

# 16-8-2 History, Production and Use

**16-8-2 stainless steel welding filler material seems to have been all but forgotten in industry today. This filler material exhibits extraordinary mechanical properties at elevated temperatures while also maintaining good low temperature toughness down to -196°C (-320°F). This alloy has been used since the 1950's and has many applications in today's modern welding environment.**

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## Introduction

Stainless Steel (SS) is one of the most versatile materials developed for industrial use. It has a long list of applications throughout the world. Stainless steel alloys are seen everywhere petrochemical, power, food and dairy, pharmaceutical, biopharmaceutical, semi-conductor, and other ultra-high purity applications, and for many everyday uses. The SS family is divided into three basic types: austenitic, ferritic, and martensitic. Austenitic stainless steels are used in over 90% of all welding applications for the simple reason that they are more weldable than the other two [1]. On the other hand, they can present their own field of problems such as heat affected zone (HAZ) cracking, crater cracking, solidification cracking or adverse ferrite content. When SS is being used for high temperature services as typically found in the petrochemical and power industries, specific problems potentially exist, including formation of intermetallic phases (sigma and chi), decreased ductility, corrosion resistance, or fatigue resistance.

There is a proven and nearly forgotten weld filler material which may provide an answer to the high and low temperature and pressure service condition problems associated with austenitic SS. This weld filler



metal is identified by its major alloying elements 16-8-2 [nominally, 16% chromium (Cr)-8% nickel (Ni)-2% molybdenum (Mo)]. It was originally developed by Babcock and Wilcox in the mid 1950's under contract to the U.S. Navy, Bureau of Ships, to evaluate 18-8Mo welding alloys for welding steam lines and pressure vessels in Navy components [2]. In a parallel and perhaps earlier effort, Murex (United Kingdom) offered an alloy (ARAMAX GT) for similar purposes in the late 1940's.

Very little is known about the early years of the 16-8-2, other than it was the result of efforts to find an alloy that would not exhibit cracking associated with the type 347H alloy that experienced problems in service up to 565°C (1050°F). There are several possible reasons for this; most of the original developers are no longer living, archive records are

not always available, and the alloy has seen limited use in the commercial arena. Further, many of the early Babcock & Wilcox records were lost in a fire in their original offices or were lost during the move to their current location in Barberton, Ohio. Documentation for the early European experience is equally sparse. The ARAMAX GT product was subsequently replaced by Metrode Products with a 17-8-2 formulation, and then a lean 16-8-2 product with restricted Mo was reintroduced in the last decade. The first known commercial use of 16-8-2 was by Babcock & Wilcox for Philo 6, the first 31 MPa (4,500 psi) ultra supercritical boiler. By 1955, Babcock and Wilcox had manufactured and used nearly 14 metric tons (30,000 lbs) of the 16-8-2 composition to fabricate austenitic boiler and piping components for high temperature service. On a parallel



Figure 1 16-8-2 Outside view of weld root on TP 316 Cb

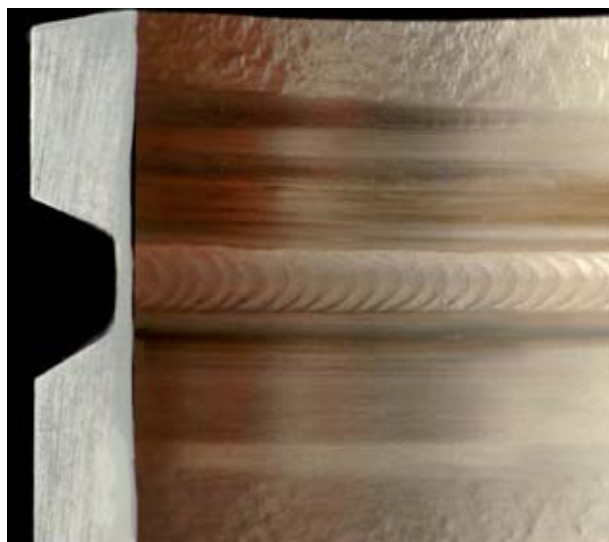


Figure 2 16-8-2 Inside view of weld root on TP 316 Cb

path, Combustion Engineering (now Alstom Power) in 1957 repaired Sultz high pressure valves at the ultra supercritical Eddystone Power Plant located in Eddystone, PA, which is still in operation today. In the mid 1960's, Combustion Engineering's version of 16-8-2 was again used at Eddystone, for repairs and reinstallation of high pressure piping [4].

### 16-8-2 Weld Filler Metal

The 16-8-2 alloy is essentially a dilute hybrid between E308H and E316H. However, rather than just matching any particular base material it can be used to weld almost any 3XX or 3XXH series of stainless steel [4]. Until its development, welding of stainless steels used in high temperature/high pressure service conditions were often plagued with a loss of high temperature ductility, fatigue resistance, or corrosion resistance. Due to elevated ferrite content associated with existing austenitic weld filler metals, problems were often encountered from the formation of intermetallic phases and resulting embrittlement. 16-8-2 typically exhibits satisfactory properties up to a service temperature approaching 800°C (1472°F) [4]. Limiting the Mo content to about 1.2 wt. % has been demonstrated to enhance ductility and reduce thermal fatigue issues. The 16-8-2 "lean version" is used in most current applications. Almost all the oil companies specify the "lean version" of the electrode to weld 316H, 321H,

347H, and 304H alloys in piping systems for high temperature/high pressure service conditions. The "lean version" is also used in the fabrication of catalytic cracking units in the petroleum refining process, which are almost always fabricated entirely out of 304H stainless steel. Current formulations of the 16-8-2 filler metal family place rigorous controls on specific residual elements. Boron (B), Niobium (Nb), Phosphorus (P), Titanium (Ti) and Vanadium (V) have been found to enhance elevated temperature creep strength while maintaining rupture ductility. The "lean version" of the 16-8-2 coupled with residual element control offers a combination of alloying elements to avoid high temperature/high pressure service condition problems.

### Mechanical Properties

16-8-2 does not exhibit extraordinary mechanical properties until elevated temperatures are reached, then it surpasses almost all other austenitic stainless steel filler metals, at least where creep ductility is concerned. Low total Cr + Mo with controlled carbon and ferrite content (2 - 5 FN) ensure high resistance to thermal embrittlement from formation of intermetallic phases (sigma and chi)" [4]. By limiting the amount of Mo, additional creep ductility and thermal fatigue is provided. The as-deposited weld metal has an excellent hot ductility property which allows the weld joint to move, thus preventing in

service joint cracking. In addition, 16-8-2 can offer service at the other temperature extremes providing good low temperature toughness, down to -196°C (-320°F). Resistance to solidification cracking is another area where the 16-8-2 alloy performs well. An example in 2001 occurred when building a new oil refinery in Alberta, Canada. The client had requested an economical stainless steel which would withstand 100,000 hrs of service life in a naphthenic acid environment. This led to a new stainless steel being developed which would be called TP 316 Cb for use on heater tubes inside the firebox [5]. The first attempt at welding this material was performed with 316 filler metal which resulted in cracking problems. After careful consideration, 16-8-2 was selected as the filler metal of choice for the root (which can be seen in Figures 1 and 2) and hot pass with the balance welded with filler material developed from the base material (TP 316 Cb); the results were crack free welds. The satisfactory results were attributed to the 16-8-2's ability to yield before the base material and heat affected zone during solidification, yet exhibit adequate strength.

### Chemical and Microstructural Properties

The specified combination of chromium (Cr), nickel (Ni), and molybdenum (Mo) is what makes the 16-8-2 unique. The lean chemical composition and low ferrite typi-

cally found in 16-8-2 type weld metals provide excellent microstructural stability and ductility retention for service at elevated temperature [6]. The nominal composition is 15.5 Cr, 8.5 Ni, and 1.5 Mo, percent by weight. Typically the final weld deposit has a ferrite number ranging from 2 to 5 FN.

Deposited ferrite content for this filler material helps to increase resistance or even eliminate microfissuring and solidification cracking during the fabrication stage. There is a widely held view that a SS weld metal must have above a 3 FN for optimum resistance to hot cracking in austenitic welds; however, past experience has shown that 16-8-2 weldments, even with 1-2 FN, are always sound [7]. Exceptional resistance to microfissuring has been demonstrated in E16-8-2 welds at 0.7 - 1.2 FN in comparison with many 300 series weld metals. Experimentation and field testing of selected solid wire has been found to have no more than 0.5 - 1.5 FN [7]. Historically 16-8-2 is one of the most reliable alloys manufactured when trying to predict the final percentage of ferrite. The weld metal is very tolerant to welding process, welder technique and cooling rate issues that typically affect the deposited FN of other austenitic weld metals.

## Conclusion

16-8-2 weld filler metal has the attributes necessary to solve nearly any austenitic 3XXH stainless steel high temperature high pressure welding problem. The combination of the filler metals' high creep rupture strength, high creep ductility, and corrosion resistance make it very appealing. It not only has applications at high temperature, but also at low temperatures down to -196°C (-320°F). This suggests an operating temperature range for this filler metal from -196°C (-320°F) to 800°C (1472°F). 16-8-2 has proven that it can be used even with new base metals such as TP 316 Cb [5]. The growing need for energy will continue to force the power and petrochemical industry to seek new and clever welding and material solutions. The 16-8-2 alloy was devel-

oped over 50 years ago and continues today to offer a creative way to weld stainless steels used in high pressure and high temperature applications.

## Acknowledgement

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## About the author

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Born and raised in Monroe, Michigan USA John began welding in high school and enjoyed it so much that he attended college and graduated in May of 2007 with a Bachelors degree in Welding Engineering Technology from Ferris State University in Big Rapids, MI. He has since took a position as a Welding Engineer with The Fluor Corporation in the summer of 2007. His career goal is to one day become a project manager in the construction industry.



## About the author

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Mr. Newell's background has involved welding engineering applications and consulting in the electric power and heavy industrial arenas for over 30 years, both domestically and internationally. He is a licensed Professional Engineer in multiple states and is a member on various ISO, ASME, AWS code committees. He is the President of W. F. Newell & Associates, Inc., a consulting firm that specializes in welding engineering and Co-Founder/Vice President - Engineering of Euroweld, Ltd., a supplier of specialty welding consumables and technology.



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