The Metallurgical Evolution of Staybrite® Alloys for Watch Case Applications

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Steel alloys are currently being optimized for watchcase and bracelet applications.
This essay discusses the metallurgical limitations of steel alloys and explains why Staybrite® alloys have always been a preferred choice for the design of watchcases in Switzerland.

Cold workability, corrosion resistance and polish ability are the most demanding requirements placed on any steel alloy for watchcase applications. Cold workability is of vital importance when it comes to the manufacturing of watchcases with complex shapes. Similarly, polishability has become a very important requirement for watchcases with large surface areas. While the fulfilment of the above-mentioned requirements is largely determined by the chemical composition of a steel alloy, some important manufacturing conditions have to be considered. Efficient production of steel implies that some inclusions and second phases

"Single-Button Chronograph"
Patek Philippe & Cie, Genève, made in 1937. Large staybrite gentleman's wristwatch with single-button chronograph, vertical register and pulsometer. Sold by Antiquorum Geneva, on November 2001, for SFr. 1,818,500.

"Three-Tone Dial"
Breitling, Swiss. Made circa 1925. Staybrite keyless dress watch with co-axial single button chronograph, register, tachymeter and telemeter.

remain in the material. These features adversely affect the polishability. On the other hand, the prevailing manufacturing conditions for watchcases are a limiting factor for further processing of special metals. Semi-finished watchcases fabricated by die cutting and embossing undergo a stress-relieving treatment at temperatures of around 1050°C, between each processing step. With each annealing treatment the micro-structure is prone to degrade by grain coarsening and precipitation reactions, whereas a sequence of a total of 30 fabrication and annealing steps is not unusual. Hence, thermal instability tends to exclude the use of higher alloyed corrosion resistant steels.

Staybrite® is a steel brand that carries a long tradition of fulfilling the specific needs of the Swiss watch industry. The metallurgical evolution of Staybrite® alloys reflects the demand for: firstly, good cold workability (Staybrite® D.D.Q.); secondly, improved corrosion resistance (Staybrite® 1.4435 W.C.Q.); and finally, improved polishability (Staybrite® 1.4435NCu).

The success of each of these alloys is based on two factors:

(1) on the proper design of the alloy composition and *(2)* on search or successful build-up of steel processing methods that are beneficial for good polishability.

The metallurgical evolution of Staybrite® alloys, and its relation to application properties is best represented by the so-called Schaeffler-Diagram.

This diagram is a means of predicting the characteristic, crystallographic structure of steel, according to its chemical composition.

These structures or phases are known as ferrite, martensite and austenite. Any arbitrary composition can result in steel composed of a single phase like austenite, or of several phases, like austenite and ferrite (duplex steel), for example.

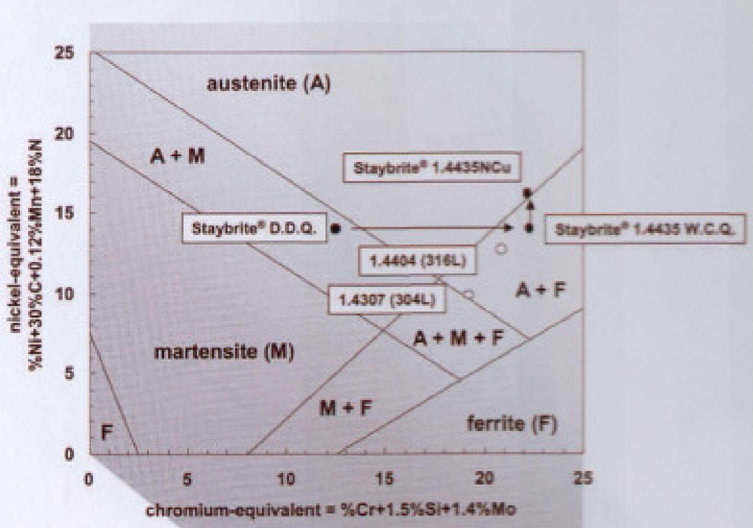
Staybrite® D.D.Q. was introduced in the early 1920s by Firth-Stahl, at that time a subsidiary of the British steel mill Firth Brown, and was proposed to Swiss watch makers for use in watchcases and bracelets. The comparative advantage of this alloy is its good cold workability provided by the alloy composition (D.D.Q. stands for Deep-Drawing-Quality).

A characteristic for Staybrite® D.D.Q. is that it has been produced with a minimum alloying effort of 12.5% nickel, 12.5% chromium and 0.05% carbon required to create a homogenous, austenitic, iron matrix. It is the relatively low alloying content that provides good cold workability and thermal stability of austenitic stainless steels. We conclude that these two properties were crucial in its long-enduring dominance of the watch industry. It has been a preferred choice for Swiss luxury watches for many decades.

The main deficiency of Staybrite® D.D.Q. is its low corrosion resistance. A chromium content of 12% provides only minimal protection against atmospheric corrosion. In order to avoid local corrosion attacks under the influence of salty water or human perspiration, a chromium content well above 18% is needed. Note also that the likelihood that a steel alloy will release nickel is directly linked to the corrosion resistance of this alloy.

Following the demand for higher corrosion resistance in the sixties and seventies an alloy of the type 1.4307 (304L) has been used for watch applications. However, compared to Staybrite® D.D.Q., this alloy was scarcely used and was later replaced. In Switzerland the 1.4435, with higher nickel and molybdenum, became the standard whereas in Asia

Attachment: „Schaeffler-Diagram"



Rolex, Ref. 1226.
Produced in the 1930's. Cushion-shaped, Staybrite gentleman's wristwatch with coaxial single button chronograph on the crown, register and pulsometer.

the classic 1.4404 (316L) is still used. The difference between 1.4307, 1.4404 and 1.4435 is essential in the context of corrosion resistance. Corrosion resistance increases with the amount of chromium and molybdenum in the alloy, and hence, increases with increasing delta-ferrite equivalent. It follows from the Schaeffler-Diagram that the corrosion resistance increases in the order 1.4307, 1.4404 and 1.4435.
Staybrite® 1.4435 W.C.Q. is a brand name that stands for special steel processing conditions, suitable for the manufacturing of watchcases (W.C.Q. stands for Watch-Case-Quality). This alloy was made available by Firth AG, which is a service center of Hempel Special Metals Group, in the late seventies. Crucial for the success of Staybrite® 1.4435 W.C.Q. was the use of steel-melting practises that resulted in the formation of soft, deformable inclusions, rather than the hard inclusions of the aluminium oxide types, which dominate the stainless steel world.

While the standard 1.4435 is well known in the chemical industry, Staybrite® 1.4435Ncu represents a new alloy composition, which has been developed and registered by Firth AG to meet the advanced requirements of the Swiss watch industry. In Staybrite® 1.4435NCu about 0.12% nitrogen and 0.75% copper is added grade 1.4435 in order achieve a homogenous, ferrite-free matrix with improved polishability, while still maintaining a good balance of workability and corrosion resistance. As can be seen from the Schaeffler-Diagram, Staybrite® 1.4435NCu differs from conventional standards 1.4307, 1.4404 and 1.4435 by the total absence of delta-ferrite, which is known to degrade the polishability of austenitic stainless steel.

The main success factor of Staybrite® 1.4435NCu, however, was the build-up of production capacities, which not only enable the production of soft inclusions, but also enable the production of austenitic stainless steels, which are free of delta-ferrite.
Austenitic stainless steels, produced in large volume, are commonly processed through the continuous casting route and the formation of some delta-ferrite is needed to avoid hot cracking during solidification. If an austenitic stainless steel free of any delta-ferrite is to be processed, a special horizontal or vertical continuous casting process must be applied. This has a strong impact on cost and availability, and explains why sub-optimal solutions have been and are still being used for watchcases. The price paid for this is degraded polishability.

Various production routes have been created by Firth AG over the past three years. In order to be in a position of continuously supporting the watch case and bracelet manufacturers with high quality stainless steel in 22 different gauges of plates and sheets, 5 different diameters of bars and a full range of different profiles coming from several suppliers in two continents, we need the support of the industry.

Chemical composition of alloys used for watchcase applications

alloy designation, trademark	alloying contents, typical averages in wt.-%							
	C	N	Si	Cr	Ni	Mo	Mn	Cu
X5CrNi13-13, Staybrite D.D.Q.	0.05			12.5	12.5			
X2CrNi18-9, 1.4307, 304L	0.02		0.5	18.5	9		1.8	
X2CrNi17-12-2, 1.4404, 316L	0.02		0.5	17	11.5	2.3	1.8	
X2CrNi18-13-3, Staybrite 1.4435 W.C.Q	0.02		0.7	18	13	2.5	1	
X2CrNi18-13-3, Staybrite 1.4435NCu	0.02	0.12	0.7	18	13	2.5	1.3	0.5

Omega, Ref. 2777-1 SC.
Made in the 1940s.
Center-seconds, Staybrite aviator's wristwatch.

"Aviator's Degree Watch"
Vacheron & Constantin, Genève.
Made in two examples in 1936.
Oversized, Staybrite aviator's wrist chronometer.

"Amelia e Earhart"
Le Coultre, "Reverso".
Made in the 1930s to celebrate the world record set by Amelia Earhart on May 8th, 1935, for the first nonstop solo flight from Mexico City to New York.
Reversible, center-seconds, "Staybrite" gentleman's wristwatch.

Whatch brands that have used staybrite

Audemars Piguet
Breguet
Breitling
Cartier
Chopard
Cyma
Ebel
Eberhard
Eterna
Fortis
Franck Muller
Glycine
Howard Non-Magnetic
IWC
Jaeger-Lecoultre
Lemania
Longines
Movado
Omega
Patek Philippe
Rolex
Tag Heuer
Tiffany
Titus
Ulysse Nardin
Universal
Vacheron Constantin
Zenith

"Two-Tone Dial"
Patek, Philippe & Cie, Genève, retailed by W. Horovitz, Alexandria.
Made in the 1930s.
Keyless, Staybrite dress watch.

Patek Philippe & Cie, Genève.
Made in the 1920s.
Center-seconds, Staybrite gentleman's wristwatch.