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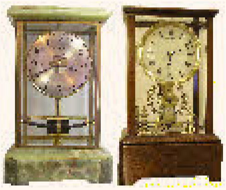

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The Bulle Isochron spring - Is it Invar ?

26th November 2004

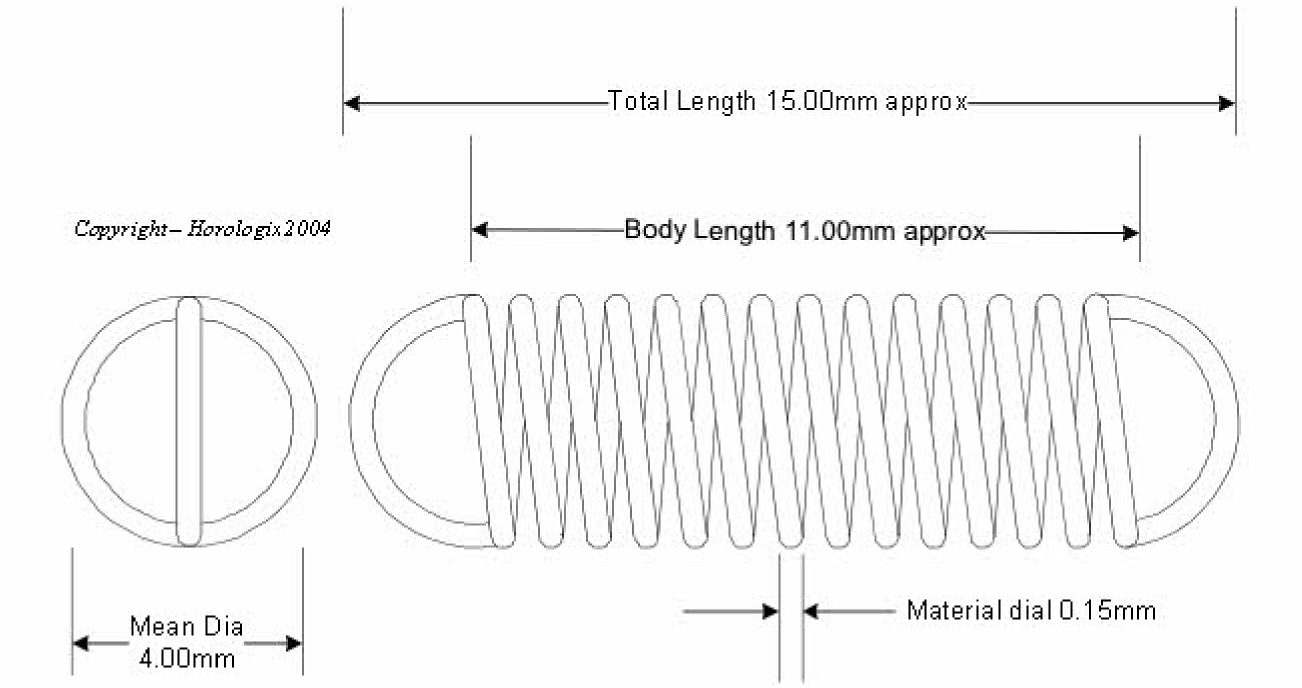
Included here are some notes on the Bulle Isochron Spring which explain (hopefully) the situation we are in with supply at this time.

The Bulle Isochron Spring

The Isochron Spring story is turning into a saga, albeit a very interesting one. Last week I spoke to the wire manufacturers who were very helpful in discussing the problems the spring maker was having in producing the Isochron spring. They in turn introduced me and the problem to a laboratory who specialised in such materials. After an interesting discussion on Invar,Alloy 36 or Nilo 36 which are all supposedly one and the same thing, I spoke to senior technologist who asked me to send him an original spring and one of the newly produced ones. This I did immediately, grateful for some technical input.

History

Before going any further, I'll just give you a bit of background to the spring and it's use. The Bulle clock was first produced in about 1923 and had a small spring called an Isochron spring that supposedly corrected the amplitude of the pendulum in response the the varying power supplied by the 1.5 volt battery fitted to the clock.
Batteries, especially at this time, are renowned for supplying power that varies considerably depending on a number of factors. Principle among them being age and temperature. Now this Isochron spring as fitted was supposed to restrict the pendulum from swing to far and increasing in



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amplitude in response to to much power being supplied. If the swing increased then the tension on the spring was increased thereby limiting the amplitude. In the late 16th century Galileo Galilei, whilst sitting in the cathedral at Pisa, noticed that the lamp hanging from the ceiling seemed to swing on it's chain in a regular and timely fashion. He later did experiments on this and proved to himself that a pendulum would swing at a constant rate for a given length. He never actually utilised this knowledge in applying it to the building of a clock. This was left to a Dutch Mathematician by the name of Huygens who turned this knowledge into a practical mechanism for a releasing the going train of a clock and producing an accurate time piece. All pendulum clocks can trace their family history back to him.

The accuracy of a pendulum clock is dependent though, on a constant source of power being applied at the right time in the swing cycle. The problem with the Bulle clock in particular is that the power produced by the battery varies as considerably. Favre Bulle, the clocks designer, thought he could overcome this problem by fitting this so called Isochron spring between the mechanism of the clock and the pendulum so that when the pendulum increased its amplitude in response to this change in power, it would arrest its progression thereby inducing a reasonably constant amplitude. Unfortunately, if the spring is made from ordinary carbon spring steel ,the length of the spring would vary dependent on the temperature. The colder it got the shorter it would get and hence the more tension it would apply. Of course the opposite would also be true; the warmer it got the longer it got and the less tension would apply. The practical upshot of which is the warmer the room the longer the spring. This meant the pendulum would swing further and the clock would run slower.

I'm sorry to be long winded about this but some people (OK - just me) find it quite interesting. I know the technically advanced among you will probably take me to task on some aspects of this story but I think readers will get the gist of the argument.

Now what Mr Bulle did was to utilise the new Nickel steels that were being produced at this time, especially one called Invar, in the manufacture of the spring. This steel had a 36% proportion of Nickel added to the Iron to produce a material that had an exceedingly low coefficient of expansion. This property in a material means that the higher the coefficient, the less it is affected by temperature. So that a steel with a high nickel content will expand much less per millimetre of length than a a steel of lower percentage content. The magic figure seems to be 36% of included Nickel., after which the amount added has a diminishing return in effect.

So Favre Bulle made his Isochron spring out of Invar and anticipated a much greater accuracy in his clock than could normally be expected from using carbon steel. He, being a shrewd business man, heavily advertised his Isochron spring as being "*...the first time a corrector of such high precision has been applied to clocks...*"

How effective the spring is in its proposed capabilities is somewhat open to conjecture. Certainly, other than his own experiments and claims, the world has yet to see convincing test results on the system. Now back to the present.

The Present

If we are to try and restore these clocks to something like an original condition especially in its prime function of timekeeping then we must, where practically possible, replace worn or missing parts with those made with the same materials and preferably in the same way. Especially, I think, in the case of the Bulle Isochron spring. Which of course is why I started off on this quest for the magic material Invar. The original manufacturer of the spring was reasonably confident of success and foresaw no initial problems. However, after producing the main body of the spring they did find themselves in difficulty producing the half loop ends. This is when the original wire manufacturer was asked for their input into the properties and the manufacture of the steel. They in turn called upon the services and expertise of a metallurgical laboratory.
The laboratory have now received the springs both old and new and mounted them for testing. A phone call made today initiated an interesting conversation along the following lines. Both springs had to be mounted in a cold cure resin because the normal resin produces too much heat and so affect the characteristics of the test samples given the small diameters in question..

Whilst waiting for the main tests to commence on Monday the samples were placed under a Scanning Electron Microscope and , whilst stressing that the time they had on the machine was minimal (it being late Friday afternoon), it was found that both materials were definitely Invar (Nilo 36) in structure. But, surprisingly the original spring had a definite trace of Chromium! This should not be present in Invar. Again it was stressed that these are just preliminary results and will have to be verified, but it does look odd. Maybe it was an accidental contamination, maybe it was deliberate. If it was then there is no known steel with this structure. Strange...

Meanwhile

At about 4:00pm today (Friday) just before the lab closed for the weekend the Hardness tests were confirmed. The original spring is approximately twice as hard as the new one?
Quote from the original email:-
"Hardness results (MHV 0.1) are as follows : -
Old Spring : 495 (range 473 - 514)
New Spring : 226 (range 206 - 241)"

So.... We now have to wait to next week for some answers. Although what this means for the manufacture of new springs I don't know. Does it mean that the originals are made from a now unknown material and therefore we'll probably never get an exact match? Or are the original springs so hard because they have work hardened in use over the last 70 years and were of the same hardness as the new ones when first manufactured? Iwish I knew the answers.

30/11/2004

Today I received the final report from the Lab. It follows in full on the next page except for Company and individual names. The photos then follow on the last page.

30th November 2004

Peter,
Please see attached note reviewing the results of our examination.

As we discussed before, the old spring is not precisely Invar, or what would be manufactured under the name NILO 36, as it has some Chromium in it. Invar is simply an alloy of 36% Ni in Fe, as if you did a graph of expansion against Ni content, it goes through a very sharp minimum at 36%. The effect of a small amount of Cr would be two-fold; it would increase the coefficient of expansion (there is another NILO alloy where this is done deliberately to give a matching expansion characteristic to glass so that the glass to metal seal in old components like thermionic valves is effective and they hold vacuum), and it would make the wire somewhat harder and stiffer.

The hardness of the wire was measured using a technique called Vickers Microhardness. The old spring is much harder than the new one (bigger MHV number).

There are two photographs attached taken through an optical microscope, showing the etched appearance of a polished section of the wire. Metals are crystalline, and in the fully annealed (soft condition) the grains (crystals) are usually fairly regularly shaped. When the metal is cold worked, such as in a wire drawing process, the grains tend to become elongated and show signs of deformation. In the new spring, there is some signs of cold work (i.e. it is not in the fully soft condition), although the grain size is quite large. In contrast, the grains in the old spring are very elongated and much smaller to start with. I would guess that the new spring wire has a limited amount of cold work in it (usually termed special temper, meaning a controlled amount of cold work) but the old spring is what we term fully hard or spring hard - it has as much cold work in it that you can get in by drawing.

The old spring is therefore much harder and "springy" than the new one. The wire supplier could no doubt comment on the temper of the wire used to produce the new springs. I am no expert in manufacturing springs, but I would say that the wire needs a higher level of cold work in it, if possible fully hard.

	"OLD" SPRING	"NEW" SPRING
Core Hardness MHV 0.1	495	226
SEM qualitative analysis	Cr, Fe, Ni	Fe, Ni
Magnetic	Yes	Yes
Photograph Reference	04BA0176	04BA0177

Regards.
<<<<>>>>
See: 04ba0177.jpg)(See attached file: 04ba0176.jpg)

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The microscope photos that were attached to the email are shown here on the right. It's interesting that the original spring had a small Chromium content. Does it mean that Favre Bulle actually had his own specification of Nickel Alloy made for the job? What was his reasoning? It seems possible but unlikely. Perhaps it was an early attempt at a high nickel content alloy that immediately passed out of use and was never fully documented. It may have had some defect and was never put into standard production. We'll probably never know. But if anybody wants to try and trace the origin of this steel I for one would be most interested.

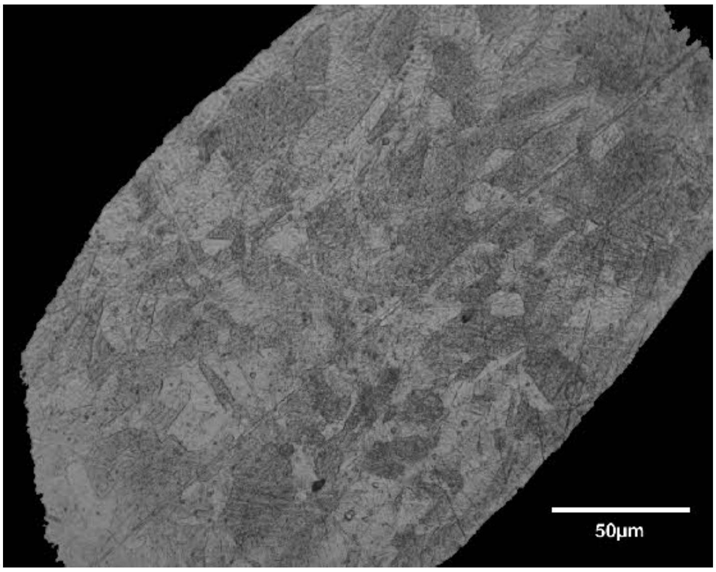

Photo *04ba0177.jpg*

Meanwhile...I have already spoken to the Wire and Spring manufacturers and they are reviewing the results over the next couple of days. The practical upshot of all this is that the new springs are made from the right alloy but it needs to be "Spring Hardened" further by the Drawing process. From what I can gather this means starting with a much larger diameter wire and drawing it through ever decreasing diameters until they arrive at the finished dimensions. This multiple drawing work hardens the material dramatically. The Chromium content is a bit academic as there seems to be no modern equivalent of the alloy with that content. Besides, the main difference in hardness is due to the Drawing process and probably not the Chromium.

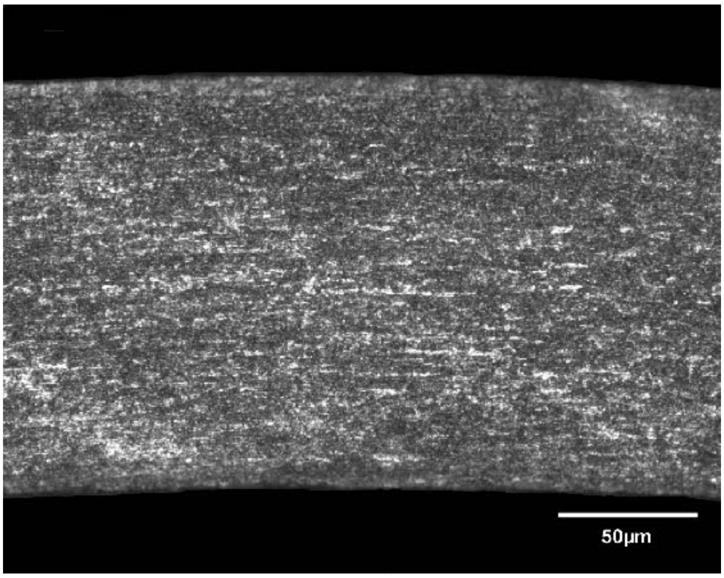

Photo *04ba0176.jpg*

<u>03/01/2005</u>
The plot thickens. Just before Christmas a tensile test was carried out on another original spring. I was on the phone to the guy at the time the test was being

conducted. Everything seemed normal for the first few seconds until the figures passed 900 N/mm² (Newtons per square mm), then we were into "Good Grief" territory or words to that affect. The intake of breath continued right up to 1500N/mm² when finally, the wire gave up. When you consider that Invar (Nilo 36) only has a Tensile strength of about 450-500N/mm² annealed or 900N/mm² spring hard it could therefore come as a bit of a surprise to see it reach 1500N/mm². So the reasoning follows that this is not Invar! Now that would be a controversial bit of news for those who have never questioned the belief that the Bulle Isochron spring was made of the stuff (that included me by the way). Especially when you read Favre Bulle's own Patent application that includes the irrefutable words "Invar" and "36% Nickel". I have never even considered the notion. I even thought that the inclusion of Chrome in the results was not intentional. Now it seems, all is open to question.

After discussing this further with all parties involved it seems the only thing to do is to spend some money on some definitive tests that will hopefully throw some light on the situation. The tests done so far have only allowed approximations of material content to be made. The new tests, which are a lot more detailed, will hopefully show material content down to half a percent. Up till now the testing has been done Free of Charge and I'm very grateful for all companies involved who have given their time and expertise so freely, generously and enthusiastically. This time though I will have to pay but I think it will be worth it to know the actual alloy composition.
The current thinking is that the material may in fact be Nispan C (C902). The main difference between Invar and this material is the increase in Nickel and the inclusion of about 5% Chromium. The email I have written to the lab is reproduced on the next page. It summaries my expectations. I hope to be able to send the order off to them within the next few days.

I must make a few points here though.

1. The two springs I have supplied for testing so far have, to the best of my knowledge, been originals.

2. They have both shown a marked difference in results to that material known as Invar (Alloy36).

3. It has been suggested that these springs may have been made in the UK for those Clockettes that were shipped as new clocks and "Put Together" here in the 1930's and 40's. They may therefore be of a different material to those manufactured by Favre Bulle in France.

4. The new testing procedure requires a minimum of 1 gramme of material for crushing. It may be that one spring alone will not be enough. If it takes two or three, how can we guarantee that they are all going to be original. It may be possible that all three have different compositions. We would therefore get a spurious combined result.

5. The original springs seem to have been Heat Treated, post formation. If true then it's another pointer to the material not being Invar as it can only be work hardened during the drawing to size process before spring formation.

For more info on nickel alloys please see
http://www.hpmetals.com/metals.php#na or
http://www.alloywire.com/nilo_alloy_36.html

22/12/2004
Sir,

Many thanks for your email and comments.
I will be sending an original spring up to you in the New Year for a fuller analysis (accompanied with the fee of course). I must admit I don't know what results I am hoping to see. But, whatever they may be, I just hope they will be conclusive one way or the other.

Correct me in I'm wrong but I am expecting the test to prove either:-

1) An Invar alloy with about Nickel 36%, Iron 64% with Chromium (if still present) being just a trace of perhaps less than 0.5%. I'm not expecting any of the other Invar effect alloys to have been used (42%, 52% etc) as they seem to be much more specialised product centred around more demanding Thermal applications.

Or

2) A Ni Span C 902 type material with about Nickel 41.5%, Chromium 5%, Titanium 2%, Aluminium <1%, traces of others with the balance being Iron.

Up until I heard the Tensile figure of about 1500 N/mm2 (when it was expected to be about 900 if it was aged spring hard Invar), I was reasonably happy that it was Invar with Chromium as an impurity. But that result certainly put the cat amongst the pigeons. From what I have read on the net, the material commonly known as Invar (36%, Free Cutting or Super Invar) or indeed any of the other Invar effect alloys, have no Chromium whatsoever. Neither has any of them anything like the strength suggested by the Tensile test. So all of it now points to something like C902.

As you are now aware the Horological world has never been in any doubt that Favre Bulle used Invar as the Isochron material. To now suggest otherwise would be akin to Heresy <G>. So before I finally commit myself to making the springs from C902, I think you can see that it must be based on solid evidence which I hope these tests will provide.

Anyway, many thanks for your expertise and assistance so far. It is greatly appreciated. Have a good Christmas and New Year.

Oh, and please correct me if you believe any of the information on the site is wrong or misleading.

Regards, Pete

After all is said and done, what does it really matter?

I think the answer is two fold.

First it matters a great deal if we look at it from an historical perspective. If it turns out to be Ni Span C, then we would have to explain the apparent contradiction to what has previosuly been accepted as fact. That Favre Bulle specifically specifies Invar 36% Nickel in his patent. Perhaps we should just take it that Bulle meant any material that had the characteristics of an “Invar effect” alloy. This could possibly include Ni Span C.

Second. If we are trying to replace the function of the spring with a component of equal charactersitics then what does it matter whether it was Invar 36 or Ni Span C. Invar 36 has a lower coefficient of Thermal expansion, but Nispan C seems to generally used as the material of choice in the Horological industries of today. It certainly would have the mechanical parameters that we seem to be seeing in the testing of the original springs so far.

I would be happy either way as long as a decent spring of comparable form and function can be manufactured. Certainly the material used in the trials so far has been dissapointing in that it seems too soft and does not hold it shape well. Perhaps this is just down to the draw hardening process and a change to this process may yield the desired qualities. We’ll have to wait for the results of the tests.

Finally I would be more that happy to hear from anyone with any information or a valid input into the investigation. Please feel free to email me.

So, I apologise for the delay but I think you’ll agree that it’s important to sort this out now.

10/01/2005

Today I have weighed three original springs to find out whether there is enough material in one of them to run the detailed tests as described earlier. Unfortunately the average weight over the three originals available to me was 0.039 grams. This means that 25 springs would be needed to satisfy the 1 gram minimum testing weight. That is a non starter. So I am again looking for someone to be able to analyse just one spring and come up with the level of accuracy required.

The words “Patience of a Saint” come to mind for some reason<G>.

Don’t worry I don’t intend to give up.

14/01/2005

I have received an email from the Labs comfirming that they can perform the tests required to confrim the alloy. The email is attached on the next page. I have already sent of the springs so I hope to have the definitive answer by Friday 21st January.

As always I’ll keep you informed.

14th January 2005

I have been asked to send you some information regards testing your springs. We would be able to use a technique called Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) to give you most of the major alloying elements of Nickel, Iron or Cobalt based alloys. This should indicate the alloy type from which the springs were made.

Elements include Silicon, Manganese, Aluminium, Chromium, Cobalt, Copper, Iron, Molybdenum, Niobium, Nickel, Titanium, Vanadium, Tungsten and Zirconium. We may also be able to report Boron, Magnesium, Phosphorus.

Because of the small sample size, the quality of data produced will be reduced. We normally take duplicate 0.5g portions to test. They are first dissolved in acids and then the solution is measured by the instrumentation. I understand that you only have a couple of springs available that will weigh less than 0.1g. This will give us one shot on reduced weight.

Elements such as Carbon/Sulphur are not possible as they would require at least another 0.5g of sample. They should not be necessary, however, to identify they alloy type.

We should have some results in 3-5 days from receipt. I can fax or email them as soon as they are available.

Best Regards

20/01/2005.

I have now received the Certificate for the last two original Isochron springs sent to the labs last week for the " *Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES)*" tests. The original certificate is shown on the next page.

The results are controversial. The two springs both showed the same mix of elements. They ARE NOT Invar. In fact the alloy is not one that is recognised in the modern world.

Element	Spring 1 %	Spring 2 %
Nickel	21.1	20.5
Chromium	1.38	2.34
Manganese	1.07	0.86
Silicon	0.48	0.46
Cobalt	0.21	0.08
Copper	0.13	0.18
Aluminium	0.08	0.03
Phosphorus	0.011	0.02
Tungsten	<0.05	0.1
Molybdenum	<0.01	<0.01
Niobium	<0.01	<0.01
Titanium	<0.01	<0.01
Vanadium	<0.01	<0.01
Zirconium	<0.01	<0.01
Iron	Balance	Balance
Total	100%	100%

The table shows the main elements .

As you can see both springs reflect approximately the same composition. Rather than waffle on about what this all means I think it best to set the main points down as specific statements so there is no confusion. I am of course open to other arguments.

1. Altogether four individual springs from four separate original clocks have been tested.

2. These tests in conjunction with the two previous tests of MHV and Tensile strength prove conclusively that the Bulle Isochron spring is not "Invar" (36% Nickel with the Balance Iron) or that of the common Nickel alloys collectively known as "Invar Effect" alloys.

3. Favre Bulle may have specified Invar in his patent, but that is not what he ended up using. It may be that he was supplied inferior product by the manufacturer who wanted to get rid of some stock; or perhaps the specification was changed by Bulle himself. We will probably never know.

4. The alloy is not recognised as a standard alloy today.

5. The springs as tested could not possibly meet the same Coefficient of Thermal Expansion as that of Invar.

5. Other than having a batch of steel specially produced to meet the specification shown in the tests, it is not possible to reproduce exactly the Bulle Isochron spring.

6. The best compromise would be a spring made from Ni Span C (C902). Once this material is formed it can

then be hardened to meet the tensile strength criteria. Invar would not be suitable becuase even if it was drawn and work hardened to its greatest degree, it would still only be 900 Newtons per square mm. That is about half of that of the tested springs.

So, unless anyone can offer a good reason why I shouldn't, then I am going ahead with a test run of Isochron springs made from Ni Span C.

14/06/2005.

I am still having difficulty in procuring supplies of C902

Nadcap PRI PERFORMANCE REVIEW INSTITUTE - Accredited -

CERTIFIED LABORATORY TEST REPORT

UKAS Testing Laboratory no. 0281

UKAS TESTING 0281

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A division of SPECIAL METALS WIGGIN LIMITED
Registered in England at the above address under number 36721

Customer
PETER SMITH

FAO: Peter Scrimshire

Certificate No.	LT 0130952/01
Dated	19 01 2005
Page No.	1 of 1
Customer Order Number	...
Date Received	17/01/2005
Laboratory Reference Number	F89844 1

Specification
None Quoted

Description of Samples
Spring
Number of Samples 2

HEAT TREATMENT ON TEST PIECES

CHEMICAL COMPOSITION Weight % (except where stated ppm)

	Si	Mn	P	Al	Co	Cr	Cu	Fe
2	0.48	1.07	0.011	0.08	0.21	1.38	0.13	Balance
3	0.46	0.86	0.020	0.03	0.08	2.34	0.18	Balance
Method of Analysis	ICP	ICP	ICP	ICP	ICP	ICP	ICP	

	Mo	Nb	Ni	Ti	V	W	Zr
2	<0.01	<0.01	21.1	<0.01	<0.01	<0.05	<0.010
3	<0.01	<0.01	20.5	<0.01	<0.01	0.10	<0.010
Method of Analysis	ICP	ICP	ICP	ICP	ICP	ICP	ICP

OTHER REMARKS/ENDORSEMENTS

Material does not match any SMW alloy type.
Small sample size - will affect quality of results obtained

DETAILS OF METHOD CODES

ICP - INDUCTIVELY COUPLED PLASMA OES

End of test results

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at a reasonable cost. If I were to go ahead with the latest quotation, the cost of each spring would be in excess of £20. So I have gone ahead with two alternatives.

The first is BU004 made from Alloy 36 (Invar) to the original Favre Bulle Patent. The springs have turned out fine except that they are quite soft and therefore not so tolerant to misuse and stretching. The reports I've had back on the samples I have sent out however are quite favourable, if they are treated respectfully and not pulled and stretched unduly. Once installed they are fine and will not stretch within the confines of the full pendulum swing. Unfortunately though, they are expensive, due to the high raw material cost.

The second BU013 is a spring made from Stainless steel and so are a lot less expensive.. These are much less likely to stretch than the Invar ones., but of course will not provide the same superb level of temperature compensation as the Invar.

05/09/2005

I have received some sample of the C902 spring and I have to admit they are excellent. Not only do they have good Thermal expansion properties but they are also robust to handle and perform well. They also look good being very similar in colour and appearance to the original. The only problem is the cost. Each one would have to sell for £22.50 to cover costs I would have to order in batches of 100 which would probably take a lifetime to sell. Anyway, if I get enough interest then I will look at ordering them. Meanwhile I recommend the BU013 Stainless steel spring as a good replacement.

14/05/2010

I have taken the plunge and ordered a new batch of springs in C902 spring steel. I think I can keep the cost down to below £10.00.

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