100 pounds have been made.

The ingot is then hot-forged and hot-rolled down to a slab or bar thickness at which hot-working becomes uneconomic. In practice, the slab may be worked to 0.050 inch, but in practice a thickness of 0.250 to 0.200 inch is preferred. The hot-working is done at above red heats, with preference for around 2000 degrees F. This is followed by a solution-annealing at 2100 to 2200 degrees F.

Illustrative of the properties of such alloys in the solution-annealed (from 2100 degrees F.) condition after the hot-working, are the values:

Table II

Alloy No.	Hardness (Vickers)
3	225
5	227
8	274
11	247
15	285

The strip is then cold-rolled at room temperature to 0.100 inch, and a further solution-annealing performed, followed by further cold-rolling to 0.040 inch. A final solution-annealing was performed from 2100 degrees F.; and then the final cold-rolling reduced the tape to 0.0044 inch. At this stage, the strength properties were:

Table III

Alloy No.	Percent Reduct.	TS	PL	YS	Mod	VHN
1	89.2	293	122	166	25.9	530
2	92.0	294	142	173	23.6	497
3	92.7	288	130	156	24.8	551
3A	90.0	294	117	142	27.6	535
4	92.7	272	155	178	22.3	516
4A	92.7	284	135	164	26.2	481
5	89.0	Not determined				
6	89.0	259	150	184	21.9	485
7	89.0	Not determined				
8	78.5	302	133	174	25.6	536
9	92.7	251	141	177	23.5	475
10	92.7	263	142	175	24.1	466
11	-----	Could not be hot rolled				
12	89.0	Not determined				
13	-----	Could not be hot rolled				
14	66.6	265	168	210	24.6	515
15	57.0	266	118	154	28.5	576

NOTE.—Alloys Nos. 14 and 15 were difficult to cold-roll due to low amount of plasticising material and the stated reductions are practicable limits.

In the above and other tables and data, TS represents tensile strength, PL proportional limit, YS yield strength, Mod modulus of elasticity, and VHN the Vickers Hardness Number. TS, PL and YS are in thousands of pounds per square inch (p. s. i.); and Mod is in millions p. s. i. YS is given with 0.02 percent offset. Bend tests, which are an index of toughness, were 180° around the arbors shown.

The tapes were then subjected to aging at 900 degrees F. for 5 hours, and, upon test, had the following properties:

Table IV

	Tensile Properties					Bend Test Diameter, Inches		
	TS	PL	YS	Mod	VHN	All Bend	Part Break	All Break
1	372	243	282	30.5	677	.125	.095	.075
2	390	231	273	29.7	790	.125	-------	.095
3	363	249	276	29.2	695	.125	.095	.075
3A	373	266	290	28.8	690	.125	.095	.075
4	347	202	260	30.0	623	.125	.095	.075
4A	358	207	269	30.9	579	.125	.095	.075
5	363	231	275	31.2	673	.095	.075	.060
6	335	224	262	30.2	664	.125	-------	.095
7	316	226	260	30.6	660	.040	-------	.032
8	381	249	292	30.2	700	.095	.075	.060
9	361	201	255	29.5	602	.095	.075	.060
10	321	190	228	29.7	486	.095	-------	.075
12	286	195	231	28.7	570	.032	-------	-------

NOTE.—Alloy No. 12 is of low strength and hardness. Alloys Nos. 14 and 15 were too brittle to test.

The alloy composition basically contains about 20 to 50 percent of cobalt and about 15 to 30 percent chromium, along with 20 to 50 percent of softening or plasticizing component including nickel. In general, these components are present as 20 to 50 percent of cobalt, 20 to 37 percent of chromium and molybdenum combined (the molybdenum being 1 to 10 percent of the alloy), and 20 to 50 percent of nickel, iron and manganese combined (the percentage of nickel being greater than that of the iron, with negligible traces to a maximum of 15 percent of iron, and the percentage of manganese being from a residual fraction to 5), and with a carbon content of about 0.05 to 0.30 percent. Beryllium may be present in low amounts, specifically from 0.01 to 0.09 percent having been found of benefit for watch mainsprings. The remainder consists of impurities concurrent with the metals introduced and those resulting from melting procedures. They should not comprise in excess of 0.05 percent of sulphur, 0.05 percent of phosphorus, and 0.05 percent of nitrogen (the nitrogen being effective as a partial substitute for carbon). Residual silicon from deoxidation during melting can be tolerated up to 0.50 percent, and in some alloys up to 1 percent when the iron content is high. Thus, the total of such concurrent and residual elements is below about 1.2 percent.

The presently preferred range of compositions, in which the ratios have been selected to permit optimum conditions of softness in solution-annealed condition, strength development during cold-working and subsequent aging, and properties superior to watch mainspring steel in the final article, comprise 28 to 45 percent cobalt, 24 to 35 percent of chromium and molybdenum combined (of which 5 to 7 percent is molybdenum), and 25.5 to 40.3 percent of nickel, iron and manganese combined (of which the iron is less than the nickel, and about 0.5 to 2 percent

is manganese). For the remainder, the alloy has about 0.08 percent to about 0.22 percent of carbon; 0 to 0.09 percent beryllium; less than about 0.15 to 0.25 percent silicon being preferred; less than 0.05 percent each of sulphur and phosphorus; other elements being present in non-significant traces. The total of such concurrent and residual elements is less than 0.5 percent.

The cobalt is a matrix ingredient to give strength. In general, increase of strength follows with increase of cobalt, but excessive amounts produce such hardness that cold-working characteristics are unsatisfactory, as the desired final strengths cannot be built up. The cobalt is furthermore believed to form an intermetallic compound with chromium which provides a hardening and strengthening component during aging.

The chromium contributes most importantly to the corrosion resistance, and cooperates with the molybdenum in that increase of one or the other or both, above the lowest values stated, lead to increased strength and hardness, so that the sum of the chromium and molybdenum is determinative when both are present.

The molybdenum is a very effective strengthening element both for its effect in the matrix and upon aging.

The plasticizing metals of the group consisting of nickel, iron and manganese are regarded as softeners of the composition in solution-annealed condition. That is, a binary alloy consisting of cobalt and chromium alone, but having good ratios of cobalt and chromium for development of strength upon cold working and aging, in accordance with our studies, is not cold workable to sufficient extent to build up its strength to the superior values which can be attained with our alloy; but upon addition of such plasticizers, the hardness of the solution-annealed alloy is reduced so that cold-worked strengths can be developed before the hardness has been increased by the cold-rolling to values which render further cold-working impracticable. In general, nickel by itself is effective; and it can be used without significant amounts of iron or manganese. In practice, iron can be used as a minor replacement for nickel and also with the great saving in that the chromium, molybdenum and manganese can be introduced as the corresponding ferro alloys which are cheaper per weight of chromium or molybdenum and also have lower melting points and thus facilitate the smelting. Iron is not permissible as a total replacement, however, due to scaling trouble upon heating; and its amount should be kept below that of the nickel. Manganese is a good deoxidizer during mixing, and also acts to overcome any harmful effect of sulfur: in the final alloy, the residual manganese cooperates with the nickel in giving the softness or workability desired: up to 5 percent can be present without harmful effect, but no specific advantage appears with more than about 2 percent.

The preference for carbon contents of 0.08 to 0.22 percent has been indicated by the above satisfactory compositions. The effect of carbon is illustrated by otherwise identical alloys of Type 3, of which Alloy A had 0.05 percent and Alloy B had 0.09 percent carbon as shown in the following Table V. The "cold rolled" condition is that given by solution-annealing and cold-rolling, while the "aged" condition is same—followed by aging for 5 hours at 900 degrees F.

Table V

Alloy No.	Condition	TS	PL	YS	Mod	VHN
A	cold-rolled	259	134	169	22.4	519
B	do	262	135	165	23.4	531
A	aged	326	193	243	29.5	635
B	do	341	219	258	29.4	681
	Effect of 0.04% C	15	26	15	-------	46

Thus, a most significant improvement in proportional limit is attained, being the property of a power spring which determines whether or not the spring will set in service and how much it will set.

The term "solution-annealing," as employed herein, defines the operation of heating the mass to a temperature at which apparent homogenization occurs, that is, at which precipitation components are brought into solution; and the cooling of the homogenized mass in order to fix this condition. This cooling must be rapid enough to prevent precipitation of such components, or premature aging, as such would lead to an undesirable hardness and resistance to cold working. In practice, the alloy should be given an initial solution-annealing at and from a temperature of 2000 to 2300 degrees F., and preferably from 2100 to 2150 degrees F.; and thereafter the intermediate and final solution-annealings can be conducted at and from temperatures as low as 1800 degrees F., but preferably from 2000 to 2100 degrees F. The rapid cooling of sections thicker than 0.200 inch requires water-quenching, while thinner sections can be effectively and more conveniently cooled in air.

The effect of the heating is to soften the alloy to suitable condition for cold working, to put certain secondary constituents into solution and to tend to produce a homogeneous structure having a faced-centered cubic arrangement, and to put the alloy into condition for good response to the age-hardening treatment.

The effect of the temperature during solution-annealing is illustrated by Alloy No. 3, which before cold-rolling had a Vickers Hardness of 240 and which was then reduced 50 percent by cold-rolling, and was then quench-annealed.

Table VI

Temp., °F.	Time	Hardness
Control as cold-rolled, 50 percent reduction.		468
1,200	30 minutes	550
1,300	30 minutes	485
1,400	30 minutes	455
1,500	30 minutes	412
1,600	30 minutes	343
1,800	30 minutes	302
2,100	30 minutes	240

From this, it will be noted that cold-rolling raised the hardness from 240 to 468, and this was further increased by treatment at 1200 and at 1300 degrees F., and is softened very little at 1400 degrees F. At the successively higher temperatures, softening occurs wherewith a satisfactory softening is obtained at 2100 degrees and a usable softening at 1800 degrees F. With alloys harder than Alloy No. 3, it is recommended to use a temperature higher than 2100 degrees F., but excessive temperature should be avoided, in order to minimize scaling and roughening the surface of the stock.

The hardness at the beginning of final cold-rolling should be below 300 Vickers (not Table II) and alloys as low as 200 Vickers have been found competent of attaining final strengths of satisfactory values. The hardness and strength increase quite rapidly in the first stages of cold-reduction and then less rapidly. For exampde, Alloy No. 3 at reductions of 75, 80, 85 and 90 percent showed hardness values of about 510, 570, 580 and 590 respectively. For watch mainsprings the cold-reduction should be carried as far as practicable, and the hardness should be at least 450 Vickers (note Table III). The thickness reduction for such mainsprings should be at least about 70 percent, and it is preferred to have reductions of at least 80 percent, and reductions in excess of 90 percent have been found of value.

The aging treatment has as its principal function the increasing of the proportional limit, the yield strength, the ultimate strength, and the modulus of elasticity. The response in the aging temperature depends to some extent upon the composition of the alloy; and is a function of the amount of the cold reduction, the final thickness of the article, the aging time, and the aging temperature.

The temperature for aging our alloy is 500 to 1200° F. The present commercial practice of aging is heating to 700 to 1150° F. for times, dependent upon the temperature used. A time of 5 hours at 900° F. has been found to give a desirable combination of strength and toughness properties. In general, the proportional limit, yield strength, and tensile strength increase with the aging temperature, up to temperatures of about 900 to 1000° F., but this increase in strength properties is at least to some extent accompanied by decrease in toughness. In particular, over-aging must be avoided because heating for such a period of time as 5 hours at temperatures of above 1200° F. causes a marked decrease in the strength properties with inadequate, if any, compensation in ductility. It may be theorized that a condition of solid solution supersaturated in precipitatable components, produced by solution-annealing, is modified by aging, in that the precipitation particles come out in submicroscopic size and in total amount corresponding to the difference in solubilities at solution temperature and at aging temperature, and when the supersaturation has essentially ceased by formation of the submicroscopic particles, a maximum of strength properties has been attained; while higher temperatures will cause more rapid precipitation but also more rapid agglomeration. In practice, 1200 degrees F. is the maximum useful temperature: but it is preferred to use lower temperatures, for the reason that the time factor is then not so critical.

In general, lengthy exposure at temperatures between 1200 and 1800 degrees F. should be avoided after the final solution-annealing. If the material is slowly dropping in temperature from solution-annealing conditions, premature precipitation with agglomeration occurs so that the material becomes too hard for cold-working and incapable of developing the strength values which can be induced by proper cold-rolling and aging; if the material is slowly increasing in temperature within this range, agglomeration occurs and then re-solution, but the homogenization does not proceed to the necessary reduction of hardness for proper cold-working or to the condition for effective precipitation during aging.

The article thus formed and constituted is a power spring capable of withstanding service conditions at which a spring of high-carbon steel, but of identical size and use, will fail. It demonstrates a tensile strength and proportional limit exceeding those of the steel spring, and under preferred conditions (Table IV) has a proportional limit in excess of about 200,000 p. s. i.; a yield strength in excess of about 250,000 p. s. i.; and a modulus of elasticity of above about 29,000,000 p. s. i.; as compared with high-quality carbon steel mainsprings which may have a proportional limit of 177,000 p. s. i.; a yield strength around 232,000 p. s. i. and a modulus of elasticity around 28,400,000 p. s. i. It is non-corrosive to atmospheric conditions, to perspiration, and is highly resistant even to strong acid and alkaline solutions. It is essentially non-magnetic and non-magnetizable. The effects of the procedure of preparation are apparent in the article: in that such a spring, when heated to 2100 degrees F. and quickly cooled undergoes severe loss of strength and hardness; in particular, the hardness will drop to below 300 Vickers, and the tensile strength falls below 200,000 p. s. i., and the article is no longer competent of use, for the reason that no known method will restore the desired values without a high cold-reduction as stated above, that is, without reducing its section and increasing its length so that it no longer is the same article. In this respect, the article is strikingly different from a carbon steel spring, which can be repeatedly hardened and tempered if care be taken to avoid scaling and decarbonization.

The practical limit of cold working our alloy, as by cold rolling, is fixed by that degree of cold working which causes damage to the material such as excessive edge cracking and surface cracking; by the degree of cold working beyond which further cold working gives little or no improvement in the strength properties of the material as cold worked or in the enhancement of the strength properties on aging; and also to some extent by the plant equipment available, but the cold working should give at least the minimum reduction disclosed hereinbefore in this specification.

The process referred to herein is set out and claimed in our concurrently filed application, Serial No. 745,715, and certain of the present alloys are set out and claimed in our concurrently filed application, Serial No. 745,716.

We claim:

1. A watch mainspring characterized in being non-magnetic, non-magnetizable and non-corrodible by atmospheric conditions and body fluids, said mainspring comprising a metallic ribbon having been solution-annealed, cold-rolled and age-hardened in sequence, and so conditioned having a hardness above 480 Vickers, a proportional limit of at least 190,000 p. s. i., a tensile strength of at least 316,000 p. s. i., a yield strength (0.02 per cent offset) of at least 225,000 p. s. i., and a modulus of elasticity of at least 28,400,000 p. s. i., said ribbon being of an alloy consisting essentially of 20 to 50 per cent cobalt, 20 to 37 per cent chromium and molybdenum together, and of which 15 to 30 per cent is chromium and 1 to 10 per cent is molybdenum, 20 to 50 per cent of nickel, iron, and manganese, the amount of nickel being greater than the amount of iron, the amount of iron being not more than 15 per cent, and the amount of manganese being less than 5 per cent, and from 0.05 to 0.30 per cent of carbon, the composition of the ranges being so correlated that the remainder is not exceeding 1.2 per cent of elements concurrent with the aforesaid elements in commercial purities thereof and elements residual from deoxidation of the melted alloy, the said alloy having a hardness of from 200 to 300 Vickers in solution-anealed condition and being capable in solution-annealed condition of reduction by cold-rolling by at least 70 per cent.

2. A watch mainspring characterized in being non-magnetic, non-magnetizable and non-corrodible by atmospheric conditions and body fluids, said mainspring comprising a metallic ribbon having been solution-annealed, cold-rolled and age-hardened in sequence, and so conditiond having a hardness above 575 Vickers, a proportional limit of at least 200,000 p. s. i., a yield strength (0.02 per cent offset) of at least 250,000 p. s. i., and a modulus of elasticity of at least 28,400,000 p. s. i., said ribbon being of an alloy consisting essentially of 28 to 45 per cent cobalt, 24 to 35 per cent chromium and molybdenum together, of which 5 to 7 per cent is molybdenum, 25.5 to 40.3 per cent of nickel, iron, and manganese, the amount of nickel being greater than the amount of iron, the amount of iron being not over 15 per cent, and the amount of manganese being about 0.5 to 2 per cent, and from 0.08 to 0.22 per cent of carbon, the composition of the ranges being so correlated that the remainder is not exceeding 0.50 per cent of elements concurrent with the aforesaid elements in commercial purities thereof and elements residual from deoxidation of the melted alloy, the said alloy having a hardness of from 200 to 300 Vickers in solution-annealed condition and being capable in solution-annealed condition of reduction by cold-rolling by at least 80 per cent.

3. A watch mainspring characterized in being non-magnetic, non-magnetizable and non-corrodible by atmospheric conditions and body fluids, said mainspring comprising a metallic ribbon having been solution-annealed, cold-rolled and age-hardened in sequence, and so conditioned having a hardness above 600 Vickers, a proportional limit of at least 230,000 p. s. i., a yield strength (0.02 per cent offset) of at least 270,000 p. s. i., and a modulus of elasticity of at least 28,400,000 p. s. i., said ribbon being of an alloy consisting essentially of 40 per cent cobalt, 27 per cent chromium and molybdenum together, and of which 20 per cent is chromium and 7 per cent is molybdenum, 15.5 per cent of nickel, 15 per cent of iron, 2 per cent of manganese, and from 0.08 to 0.22 per cent of carbon, with the remainder not exceeding 0.50 per cent of elements concurrent with the aforesaid elements in commercial purities thereof and elements residual from deoxidation of the melted alloy, the said alloy having a hardness below 300 Vickers in solution-annealed codition and being capable in solution-annealed condition of reduction by cold-rolling by at least 90 per cent.

4. A watch mainspring characterized in being non-magnetic, non-magnetizable and non-corrodible by atmospheric conditions and body fluids, said mainspring comprising a metallic ribbon having been solution-annealed, cold-rolled and age-hardened in sequence, and so conditioned having a hardness above 600 Vickers, a proportional limit of at least 230,000 p. s. i., a yield strength (0.02 per cent offset) of at least 270,000 p. s. i., and a modulus of elasticity of at least 28,400,000 p. s. i., said ribbon being of an alloy

consisting essentially of 40 per cent cobalt, 27 per cent chromium and molybdenum together, and of which 20 per cent is chromium and 7 per cent is molybdenum, 15.5 per cent of nickel, 15 per cent of iron, 2 per cent of manganese, and from 0.08 to 0.22 per cent of carbon, with the remainder not exceeding 0.50 per cent of elements concurrent with the aforesaid elements in commercial purities thereof and elements residual from deoxidation of the melted alloy, such remainder including in addition 0.01 to 0.09 per cent of beryllium, the said alloy having a hardness below 300 Vickers in solution-annealed condition and being capable in solution-annealed condition of reduction by cold-rolling by at least 90 per cent.

OSCAR E. HARDER.
DIMON A. ROBERTS.

REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
1,698,935	Chesterfield	Jan. 15, 1929
1,917,723	Koster	July 11, 1933
1,942,150	Rohn	June 2, 1934
1,949,313	Koster	Feb. 27, 1934
1,974,695	Straumann	Sept. 25, 1934
2,044,165	Halliwell	June 16, 1936
2,103,500	Touceda	Dec. 28, 1937
2,245,366	Rohn	June 10, 1941
2,419,825	Dinerstein	Apr. 29, 1947
2,469,718	Edlund et al.	May 10, 1949
2,475,642	Scott et al.	July 12, 1949

FOREIGN PATENTS

Number	Country	Date
510,154	Great Britain	July 24, 1939

OTHER REFERENCES

Age Hardening of Metals, 1940, p. 321; pub. by American Society for Metals, Cleveland, Ohio.

Progress Report on Heat Resisting Metals for Gas Turbine Parts (N-102), pub. by War Metallurgy Division N. D. R. C., September 21, 1943, pp. 1, 6, 9, 10, 11.