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Welding of dissimilar metals in different welding positions

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ABSTRACT

The three boiling water reactors (BWR) in Oskarshamn produce about 10 % of the electrical power in Sweden. The combination of intense radiation fluxes and high temperatures in nuclear reactors creates an extraordinary environment. Therefore, a number of material challenges arise at a nuclear power plant that needs to be solved in order to maintain the nuclear power production, safety and reliability.

Dissimilar metal welds can be found at a lot of places in nuclear power plants and due to reparations or replacement some dissimilar metal welds need to be welded on site. The technical regulations for the Swedish nuclear power plants specifies that welding of dissimilar joints shall be made with gap of at least 1.5 mm and in horizontal position. Welding a dissimilar joint on site makes it difficult to follow the technical regulations, therefore, the aim with this study is to determine if different welding positions of dissimilar metal welds affect the structure and composition of the weld metal in a negative way and to investigate the importance of a gap in the root.

In this study six samples were welded in three different welding positions, horizontal, vertical and reversed vertical with or without a gap of 1.5 mm in the root. The samples were evaluated by non-destructive testing, optical microscopy, chemical analysis, tensile testing, bend testing and hardness measurements.

The results shows that two of the samples welded without gap failed the transverse root bend test, the same samples did also have high hardness values in the root bead.

The conclusions are that the welding position, horizontal, vertical or reversed vertical does not affect the weld negative in a noticeable way. However, the gap and a good dilution with the filler metal are important.

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1. INTRODUCTION

The three boiling water reactors (BWR) in Oskarshamn produce about 10 % of the electrical power in Sweden. The combination of intense radiation fluxes and high temperatures in nuclear reactors creates an extraordinary environment. Therefore, a number of material challenges arise at a nuclear power plant that needs to be solved in order to maintain the nuclear power production, safety and reliability. [1] In the complex environment, the choices of right materials are extremely important and lots of material mixes are made. Often, in primary systems a low alloyed or carbon steel is welded together with a stainless steel in a so-called dissimilar metal weld. Due to the combination of materials a complex structure of several different metallurgical zones can be created. These zones can have significant differences in mechanical properties and therefore affect the lifetime of the dissimilar metal weld.

The transitions from low alloyed or carbon steel to stainless steel in nuclear power plants are mainly made to decrease the risk of and sensitivity to erosion corrosion. Another example when dissimilar metal welds are used in nuclear power plants is in the transitions to small bore piping with a nominal diameter smaller than 50 mm. The small bore piping systems are usually made of stainless steels due to economic reasons. The difference in material costs per unit length is insignificant at such small dimensions. [2] It is also possible to have a low alloyed pipe connecting to a valve of stainless steel or vice versa with a dissimilar metal weld. In a nuclear power plant there is approximately 20 000 valves. [3] Every year around 50 dissimilar metal welds are welded at the yearly outage of a unit in Oskarshamn. [4] In total that is a big number of dissimilar metal welds.

1.1 Challenges with welding dissimilar metal welds

The knowledge of how dissimilar metal welds behave is therefore very important, both for the welds already existing, during reparations etc., but also for construction of new nuclear power plants. In the requirements documents of the nuclear power plants in Sweden, *Technical regulations for mechanical equipment,* there is stated that (§4.1.3.2): *”For dissimilar joints, there shall be a gap of at least 1.5 mm between the weld ends before start of the welding and the welding should be made in a horizontal position and if possible in bench.”* [5] These requirements are stated to ensure that the dissimilar joint will not fail in an un-controlled manner. The requirement of 1.5 mm gap is to ensure that enough amount of welding consumable always is added in the root bead. If not enough amount of welding consumable is added, there is a risk that the weld will not exhibit the required mechanical properties. The requirement of welding in a horizontal position is important to control the composition in the weld metal and to control the mixture of the filler metal and parent metals. By practical and/or production reasons it is sometimes difficult to fulfill the requirements in the requirement documents *Technical regulations for mechanical equipment* [5].

1.2 Aim with this study

The primary goal with this study is to determine if different welding positions of dissimilar metal welds affects the microstructure and composition of the weld metal. A second goal is to investigate the importance of the proposed gap size.

2. WELDING THEORY AND DISSIMILAR METAL WELDS

2.1 Dissimilar metal welds

In modern steel constructions it is extremely important, and sometimes unavoidable, to perform a durable dissimilar metal weld between low alloyed or carbon steel and stainless steel. A schematic picture of a dissimilar metal weld is presented figure 1. When welding such dissimilar metal welds the choice of filler metal plays a big role and usually has a composition differing from both of the parent metals. The composition of the weld metal will therefore be a mix of the parent metals and the filler metal at some specific ratio. [6]

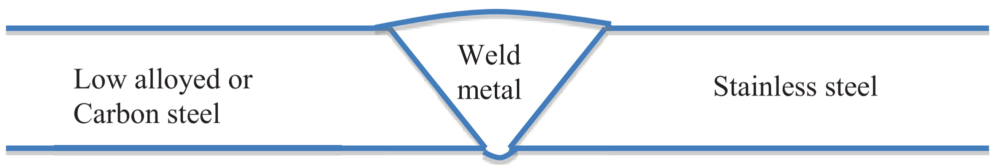


Figure 1, Schematic picture of a dissimilar metal weld

During welding of dissimilar metal welds it is important to control the composition of the weld metal. From assumptions that the weld metal consists of a mix of the parent metals and the filler metal the composition can be estimated. Narrow control of the resulting weld metal composition is important to decrease the risk of defects in the weld, such as hot cracks or sigma phase formation. The composition is also important to control so that the weld metal properties corresponds the required ones. The filler metal normally used in dissimilar metal welds is over-alloyed austenitic stainless steel with a relatively large amount of ferrite. If the welds are exposed to high temperatures or an intense thermal cycle, nickel based alloys are usually used as filler metal. [6]

In a dissimilar metal weld between carbon steel and stainless steel it is important to reduce the dilution with the carbon steel, in order to obtain a good microstructure. It is therefore common to not point the arc directly on the carbon steel side, but rather to angle the torch slightly toward the stainless steel. Another important factor to optimize during welding of a dissimilar metal weld is the interpass temperature, i.e. the actual temperature in the already present weld bead before welding starts during multipass welding. A common interpass temperature used when welding dissimilar metal welds is 150 °C. According to the *Technical regulations for mechanical equipment* [5], a requirement document for the nuclear power plants in Sweden, it states that *"for welding in primary water systems with an operating temperature over 100 °C the interpass temperature must not exceed 100 °C"*.

Welding dissimilar metal welds faces many characteristic problems caused by structural changes and several constitutional changes can occur during welding. Changes in the dilution ratio of the parent metals are possible and affected by the welding conditions. During welding a stable manufacturing and good crack resistance is important. If the dilution between the filler metal and parent metals increases, the ferrite content will decrease in the case of welding low alloyed or carbon steel to stainless steel with a filler metal of over-alloyed austenitic stainless steel. If the amount of stainless steel diluted to the weld metal increases the structure can be fully austenitic and the risk of hot cracking increases significantly. On the other hand, if the dilution with the low alloyed or carbon steel increases a structure with more martensite is created which is a hard and brittle structure. If the ferrite content becomes too high, thermal ageing during operation at elevated temperatures may lead to a transformation of the ferrite to sigma phase or as spinodal decomposition. The sigma phase is very brittle, due to this joints used in systems that operates at high temperatures should have as low ferrite content as possible. [6]

2.1.1 General welding of dissimilar metals

The weld metal composition is usually not uniform throughout the weld, especially in multipass welds. A composition gradient is likely to arise in the weld metal between the two parent metals. The solidification procedure of the weld metal is influenced by the dilution and the composition gradients, this is important with respect to hot cracking. When designing a dissimilar metal weld final weld metal and the mechanical properties must be considered. [7]

The factors that usually are responsible for failure of dissimilar metal welds are: [8]

- Alloying problems and formation of brittle phase and limited mutual solubility of the two metals
- Widely differing melting points
- Differences in thermal expansion coefficients
- Differences in thermal conductivity

Selecting an appropriate filler metal is important when producing a dissimilar metal weld that is expected to perform well in service. It is important that the filler metal is compatible with both of the parent metals and capable of being added with a minimum amount of dilution. The Schaeffler diagram is normally used to predict the microstructure of the weld metal and to predict and select a proper filler metal when welding a dissimilar metal weld of low alloyed or carbon steel to stainless steel. [7]

When designing a butt weld to a dissimilar metal weld, attention must be given to the melting characteristics of the both parent metals and the filler metal, as much as to the dilution effect. Large joints will permit better control of the molten weld metal, decrease the dilution and provide room for control of the arc for good fusion. It is important that the joint design provides appropriate dilution for the first few passes. Inadequate dilution could give a layer of weld metal with inappropriate mechanical properties, especially if the dissimilar metal weld will be exposed for cyclic stresses. [7]

It is not unusual for dissimilar metal welds to have a failure in shorter time than the expected lifetime. Most of the failures of a dissimilar metal weld between austenitic steel and low alloyed steel occur in the HAZ on the low alloyed steel side, close to the weld interface. Theses failures usually fulfill one or more of the following criteria: [7]

- High stresses resulting in creep at the interface between the weld metal and parent metals due to differences in thermal expansion.
- A weakening in the HAZ on the low alloyed or carbon steel side due to carbon migration from the low alloyed steel side to the austenitic steel side.
- Oxidation at the interface that is accelerated by the presence of the stresses induced by the welding.

A chemical composition gradient is likely to arise in the weld metal and especially close to the parent metals. If the dissimilar metal weld is operating at an elevated temperature interdiffusion between the parent metals and weld metal is possible which could result in a modified microstructure. This is can happen when an austenitic stainless steel is used as a filler metal. Chromium that has a greater affinity to carbon than iron, therefore it is likely for the carbon to diffuse from the parent metal to the weld metal during temperatures above 425 °C. Carbon migration usually takes place during post-weld heat treatment or when operating at elevated temperatures. [7]

The parent metals and the weld metal has different corrosion behaviors that must be considered when producing a dissimilar metal weld. For example a galvanic cell could be created and trigger corrosion of the most anodic metal or the most anodic phase in the weld. Corrosion at a microstructural level is possible in the weld metal that usually consists of several different microstructural phases. To avoid galvanic corrosion the composition of the weld metal could be changed to provide a cathodic protection to the parent metal that is the most vulnerable to corrosion attack. A cathodic protection is a good option as long as it does not threaten the mechanical properties of the dissimilar metal weld. [7]

2.2 The Heat-affected zone

The heat-affected zone (HAZ) is the unavoidably heat treated area in the parent metal near the fusion zone during welding where structural transformations occur. [9] The properties of the HAZ are very important after performing a weld, because it is often there the failure occurs. Depending on the distance from the weld, the different parts of the HAZ will be affected differently during the welding thermal cycle. The HAZ can be divided into four different zones that are subjected to different heat treatments, see figure 2. The width of the different zones in the HAZ depends on the preheating level or interpass temperature and the specific heat input of a particular welding procedure it also depend on forced cooling or the a lack of forced cooling, the size of workpiece, thickness and so on. [10] A general width of the HAZ ranges from one up to a few millimeters. [9]

The four zones are: [10]

- Coarse grain zone, 1200 °C to $T_{Solidus}$
  Complete transformation to austenite and grain growth. Lowest toughness in the HAZ.
- The normalized zone, A_3 (transformation from austenite to austenite and ferrite) to 1200 °C
  Complete transformation to austenite, during cooling a fine grained structure is formed.

- The partially transformed zone, A_1 (transformation from austenite and ferrite to ferrite and cementite in low carbon steels) to A_3
  Partially transformation to austenite, somewhat larger grain size than the normalized zone.
- The annealed zone, up to 600 °C
  Insignificant changes of the parent metal

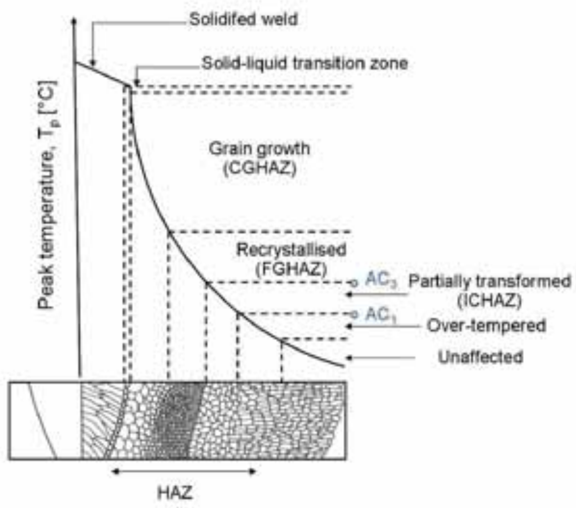


Figure 2, Schematic picture of the heat-affected zone [11]

The mechanical properties and microstructures of the HAZ have its origin in the thermal heat treatment during welding and primarily depend on: [10]

- The position in the joint
- The heat input
- The thickness of the joint
- The joint-type
- The preheating temperature (if it is used)

2.3 Schaeffler constitutional diagram

Estimation of properties and microstructures for austenitic stainless steel has been the topic of many studies, and eventually lead to the Schaeffler constitutional diagram, see figure 3. The Schaeffler diagram [12] was first published in 1949 and has since that been used to predict the ferrite content in austenitic stainless steels. The diagram is composed of phase fields and isoferrite lines. The elements that are used to calculate the nickel equivalent promotes the formation of an austenitic structure and the elements that are used to calculate the chromium equivalent promotes the formation of a ferritic structure. The nickel and chromium equivalents give together an estimation of the ration between the different phases in the microstructure. Today the diagram is most used to predict ferrite content in dissimilar metal welds. [13] A proper amount of ferrite in the weld metal is essential. The ferritic structure inhibits hot-cracks in the weld metal since it is able to incorporate elements such as sulfur and phosphor which otherwise can segregate in the weld metal and increases the risk of cracks when the residual stresses increases. The negative effect of ferrite is that it could be attacked by selective corrosion in corrosive media. The grain boundary ferrite is continuous from around 10 % and upwards, it is in those cases selective corrosion can lead to fracture. 2-10 % ferritic structure in a stainless steel weld metal is desirable. [14]

Another common constitutional diagram is the DeLong diagram that was published in 1974. The DeLong have two major improvements, the ferrite content is calculated as magnetically based ferrite number (FN) and the nickel equivalent include nitrogen content. However, the DeLong diagram is valid for a more narrow range of compositions than the Schaeffler diagram. This makes the Schaeffler diagram more suitable for dissimilar metal welds. [13]

Since the development of the Schaeffler diagram and DeLong diagram some research has been made to develop the diagrams, since they are very useful. First was the WRC-1988, which more or less can replace the DeLong diagram. An improvement of WRC-1988, WRC-1992, has been developed to give more accuracy to stainless steels that have a significant copper content and the diagram have extended axes for improved prediction of FN-numbers for dissimilar metal welds. [13] However, it should be noted that the different diagrams just give a prediction and for dissimilar metal welds between low alloyed or carbon steel and stainless steels the Schaeffler diagram can be used successfully. More exact measurements of the ferrite content in the weld metal can be made by using instruments that take advantage of the ferromagnetic properties of the ferrite phase such as a ferrite scope. [7]

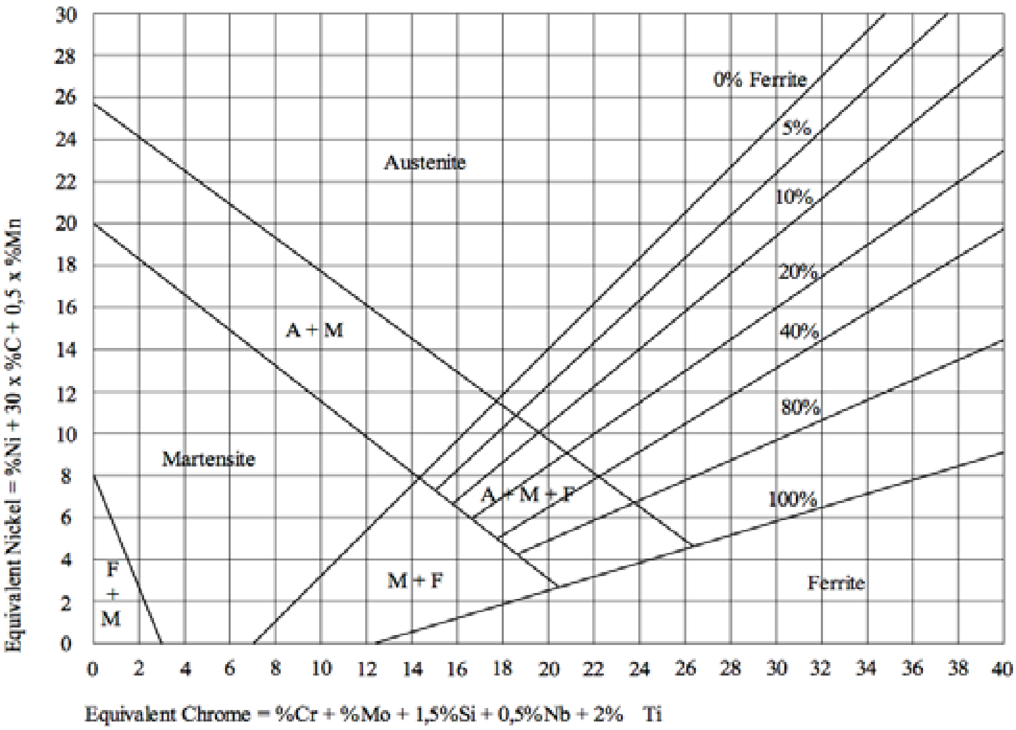


Figure 3, Schaeffler constitutional diagram for stainless steel weld metal [15]

2.4 Tungsten inert-gas arc welding

Tungsten inert-gas arc welding (TIG) is a fusion welding method that was developed in the late 1930's, see figure 4. [7] The TIG-method is characterized by its high quality weld metal deposits, great precision, superior surfaces and excellent strength. TIG is the most common welding method used for pipes and tubes with a wall thickness from 0.3 mm and upward. [8] In the TIG-method a non-consumable electrode of tungsten or tungsten alloy is used, in comparison to other common welding methods where the filler metal also is the electrode. [7]

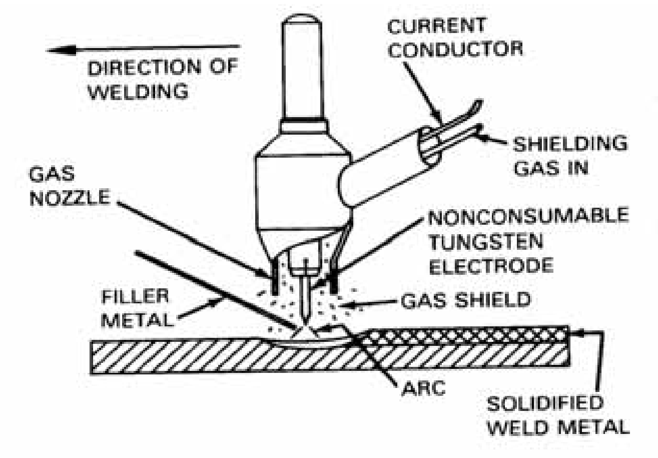


Figure 4, Schematic picture of tungsten inert gas arc welding [16]

To prevent oxygen in the air from oxidizing the weld pool and the heated material, a shielding gas is used during TIG-welding. The shielding gas is also important to promote a stable metal transfer through the arc, the shielding gas commonly used for TIG-welding is argon. The root side of the weld also needs protection from oxidizing in form of a backing gas during the production of the first weld beads. The backing gas helps the weld bead to form correctly and keep the weld bead from becoming porous or crack. The backing gas that gives the lowest levels of oxidation is a mixture of nitrogen and hydrogen, usually 90 % N_2 and 10 % H_2 [8].

The TIG-welding method has some great advantages, they are: [7]

- Produces a high quality and a low-distortion weld
- Free of splatter that is associated with other methods
- Can be used with or without filler metal
- Can be used in a wide range of power supplies
- Can weld almost all metals, including dissimilar metal welds
- Gives precise control of welding heat

Even if the TIG-method is a very high quality welding method there are some limitations that could be summarized as: [7]

- Creates lower deposition rates than consumable electrode arc welding processes

- Demands somewhat more skill and welder coordination than gas metal arc welding or shield metal arc welding when welding manually
- Less economical than consumable electrode arc welding for sections thicker than 9.5 mm
- Challenging in draughty environments due to difficulty in shielding the weld zone properly
- Tungsten inclusions can be created if the electrode make contact with the weld pool

3. STRESS CORROSION CRACKING OF STAINLESS STEEL – A LITERATURE STUDY

A lot of research is going on in the world of nuclear energy business and of course a lot of other research that could be applicable in the nuclear energy field. The current nuclear reactors are getting older and are in need of methods for repairs, replacements and upgrades, at the same time as new nuclear reactors are built. Welding of dissimilar metal welds is important in all of the cases. Welding of dissimilar metals in a nuclear environment is often made with a nickel based filler metal if the joint is subjected to an elevated temperature. If the joint is working at a lower temperature the weld is more often made with a filler metal of austenitic stainless steel with high ferrite content.

The three sites with nuclear power plants in Sweden collaborate in the field of materials research with respect to nuclear safety issues, to ensure safe and stable operation in a forum called Swedish Utilities Materials Group (MG). One of the priority areas is intergranular stress corrosion cracking (IGSCC) propagation to have as a background to failure analysis. The units Oskarshamn 2 and Oskarshamn 3 have test loops are installed in re-circulation system 321, the cooling system for a shutdown reactor. The test loops consists of five vessels in each unit and are used to test different kinds of materials and their resistance to crack initiation or crack growth due to IGSCC at authentic BWR environment. The test loops are the only ones of its kind in the world, so the test results are coveted worldwide. The tests that are carried out are often long-term tests with an operating time of up to 100 000 hours. Different types of test specimens are used, but the two most common are bolt-loaded compact-tension specimens and 3-point-bend specimens.

One project within MG considers stress corrosion cracking tests of stainless steel weld metal 308LSi with low ferrite contents. The purpose of the study is to investigate how the sensitivity for IGSCC is affected if the ferrite content is lower than 5 %. The study is still ongoing but the first results shows that the average crack propagation rate increases with decreasing ferrite content. The results also shows that the percent engagement of the crack, i.e. an indirect measure of the specimens "willingness" to initiate cracking, is larger for the specimens with lower ferrite content than those with higher ferrite content, the cracks had spread over the whole crack front. The results indicate that there is a connection with the ferrite content and the susceptibility for intergranular stress corrosion cracking. The susceptibility for cracks due to different ferrite contents is important also for dissimilar metal welds. Usually a ferrite content over 2 % is desirable but the results from this study clearly show that a ferrite content over 5 % is better. [17]

There is a complex environment in a nuclear power plant that occurs due the combination of the water chemistry, temperature and radiation. Welds are often vulnerable and are usually the weak link in a construction. In an article by Zinkle and Was the materials challenges in nuclear energy is compiled. The three major materials challenges for continued safety and reliability at the nuclear power plants all over the world are summarized in three points: [18]

- Improved understanding of the corrosion mechanisms and stress corrosion cracking of austenitic stainless steel and nickel base alloys

- Improved understanding of radiation hardening and degradation in ductility and fracture toughness of complex structural alloys
- Improved fuel systems with more reliability and accident tolerant issues

As mentioned above, these problems arise due to the extraordinary environments for materials in the nuclear reactors. The materials have to manage an environment that is a combination of high temperatures, high stresses, intense radiation fluxes and a coolant. It could be noted that historically in the nuclear power plants, the main materials degradation problems that have arisen in boiling water reactors (BWR) are intergranular stress corrosion cracking (IGSCC) of pipes. One of the factors contributing to IGSCC in pipes is weld-induced residual stress. In all major systems exposed to an environment with water, corrosion can occur in all sorts of alloys such as stainless steel, carbon and low alloyed steels, nickel based alloys and zirconium alloy fuel cladding. [18]

Stress corrosion cracking (SCC) arises due to a combination of three factors that are; a susceptible material, corrosive environment and tensile stresses as seen in figure 5. In dissimilar metal welds the residual stresses that arise from welding can be large enough to induce SCC if the other factors are fulfilled. SCC tends to develop more rapidly at higher temperatures than at lower temperatures, the process is thermally activated and can be represented by Arrhenius' law with the correlation: $e^{\frac{Q}{R\cdot T}}$, where T is temperature. In BWR chemistry, materials tend to be susceptible to SCC at temperatures above 100 °C. The operating method and temperature in a nuclear power plant are also factors that contribute in significant manner to SCC. The concentrations of oxygen and hydrogen, the corrosion potential, impurities and the pH balance of the solution play important roles in this process.

Figure 5, The factors that gives SCC

One common material in a nuclear power plant is the austenitic stainless steel 316L. Therefore naturally, a lot of studies are made with 316L. The susceptibility to SCC in the HAZ of the 316L material is evaluated by Abreu Mendinca Schvartzman et al. in an environment of the primary circuit of a pressurized water reactor (PWR) at 303 °C and 325 °C [19]. TIG-welded samples were analyzed by optical microscopy and slow strain rate to analyze the susceptibility to SCC. The study concludes that the HAZ of AISI 316L was susceptible to SCC. The tests showed that at the higher temperature the samples were exposed to the more susceptible to SCC due to lower mechanical properties and strength. Even though the primary circuit of a PWR differs from the BWR environment in the case of temperature and pressure, 288 °C in a BWR it is concluded that a higher temperature makes 316L more susceptible to SCC. [19]

The crack growth rate is an important factor in a nuclear power plant due to the long operation times. A study by del P Fernández et al. [19] has reviewed the growth rate of SCC. In the study ferritic steel was welded together with austenitic stainless steel in a dissimilar metal weld. A buttering layer with nickel based filler metal was first welded on the ferritic steel side before the two parent metals was joined together by TIG with the same filler metal as the buttering layer. The welded samples were subjected to a cyclic load in a simulated BWR environment. The study concluded that a crack grows preferably on the ferritic steel side. [20]

The advantages of a nickel based filler metal between low alloyed and austenitic stainless steel is well known due to the better impact fracture energy. It is shown by Hajiannia et al. [21] that in a weld between low alloyed steel and austenitic stainless steel a nickel based filler metal is to prefer compared to an austenitic stainless steel filler metal. In the weld with the austenitic stainless steel filler metal a thin martensite layer with high hardness is found in the fusion line, but no martensite layer is found in the weld with the nickel based filler metal. All tensile tests were as would be expected broken in the HAZ on the low alloyed steel side. The nickel based weld also had the highest impact energy. However, the highest and the lowest hardness values were found in the weld with nickel based filler metal. [21]

The presence of a martensite layer close to the fusion line in dissimilar metal welds is a well-known phenomenon. A martensite layer is created due to a formation of intermediate compositions with high hardenability and formed during the rapid cooling in the welding thermal cycle. The martensite layer will create a gradient in mechanical properties along the weld interface that could be responsible for premature failure of the dissimilar metal weld. Dissimilar metal welds are usually welded with austenitic steel filler metal or a nickel based filler metal. The nickel based filler metal tends to give a thinner martensite layer. A study by DuPont and Kusko, [20], has demonstrated that the nickel based filler metal will give a steeper concentration gradient in the partially mixed zone compared to austenitic steel filler metal. The steeper concentration gradient will force the start temperature for martensite formation to intersect room temperature at a quite small distance within the partially melted zone. This will stabilize austenite and cause the relatively thin martensite layer detected in the dissimilar metal welds with nickel based filler metal. [22]

The dissimilar metal welds are known for its complex combinations of the different materials, heat affected zone and carbon depleted zone due to the welding thermal cycle. The fracture behavior of these dissimilar metal welds is therefore very important for safety and design point of views. Samal et al. [23] has investigated the fracture behavior of dissimilar metal welds through analyzing single-edged notched bend type specimens with initial cracks made at different locations. The study shows that an initial crack at the buttering-weld interface has the lowest fracture resistance behavior because the presence of the heat affected zone at the end of the welding area. [23]

Some areas in the field of dissimilar metal welds can successfully be analyzed by models and the use of different soft-wares. In a study by Ranjbarnodeh et al., [24], a three-dimensional model has been developed to predict the temperature distribution and weld-pool geometry during TIG-welding of a carbon steel and ferritic stainless steel. The model was then used to evaluate the effect of welding parameters on grain growth in the heat affected zone of welded samples. The results showed that the model had reasonable consistency with the model and the measured weld-pool geometries. The temperature was unevenly distributed, the highest temperature occurred at the carbon steel side. At last it was concluded that the grain size and grain size distribution was strongly related with the heat input, higher heat input gave larger grain size and a more homogeneous grain size distribution. [24]

4. MATERIALS USED IN THIS STUDY

In this study a dissimilar metal weld was made between the austenitic stainless steel 316L and the low alloyed steel 15Mo3 with the over-alloyed austenitic filler metal Avesta P5, also known as 309MoL.

The austenitic stainless steel, 316L, is a common austenitic stainless steel in the nuclear power industry. It is often used in pipes or valves in the primary and secondary water system but also as internal parts in the reactor pressure vessel.

The low alloyed steel used in the study is 15Mo3, and is also a commonly used low alloyed steel in the nuclear power industry. 15Mo3 is frequently used in pipes or valves in the secondary systems.

The filler metal, Avesta P5, is also known as 309LMo and is a common material used for filler metal in dissimilar metal welds. The filler metal is an over-alloyed austenitic stainless steel.

4.1 Austenitic stainless steel 316L

The chemical composition for the tubes in 316L according to ASTM and according to the material certificate is specified in table 1. For material certificate see appendix A.

Table 1, Chemical composition of 316L

Element	ASTM, %	Material certificate, %
Carbon, C	≤ 0.030	0.016
Silicon, Si	≤ 1.00	0.40
Manganese, Mn	≤ 2.00	1.42
Phosphorus, P	0.045	0.024
Sulfur, S	0.015	0.008
Chromium, Cr	16.5-18.5	16.78
Molybdenum, Mo	2.00-2.50	2.03
Nickel, Ni	10.0-13.0	11.17
Nitrogen, N	≤ 0.11	0.057
Cobalt, Co	-	0.089
Iron, Fe	Bal	Bal

4.2 Low alloyed steel 15Mo3

The chemical composition for the tubes according to EN and according to the material certificate is specified in table 2. For material certificate see appendix B.

Table 2, Chemical composition of 15Mo3

Element	EN, %	Material certificate, %
Carbon, C	0.12-0.20	0.18
Silicon, Si	≤ 0.35	0.20
Manganese, Mn	0.40-0.90	0.66
Phosphorus, P	0.025	0.004
Sulfur, S	0.010	0.003
Chromium, Cr	≤ 0.30	-
Molybdenum, Mo	0.25-0.35	0.28
Nickel, Ni	≤ 0.30	-
Copper, Cu	≤ 0.30	-
Nitrogen, N	≤ 0.012	-
Iron, Fe		Bal

4.3 Filler metal Avesta P5

The chemical compositions for the welding wires according to Avesta welding and according to the material certificate are specified in table 3 for the 2.4 mm wire and table 4 for the 1.6 mm wire. The 1.6 mm wire is used for the root bead and the first weld bead and the 2.4 mm wire for the rest of the weld beads. For material certificate see appendix C for the 2.4 mm wire and appendix D for the 1.6 mm wire.

Table 3, Chemical composition of P5 2.4 mm

Element	Avesta welding, %	Material certificate, %
Carbon, C	0.02	0.012
Silicon, Si	0.35	0.33
Manganese, Mn	1.5	1.4
Phosphorus, P	-	0.020
Sulfur, S	-	0.004
Chromium, Cr	21.5	21.4
Nickel, Ni	15.0	15.0
Molybdenum, Mo	2.7	2.57
Niobium + Tantalum, Nb + Ta	-	0.00
Copper, Cu	-	0.10
Nitrogen, N	-	0.053
Iron, Fe	Bal	Bal

Table 4, Chemical composition of P5 1.6 mm

Element	Avesta welding, %	Material certificate, %
Carbon, C	0.02	0.013
Silicon, Si	0.35	0.40
Manganese, Mn	1.5	1.5
Phosphorus, P	-	0.020
Sulfur, S	-	0.004
Chromium, Cr	21.5	21.5
Nickel, Ni	15.0	15.4
Molybdenum, Mo	2.7	2.59
Niobium + Tantalum, Ni + Ta	-	0.01
Copper, Cu	-	0.10
Nitrogen, N	-	0.051
Iron, Fe	Bal	Bal

5. METHOD

5.1 Calculations with the Schaeffler constitutional diagram

With the chemical compositions of the two parent metals and the filler metal, the Schaeffler diagram can be used to estimate the composition of the weld metal. The composition of the 1.6 mm P5 filler metal is used in the calculations, since the structure of the root bead is considered as the most important. The nickel and chromium equivalents that are a part of the Schaeffler diagram are calculated with equation 1 and 2 for the two parent metals and the filler metal are listed in table 6. It is assumed that the two parent metals contributes equally to the weld pool, therefore new nickel and chromium equivalents are calculated with equation 3 and 4 as a mean value.

$$Ni_{eq} = \%Ni + 30 \cdot \%C + 0.5 \cdot \%Mn \qquad (1)$$

$$Cr_{eq} = \%Cr + \%Mo + 1.5 \cdot \%Si + 0.5 \cdot Nb + 2 \cdot \%Ti \qquad (2)$$

Table 6, Nickel and chromium equivalents for parent metals and filler metal

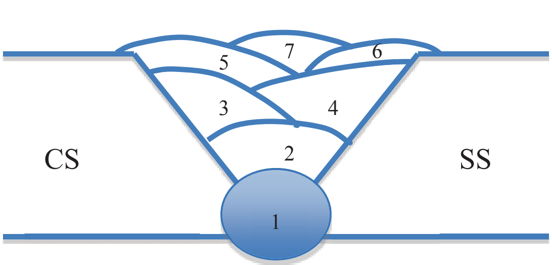
	Stainless steel 316L	Low alloyed steel 15Mo3	Filler metal Avesta P5
Ni_{eq}	12.89	5.73	16.06
Cr_{eq}	19.41	0.58	24.465

$$Ni_{eq} = \frac{12.89+5.73}{2} = 9.31 \qquad (3)$$

$$Cr_{eq} = \frac{19.41+0.58}{2} = 9.995 \qquad (4)$$

Figure 6 to 9 shows the schematic sketches of the samples that are welded in this study. Sample 3 and 4 are welded with the stainless steel upwards and sample 5 and 6 are welded with the low alloyed steel upwards. Sample 1, 3 and 5 are welded with a gap between the two base materials in the root bead where-as sample 2, 4 and 6 are welded without gap. The figures show that maximum eight weld beads are made. When TIG-welding is used it is assumed that 30 % of the parent metals/previous weld bead and 70 % of the filler metal is contributing to the molten weld pool.

By assuming 30 % of the parent metals contribute to the dilution in a TIG-welding method the nickel and chromium equivalents can be calculated for the eight weld beads. When the Schaeffler diagram is used it is assumed that the parent metals contribute to the molten weld pool only in the first weld bead. In the following weld beads the latest made weld bead contributes by 30 % to the molten weld pool. The filler metal contributes to the remaining 70 % in both cases. The equivalents for the different weld beads are showed in table 7. Note that in worst case scenario, the first weld bead of a sample welded without gap can consist of a mix without any filler metal at all.



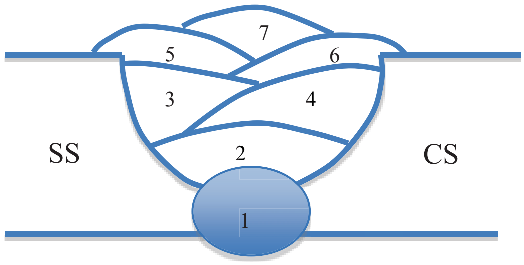
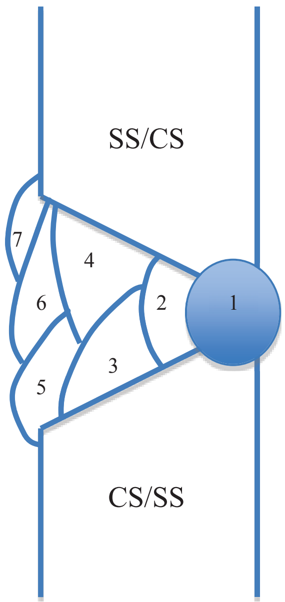


Figure 6, Schematic sketch of how sample 1 (with gap) is welded.

Figure 7, Schematic sketch of how sample 2 (without gap) is welded.



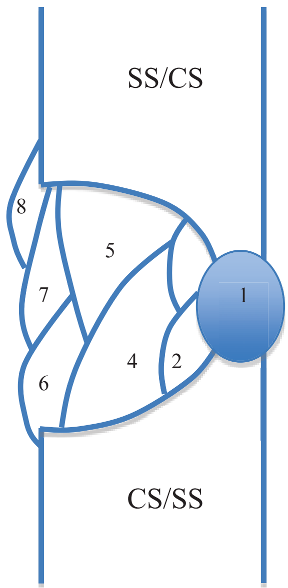


Figure 8, Schematic sketch of how sample 3 and 5 (with gap) are welded.

Figure 9, Schematic sketch of how sample 4 and 6 (without gap) are welded.

Table 7, Nickel and Chromium equivalents for the different weld beads

	Ni_{eq}	Cr_{eq}
1	**14.035**	**20.124**
2	**15.453**	**23.163**
3	**15.878**	**24.074**
4	**16.005**	**24.348**
5	**16.044**	**24.430**
6	**16.055**	**24.456**
7	**16.059**	**24.463**
8	**16.058**	**24.464**

5.2 Welding procedure specification

The samples are welded according to the welding procedure specification (WPS): OKG-1.1/8.1-004, see appendix E. Some of the most important parameters from the WPS are listed in table 8. The maximum temperatures of the samples between weld beads, the interpass temperature, are 100 °C, to decrease the risk of sensitization of the stainless steel. The samples with gap (1, 3, 5) are prepared to a V-joint, see figure 10, and the samples welded without gap (2, 4, 6) are prepared to a U-joint, see figure 11. The reason for choosing a U-joint to the samples welded without gap is to ensure that enough filler metal are added to the molten weld pool.

Table 8, Parameters for welding according to the WPS

Weld bead	Method	Filler metal	Dimension, mm	Current, A	Voltage, V	Current type, polarity	Velocity, cm/min	Heat input, kJ/mm
1	141-TIG	P5 Avesta	1.6/2.0/2.4	55 – 75	10 – 12	DC- pol	3 – 3.6	0.6 – 1.1
n	141-TIG	P5 Avesta	1.6/2.0/2.4	85 – 115	10.5 – 12.5	DC- pol	4.3 – 6.6	0.5 – 1.2

To acquire a good quality of the welds AGA Argon is used as shielding gas and as root protection gas AGA Fromier 10 that consists of 90 % N_2 and 10 % H_2. The AGA Formier 10 gives, compared to pure argon gas, a smoother root and better corrosion properties. [25]

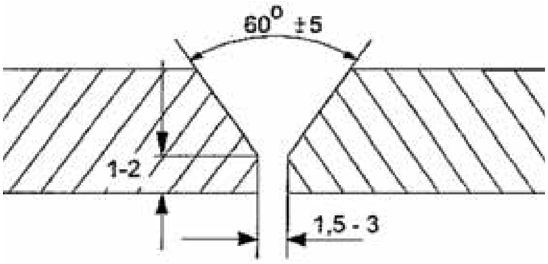


Figure 10, Schematic sketch of V-joint.

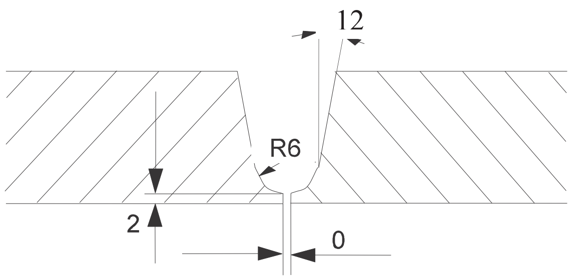


Figure 11, Schematic sketch of U-joint.

5.3 Welding procedure

Both the 316L pipe and the 15Mo3 pipe have a diameter of 114.3 mm and a thickness of 10 mm. In total 6 different samples are welded, three of them with 3 mm gap and 3 of them without 3 mm gap. The different positions are horizontal, see figure 12, vertical with the stainless steel on the top and reversed vertical position with the low alloyed steel at the top, see figure 13. Table 9 gives an overview of in which position the samples are welded and how they are denoted.

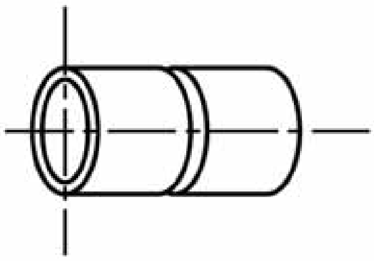


Figure 12, Horizontal position, with rotating pipe [26]

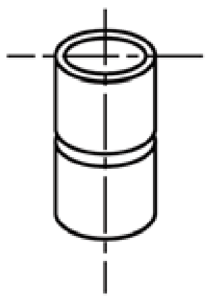


Figure 13, Vertical position [26]

Table 9, How the samples are denoted

	Horizontal position	Vertical position	Reversed vertical position
With 3 mm gap	**1**	**3**	**5**
Without gap	**2**	**4**	**6**

5.4 Non-destructive testing

Non-destructive testing is made to ensure that there are no manufacturing defects open to the surface or embedded in the weld or HAZ. Liquid penetrant testing is made according to the standard SS-EN 571-1 to identify discontinuities such as cracks, laps, folds, lack of fusion and porosity which are open to the surface. In order to achieve a successfully liquid penetrant test, the surface to be investigated shall be cleaned and dried. After that the penetrant is applied on the weld and the surrounding area so that the penetrant can enter into discontinuities open to the surface. When the penetration time has elapsed, in this case 20 minutes, the penetrant is removed from the surface and dried for 5 minutes. The developer is applied with a developing time of 0 to 30 minutes. The developer absorbs the penetrant that have entered discontinuities and give a visible enhanced indication of the discontinuity. Before any other non-destructive testing could be performed the surface shall be cleaned carefully after a liquid penetrant test. Acceptance criteria of indications in the weld and adjacent HAZ are according to the standard SS-EN ISO 23277:2009 and can be seen in table 10.

Table 10, Acceptance levels for indications

Type of indication	Acceptance level [a]		
	1	**2**	**3**
Linear indication *l*=**length of indication**	$l \leq 2$	$l \leq 4$	$l \leq 8$
Non-linear indication *d*=**major axis dimension**	$d \leq 4$	$d \leq 6$	$d \leq 8$

[a] Acceptance levels 2 and 3 may be specified with a suffix "X" which denotes that all linear indications detected shall be evaluated to level 1. However the probability of detection of indications smaller than those denoted by the original acceptance level can be low.

After the liquid penetrant test a radiographic test is made in order to ensure that there are no embedded defects. The radiographic testing is made according to the standard SS-EN ISO 17636-1 Class B that specifies techniques of radiographic evaluation using industrial radiographic film on fusion welded joints in metallic materials. The acceptance criteria are according to SS-EN 12517-1:2006. The tests are made with X-ray and with 9 films on each sample to cover the whole pipe.

5.5 Macroscopic and microscopic examination

A transverse section of each sample is mechanically cut so that it includes the heat affected zones of both sides of the weld and the weld metal itself. The specimens are prepared by mounting, grinding and polishing. After that the specimens are etched with Nital, 2 % HNO_3 in alcohol to reveal the microstructure on the low alloyed steel side and the microstructure on the low alloyed steel side is evaluated. Finally an electrolytic etching with oxalic acid 10 % $H_2C_2O_4$ in water to reveal the microstructure in the weld and on the stainless steel side, and the weld and stainless steel side are evaluated in light optic microscope.

5.6 Chemical analysis with EDS

In order to study the dilution between the parent metals and the filler metal in the weld, chemical analysis of the samples are made. The analysis is made from the unaffected parent metals through the weld metal to the other unaffected parent metal. The chemical analysis is made at three different positions in the weld which are the root, the first weld bead and the top. The analysis is made in a scanning electron microscope (SEM) with electron-dispersive spectroscopy (EDS). A high-energy electron beam interacts with the specimen and an X-ray is generated, the energy created is characteristic to the atoms in the specimens. The intensity of the created energy is measured and compared to a reference so that the concentration of each element can be determined.

5.7 Tensile testing

To ensure that the weld metal not is weaker than the rest of the materials tensile testing is made, one for each sample. The specimen is taken transversely from the weld joint so that the weld axis remains in the middle of the parallel length of the specimen, see figure 14 and figure 15. It is important that the mechanical or thermal processes to produce the specimen do not affect the properties of the specimen in any way. It is also important that the surface is free from notches or scratches that otherwise could induce a fracture. During a tensile testing is the specimen is subjected to a continuously growing tensile load in room temperature until fracture occurs.

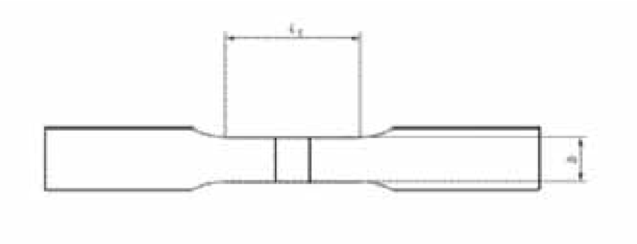


Figure 14, Schematic sketch of a tensile test specimen.

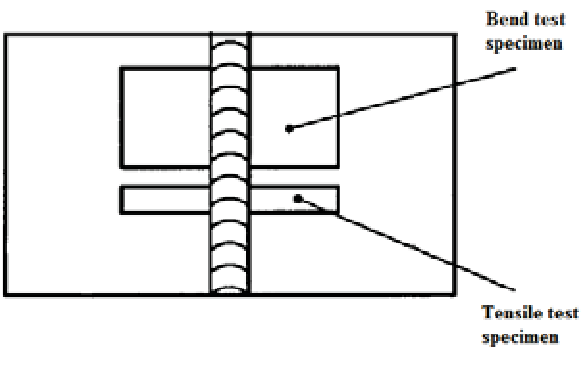


Figure 15, Schematic sketch of how the bend test specimen and tensile test specimen are located.

5.8 Bend testing

Bend tests are made in order to determine if the welded samples are ductile enough. The bend tests are made according to the standard SS-EN ISO 5173. A specimen is taken transversely from the welded joint and deformed plastic by bending, see figure 14. The tests were made in room temperature. The bend tests are made in two directions on each sample; transverse face bend test and transverse root bend test. All the samples were bent to an angle of 180 °.

5.9 Hardness measurements

A simple and economical way to characterize the mechanical properties and microstructure is by performing hardness measurements. By performing hardness measurements the highest and lowest levels of hardness can be determined. In dissimilar metal welds the hardness level of parent metals and weld metal are determined. The most interesting part is where the transition from parent metal to weld metal takes place and in the root bead of the weld.

A cross-section from each sample is taken transverse the weld by mechanical cutting. It is important that the preparations of the samples do not affect the surface metallurgical by hot or cold work. After the samples are cut they are grinded and polished in order to make as good preparation as possible. The numbers of indentations need to be enough to assure that hardened and softened zones are tested, i.e. that the indentations do not affect each other. The hardness indentations are performed in rows at three different positions of the weld; the root bead, the first weld bead and the top weld. The samples are tested with HV 0.5, except for sample 1 which is tested with HV 1. HV 0.5 means that 0.5 kg load is applied during the hardness measurement, corresponding to 1 kg for HV 1.

6. RESULTS

6.1 Calculations with the Schaeffler constitutional diagram

In the Schaeffler diagram, figure 16, the nickel equivalent is represented on the y-axis and the chromium equivalent is represented on the x-axis. By plotting the points of the parent metals and filler metal in the Schaeffler diagram, see figure 16, it is easy to get an overview of the composition range by drawing tie lines between the points. The low alloyed steel, 15Mo3, is located in the martensitic and ferritic area. The other parent metal, the stainless steel, 316L, is located in the 100 % austenitic area, just on the edge to the austenitic and ferritic area. The blue tie line in figure 13 represents the composition if only the two parent metals are melted together at different dilution ratios, which goes from the ferritic and martensitic area, through the 100 % martensitic area. After that the blue tie line comes in an area of austenite and martensite and will for the 316L end up in the 100 % austenitic area. If the two parent metals contribute equally and are mixed together equally the structure will be 100 % martensitic.

The filler metal, P5, have a structure of around 7 % ferrite and 93 % austenite. The red tie line represents how the structure will vary with different dilutions of the filler metal. With the assumption that the parent metals contributes by 30 % to the dilution the root bead will give a 100 % austenitic structure, just on the edge to have a small amount of ferrite in the structure. The first weld bead will get 30 % of the dilution from the metal in the root bead and 70 % from the filler metal, which will give a structure of around 2 % ferrite and 98 % austenite. The following weld beads, 3 to 8, are located very close to each other and they will have a structure of around 7 % ferrite and 93 % austenite. All the weld beads except from the root bead fulfill the criteria of 2-10 % ferrite in the weld bead structure.

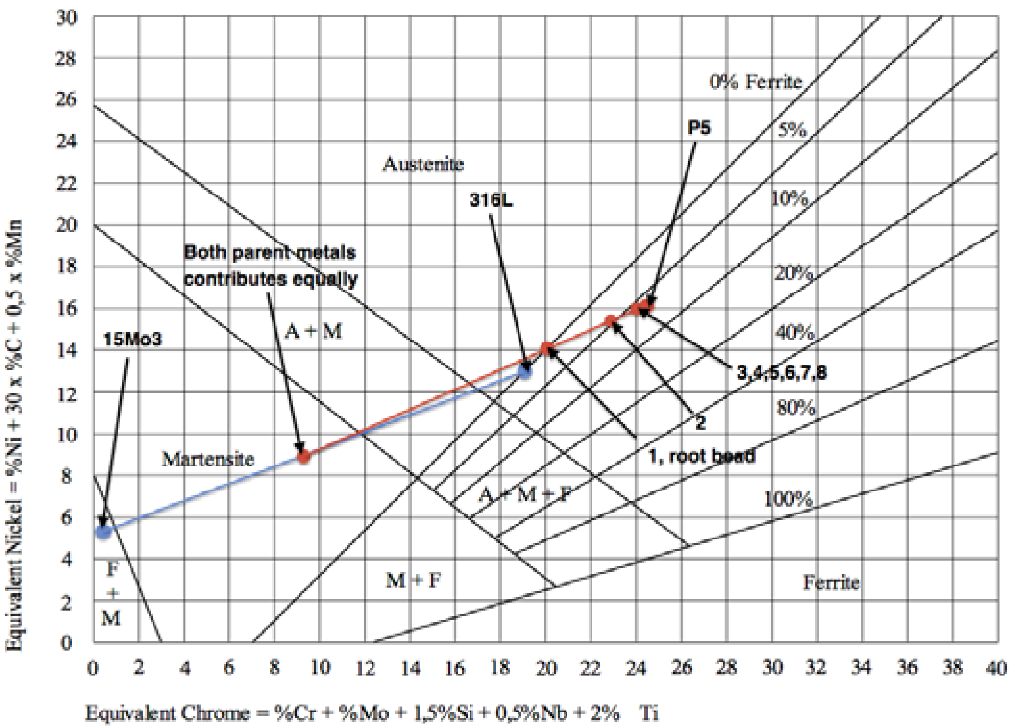


Figure 16, Schematic figure of the calculations with the Schaeffler constitutional diagram [16]

6.2 Non-destructive testing

Both the penetrate test and the radiographic test are made and approved by the accredited laboratory DEKRA Industrial [27]. For testing and acceptance procedure see part 5.2. See appendix F for the protocol from the radiographic test and appendix G for the protocol from the penetrant test.

6.3 Macroscopic and microscopic examination

The samples were made with two different edge preparations, the V-joint for the ones with gap and U-joint for the ones without gap. The different edge preparations will give the samples a slightly different appearance, which are shown in figure 17-19. Figure 17 shows the V-joint in sample 5, and figure 18 and 19 shows the U-joint in sample 2 and 6. In figure 15 the HAZ is shown clearly. The transition from unaffected parent metal to a decrease in grain size and the line between the parent metal and weld metal is clearly shown. In figure 17 and 19 the weld metal is etched and if one looks carefully the individual weld beads are shown. In figure 18 the low alloyed steel is etched and an overview of the HAZ and the transition unto unaffected low alloyed steel.

Figure 17, overview of sample 5 with etched weld metal (2x)

Figure 18, overview of sample 2 with etched low alloyed steel (2x)

Figure 19, overview of sample 6 with etched weld metal (2x)

The microstructure of all the samples looks similar in the microscopic evaluation. The microstructure of the unaffected low alloyed steel in sample 1 is seen in figure 20 and 21. Figure 21 is an enlargement of figure 20. A piece of sample 2 is shown in figure 22, the top of the weld with the weld metal on the left hand side, diagonally in the figure is the transition zone to the stainless steel. The austenitic grains can be seen very clearly in the stainless steel parent metal on the right hand side in figure 22.

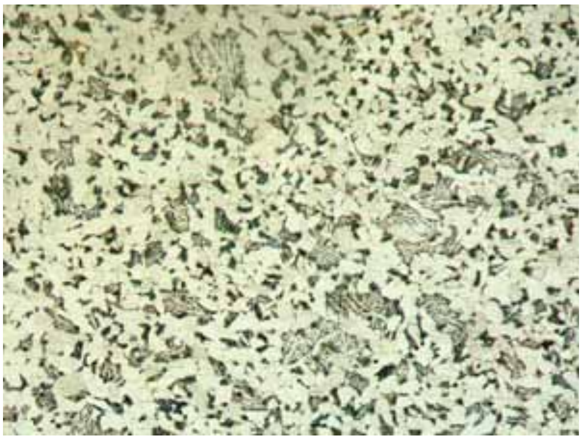


Figure 20, unaffected low alloyed steel in sample 1 (10x)

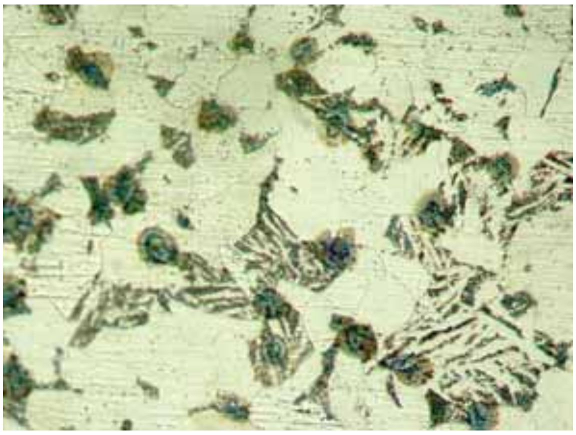


Figure 21, unaffected low alloyed steel in sample 1 (50x)

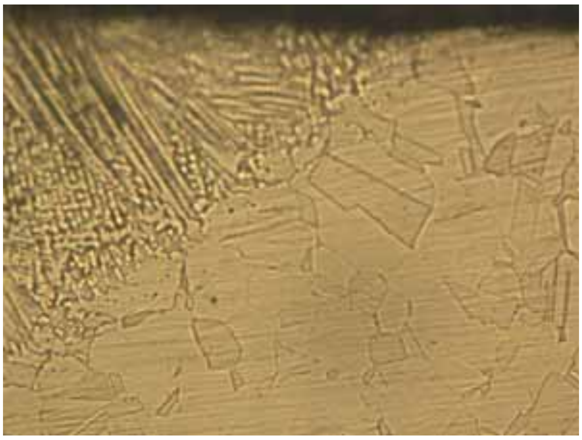


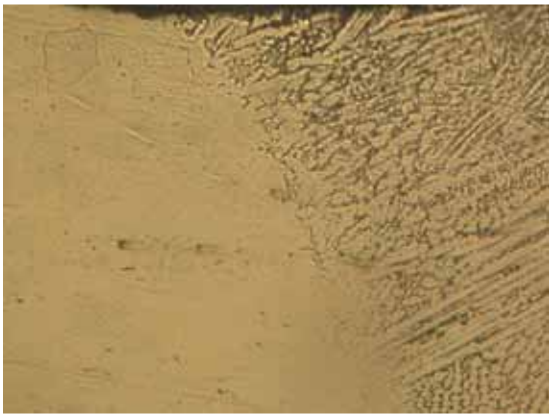
Figure 22, in the top weld of sample 2, weld metal and stainless steel (20x)

The purpose of a weld is to join two pieces of metals and that the weld will have at least as good mechanical properties as the parent metals. A good dilution between the parent metals and the filler metal will help to achieve a weld metal with sufficient mechanical properties. Figure 23 is taken from sample 3 and shows the stainless steel on the left hand side and the weld metal on the right hand side. Figure 24 is an enlargement of the weld metal in sample 3 and there is a piece of low alloyed steel in the weld metal that has not got molten up and mixed with the weld metal properly.

Figure 23, in the root of sample 3, transition from stainless steel to weld metal (5x)

Figure 24, in the root of sample 3, part of low alloyed steel that is not dissolved in the weld metal (10x)

Figure 25 shows a part of sample 4 with the stainless steel on the left hand side and the weld metal on the right hand side. The transition from parent metal to weld metal is shown on the diagonally in the picture and happens rather quickly. A clear line where the stainless steel ends and the weld metal starts is shown in figure 25. Since the HAZ is as important as the weld metal it needs to be studied and the structure of the HAZ is described earlier in the report. In figure 26 the HAZ of sample 5 is viewed at the top side of the weld on the low alloyed steel side. It is clearly seen that closest to the weld metal the coarse grained zone is located with its grain growth. After the coarse grained zone the normalized zone is located with its fine grained structure. An increase in grain size starts gradually and the partially transformed zone is entered. Finally the unaffected low alloyed steel is viewed in the lower right corner.



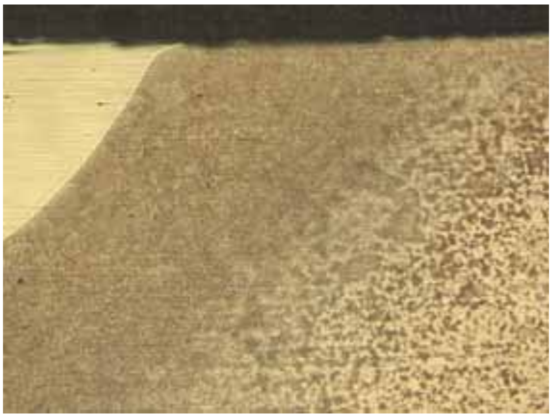


Figure 25, in the top of sample 4, transition from stainless steel to weld metal (20x)

Figure 26, in the top of sample 5, HAZ on the low alloyed steel side (5x)

The two figures 27 and 28 shows the difference of the two different parent metals and their transition to the weld metal. Figure 27 shows the transition from low alloyed steel with its typical mixed structure of ferrite and perlite and the transition to weld metal with a decrease of ferrite. An enlargement of the grain size is seen just before the solid/liquid transition zone in figure 27. Figure 28 shows the weld metal to the left and the transition to stainless steel in the middle of the figure, there are the austenitic grains seen very clearly.

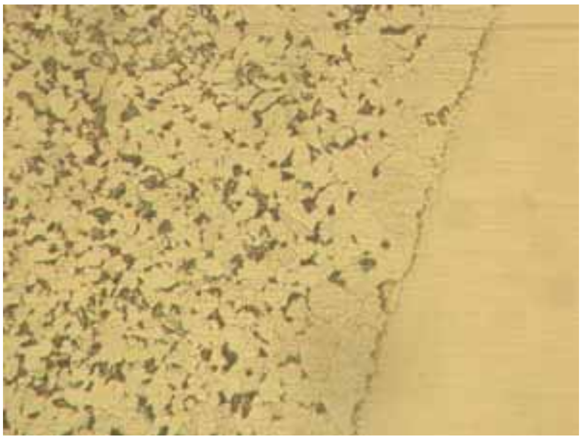


Figure 27, low alloyed steel and the transition to weld metal in sample 6 (50x)

Figure 28, stainless steel and transition to weld metal in the root of sample 6 (5x)

6.4 Chemical analysis with EDS

Chemical analysis was performed on all the samples at three different positions in the weld, one in the root bead, on in the first weld bead and one in the top weld. The results are presented in diagrams below with the low alloyed steel on the left hand side in the figure, the weld metal in the middle and the stainless steel on the right hand side. The iron content is displayed on the secondary x-axis on the right hand side in the diagrams. The distance between the measuring points are 0.25 mm, the energy used for the analysis was 20 kV and the volume of excitation was 1 μm^3. The time for analyzing one measuring point was set to 30 s.

Since OKG do not have the equipment to do the measurements themselves, samples were sent to SWEREA KIMAB. Some of the results may be questioned if they really belong to that position of the weld. Like the root bead of sample 2 welded without gap should have a weld metal that is 11 mm wide is not possible, especially compared to the actual weld where the root bead is measured to around 5 mm. However, the chemical analysis of the samples does look as expected excluding the width of the different weld beads.

6.4.1 Chemical analysis of sample 1

Figure 29, figure 30 and figure 31 are diagrams for the chemical analysis in sample 1 which is welded in horizontal position with 1.5 mm gap in the root. All three measurements display the transition from low alloyed steel to weld metal, figure 31, for the top weld bead also displays the transition from weld metal to stainless steel. The most remarkably in the chemical analysis of sample 1 is in the root bead, figure 29, where it is an abruptly increase of molybdenum and manganese in the transition from low alloyed steel to weld metal. The width of the weld metal in figure 29, root bead, is according to the diagram more than 11 mm which could be questioned. Otherwise the diagrams from the first weld bead and top weld bead looks as expected the analysis is a bit more unstable in the first weld bead, figure 30, and in the top weld bead, figure 31, compared to the root bead, figure 29.

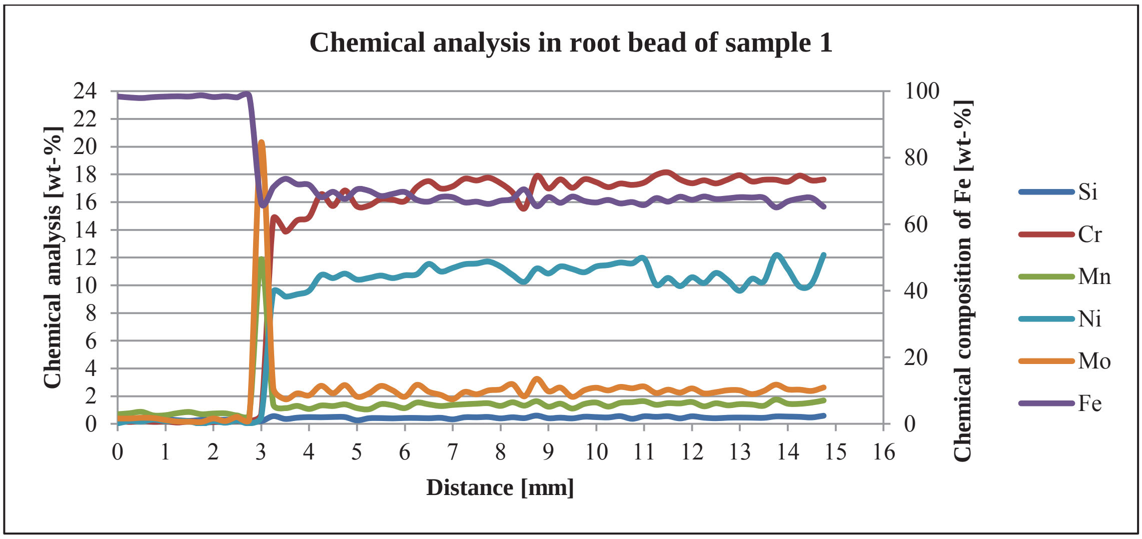


Figure 29, chemical composition in root bead of sample 1

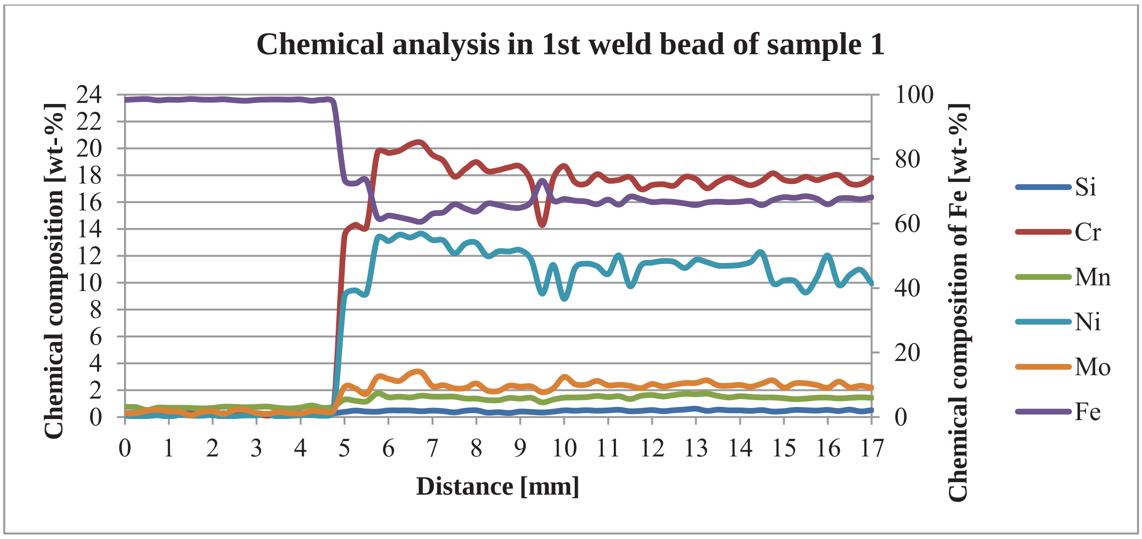


Figure 30, chemical composition in the first weld bead of sample 1

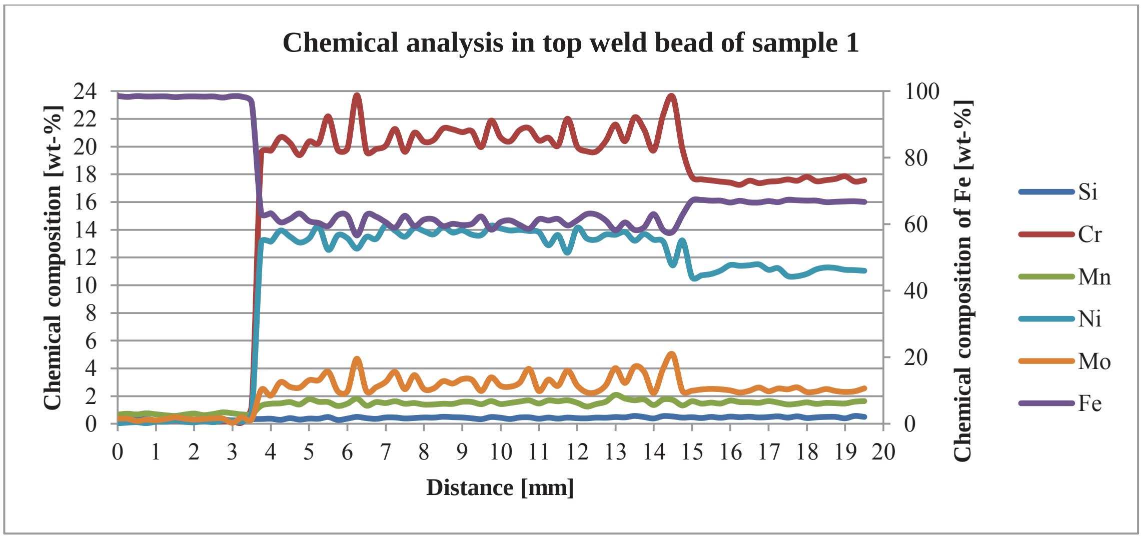


Figure 31, chemical composition in top weld bead of sample 1

6.4.2 Chemical analysis of sample 2

Figure 32, figure 33 and figure 34 are diagrams for the chemical analysis in sample 2 that is welded without gap in the root and in horizontal position. The diagram for the root bead, figure 32, shows the transition from low alloyed steel to weld metal and then to stainless steel. The root bead of sample 2 welded without gap should have a weld metal that is 11 mm wide is not possible, especially compared to the actual weld where the root bead is measured to around 5 mm. The diagram for the first weld bead and the top weld bead, figure 33 and figure 34, shows the transition from low alloyed steel to weld metal. The analyses for the first weld bead and top weld bead have a few peaks of chromium and molybdenum at the same time as the nickel content drops. Otherwise the analyses are as expected.

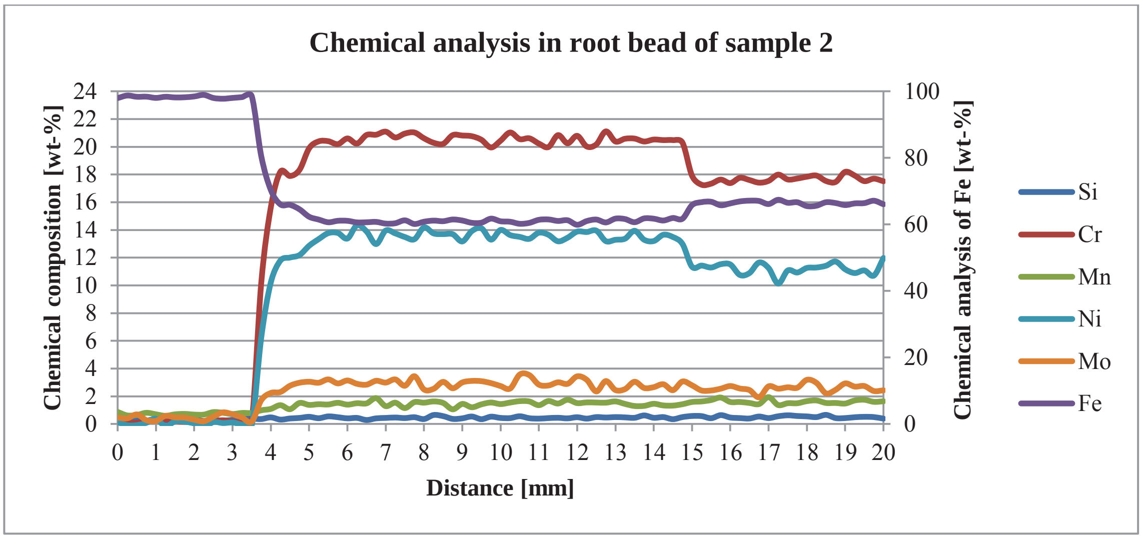


Figure 32, chemical composition in root bead of sample 2

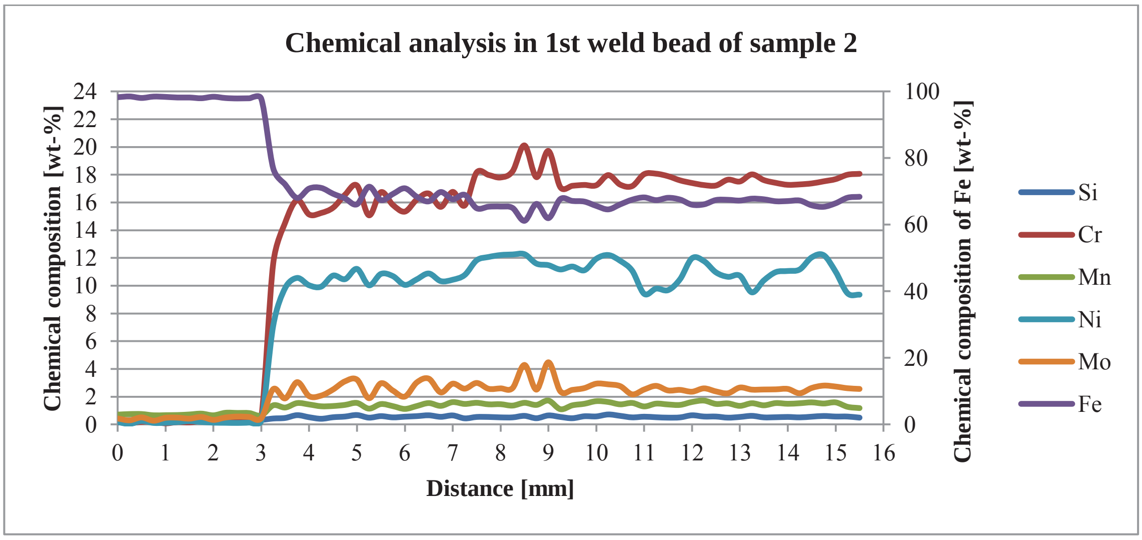


Figure 33, chemical composition in first weld bead of sample 2

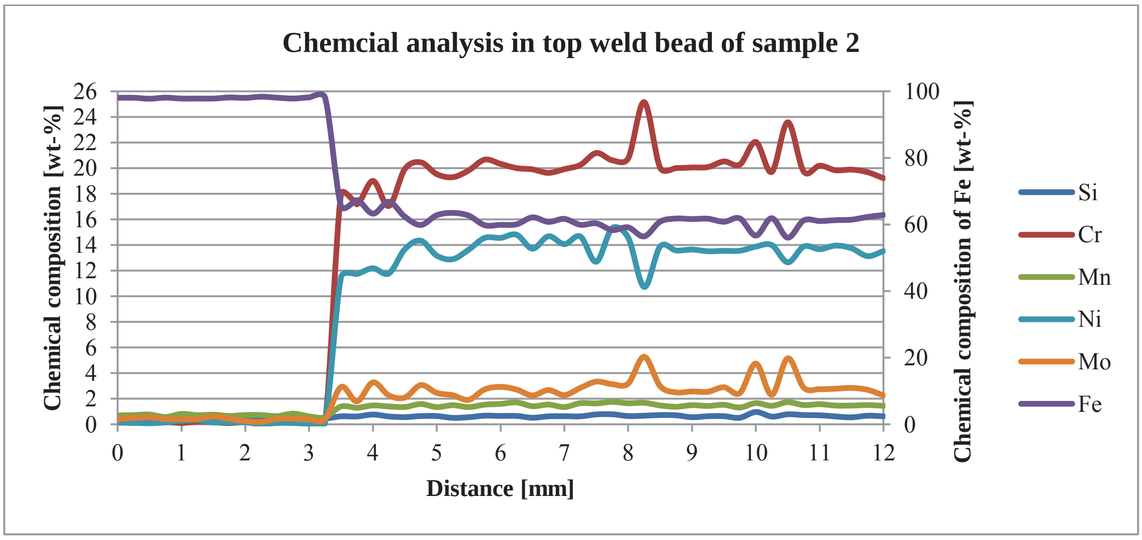


Figure 34, chemical composition in top weld bead of sample 2

At the same time as the chemical analyses were done, a series of SEM-pictures were taken. A 5 µm wide irregularity in form of lack of fusion can be seen in the SEM-picture of sample 2, see figure 35. However, this irregularity is too small to make the weld weaker.

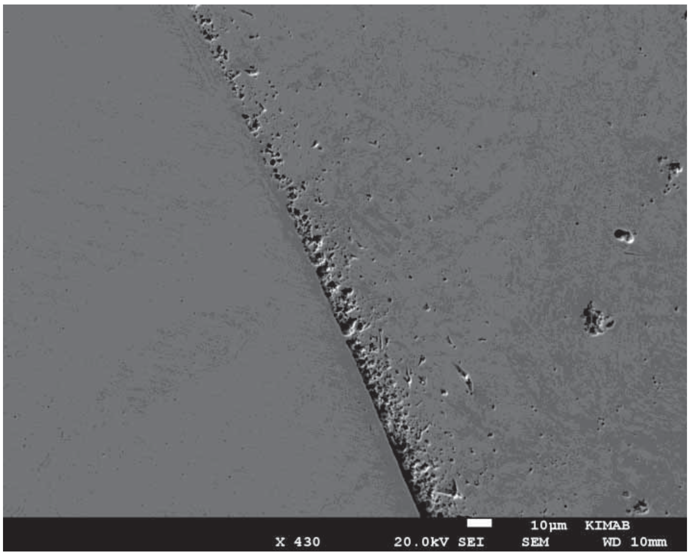


Figure 35, SEM-picture of sample 2

6.4.3 Chemical analysis of sample 3

Figure 36, figure 37 and figure 38 displays the chemical analyses for sample 3 that is welded with 1.5 mm gap in vertical position with the stainless steel on top. All analyses have the transition from low alloyed steel to weld metal and in the first weld bead, figure 37, the transition from weld metal to stainless steel is also shown. The analysis in the root bead of sample 3, figure 36, have smooth variations due to fewer measuring points compared to the other analyses, but otherwise it looks as expected. The first weld bead, figure 37, has a few higher peaks in the chromium and molybdenum at the same time as the nickel content goes down. In the top weld, figure 38, the chromium, nickel and molybdenum content goes up over the expected value just in the transition from low alloyed steel to weld metal after that the values are stable.

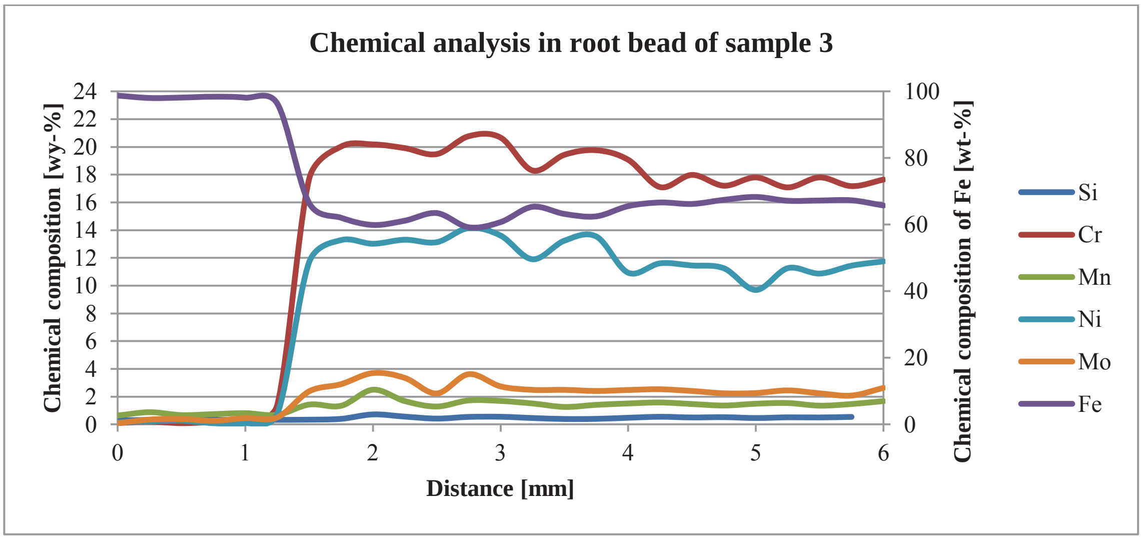


Figure 36, chemical composition in root bead of sample 3

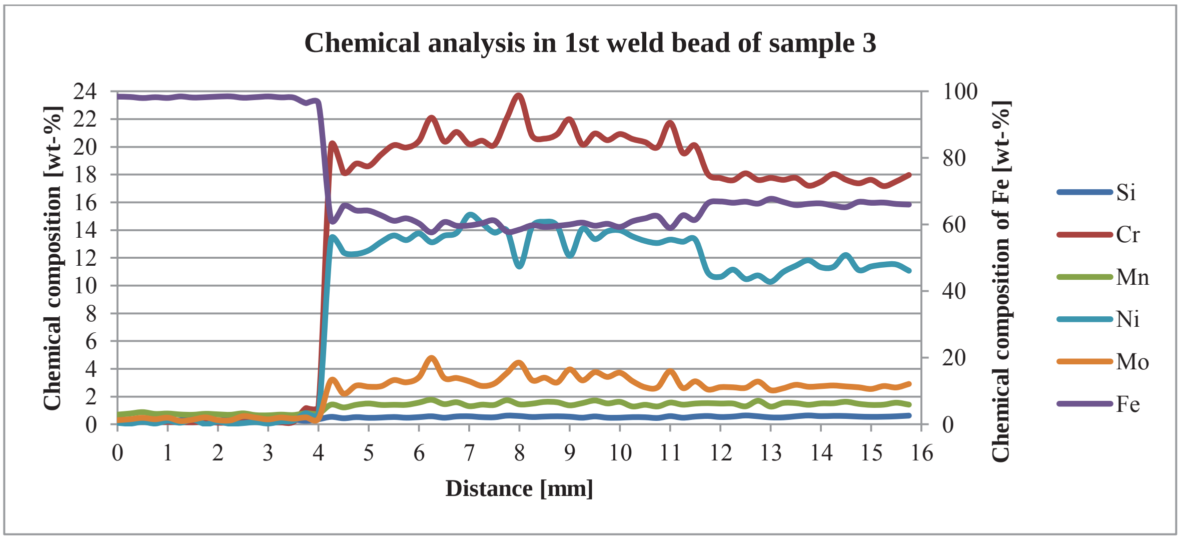


Figure 37, chemical composition in first weld bead of sample 3

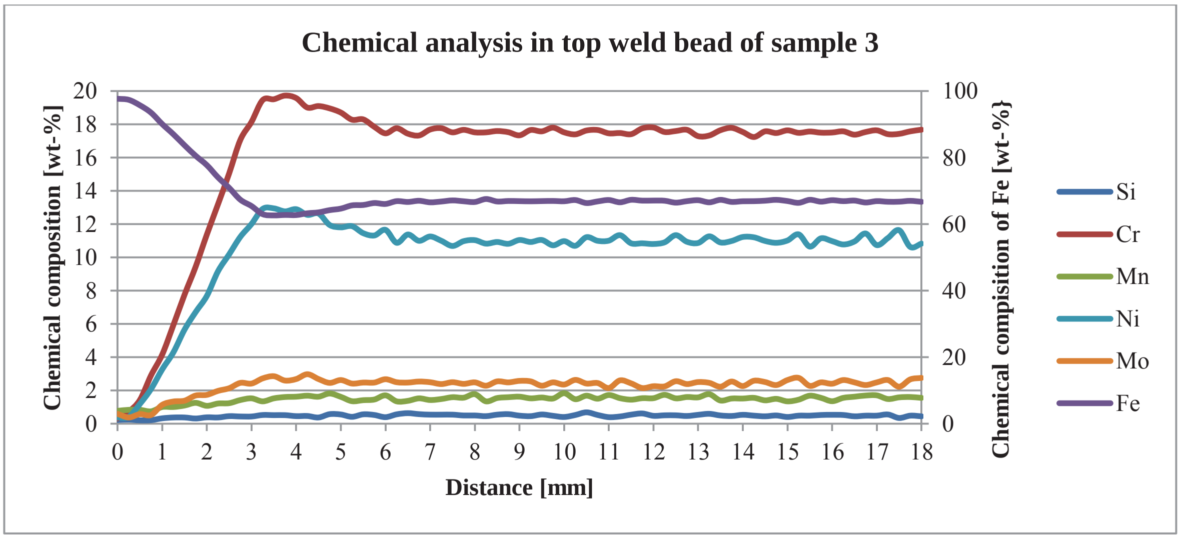


Figure 38, chemical composition in top weld bead of sample 3

6.4.4 Chemical analysis of sample 4

Figure 39, figure 40 and figure 41 displays sample 4 that is welded without gap in vertical position with the stainless steel on top. The chemical analysis of the root bead, figure 39, shows the transition from the root bead to weld metal and then to the stainless steel. The width of the weld metal in figure 39, root bead, is according to the diagram more than 10 mm which could be questioned. In figure 40, the chemical analysis of the first weld bead is very irregular both in the low alloyed steel and especially in the weld metal. In the top weld bead, figure 41, on the other hand rather stable.

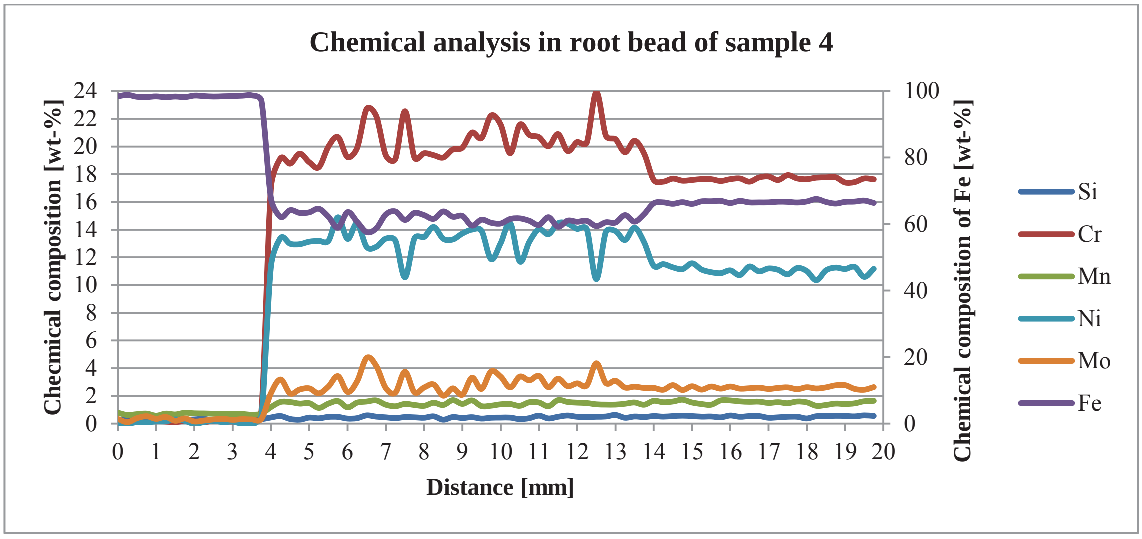


Figure 39, chemical composition in root bead of sample 4

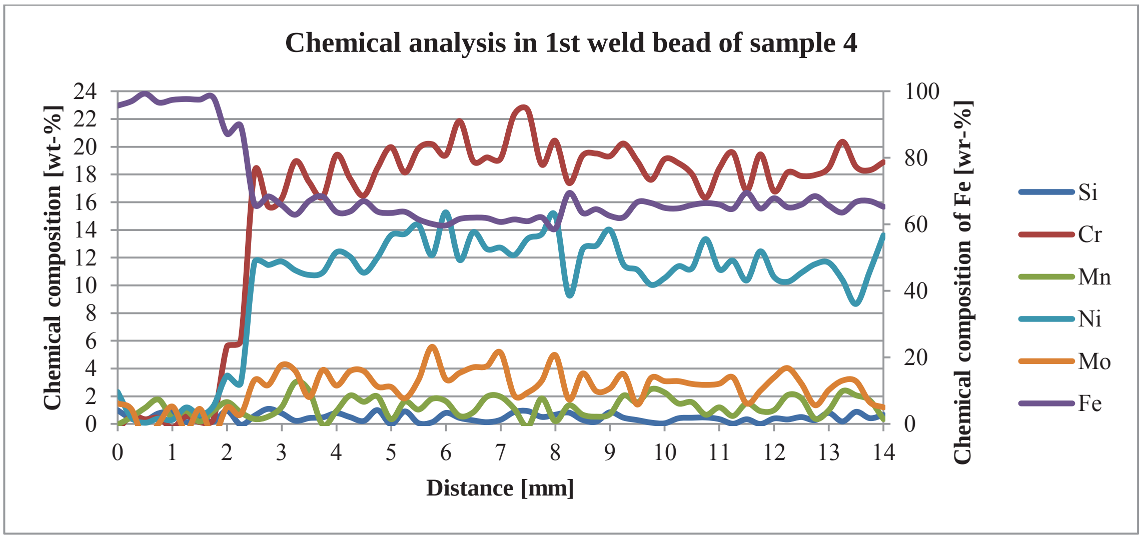


Figure 40, chemical composition in first weld bead of sample 4

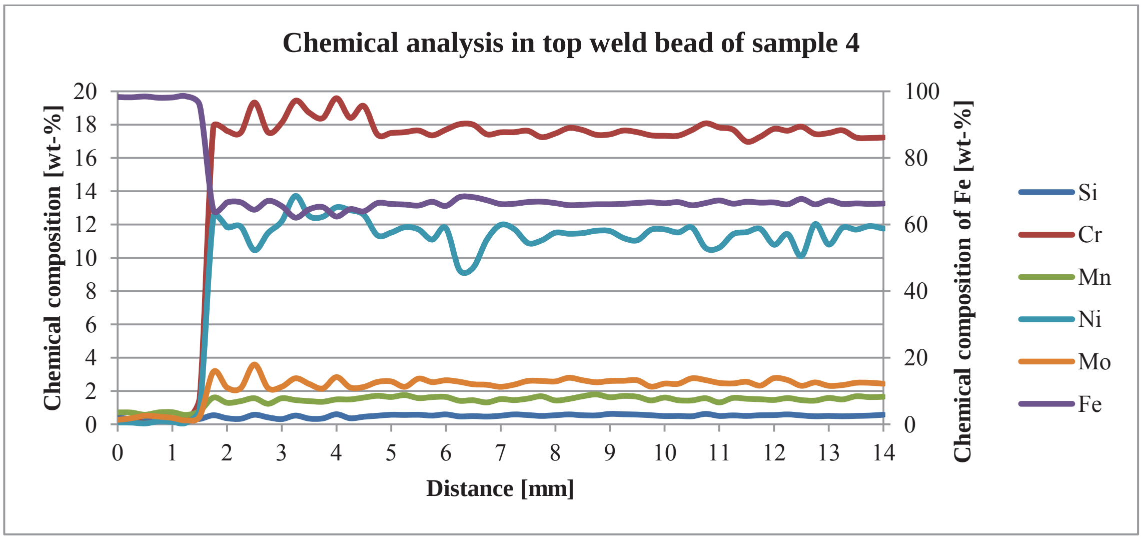


Figure 41, chemical composition in top weld bead of sample 4

6.4.5 Chemical analysis of sample 5

Figure 42, figure 43 and figure 44 displays the chemical analyses of sample 5 that is welded with 1.5 mm gap in reversed vertical position with the low alloyed steel on top. All three chemical analyses show the transition from low alloyed steel to weld metal. The analysis for the root bead, figure 42, is rather stable. Figure 43 shows the analysis for the first weld bead that also is rather stable, a little increase of chromium, nickel and molybdenum just after the transition to weld metal. The analysis in the top weld bead, figure 44, shows the same behavior as the first weld bead with the increase of chromium, nickel and molybdenum. The width of all the weld metals, root, middle and top are, compared to the other samples, much smaller which could be questioned if they really are belonging to this sample.

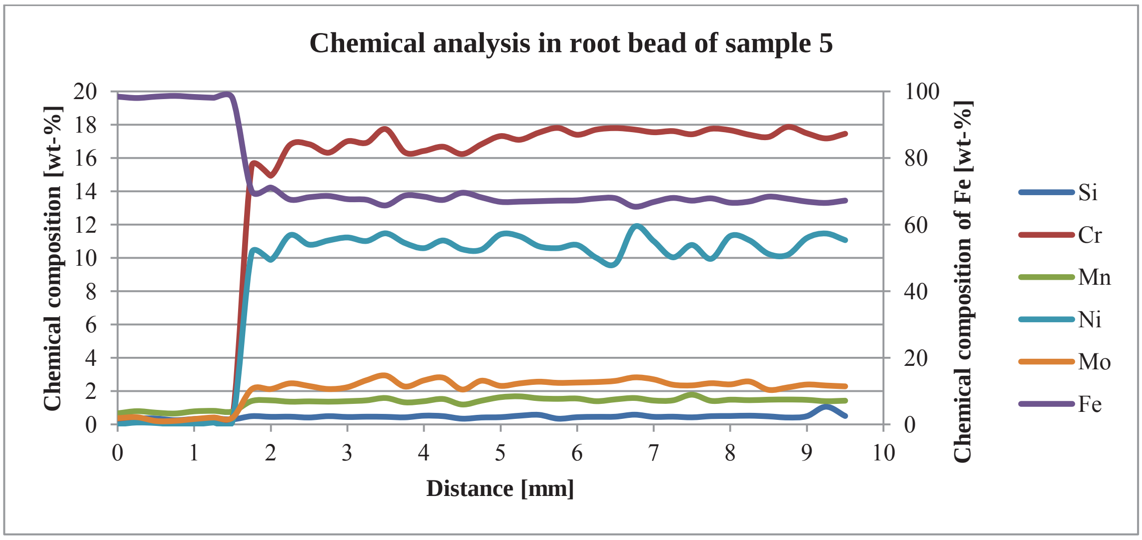


Figure 42, chemical composition in root bead of sample 5

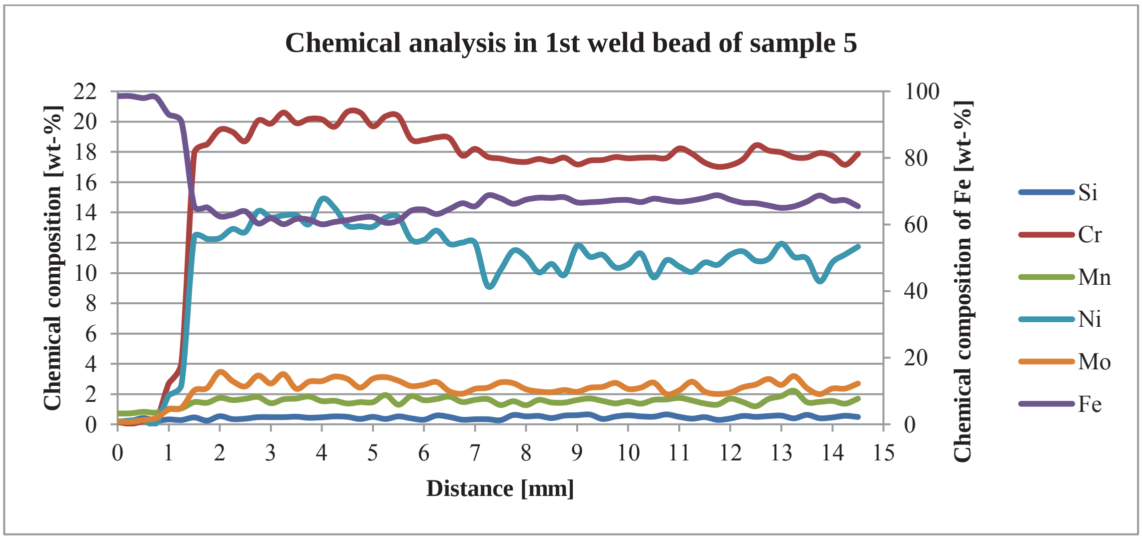


Figure 43, chemical composition in first weld bead of sample 5

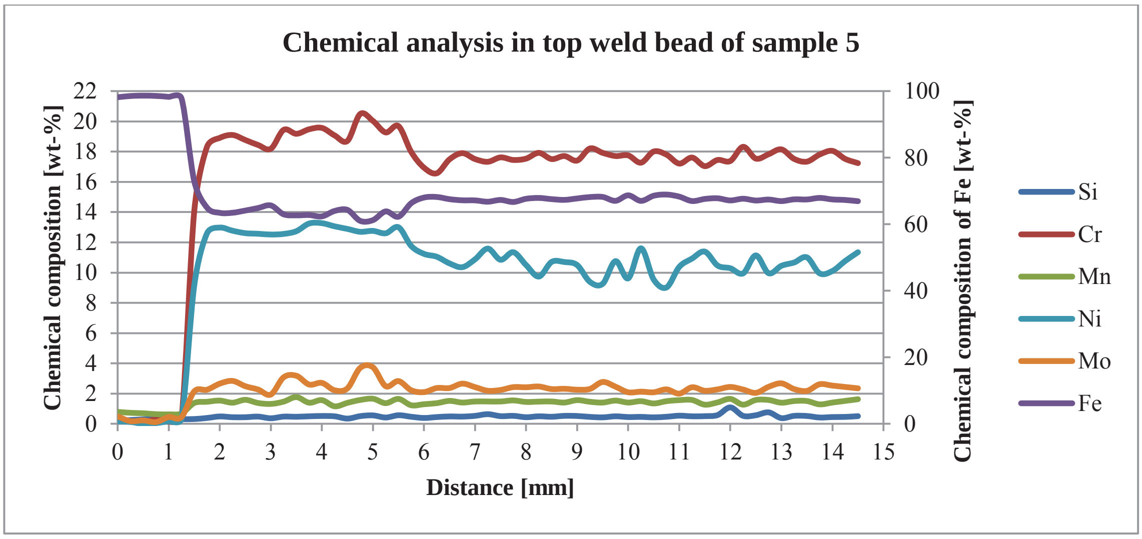


Figure 44, chemical composition in top weld bead of sample 5

6.4.6 Chemical analysis of sample 6

Figure 45, figure 46 and figure 47 display the chemical analyses of sample 6. The chemical analysis in the root bead, figure 44, shows the transition from low alloyed steel to weld metal and then to the stainless steel. Figure 46, the chemical analysis in first weld bead is very irregular in the weld metal with a dip of the chromium and nickel content and at the same time a top in the iron content. The chemical analysis of the top weld bead, figure 47, shows the transition from low alloyed steel to weld metal, and then a very thin section of weld metal before a transition to stainless steel. Such a small weld metal width of the top weld compared to the width of the weld metal in the root bead could be questioned if they are not mixed up.

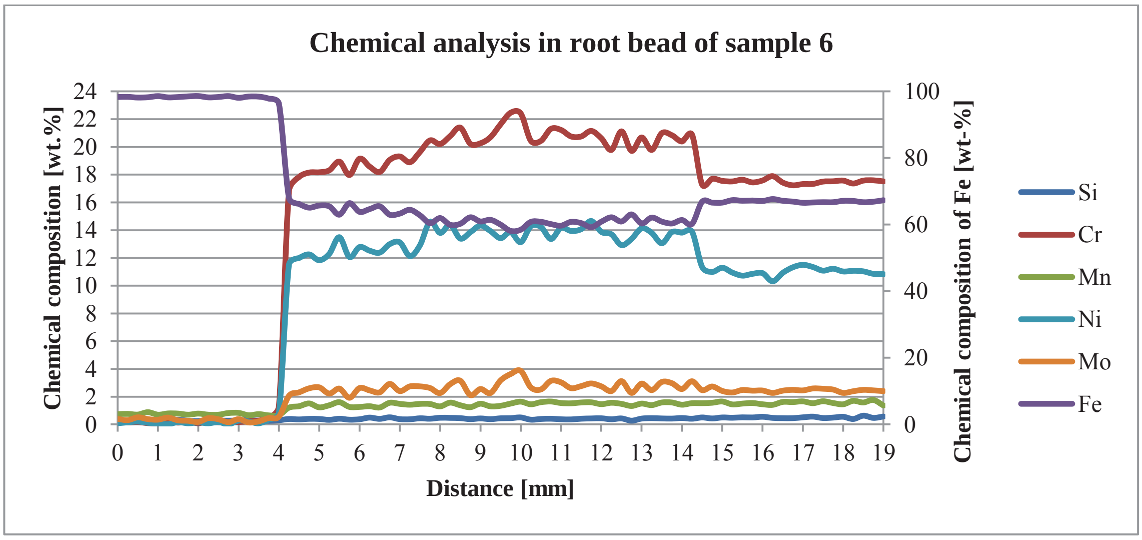


Figure 45, chemical composition in root bead of sample 6

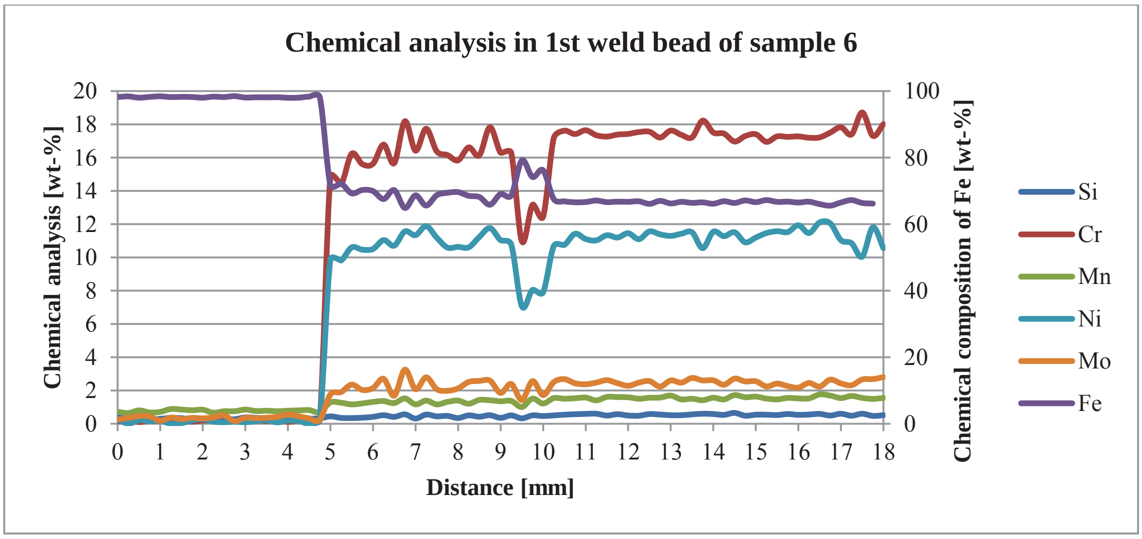


Figure 46, chemical composition in first weld bead of sample 6

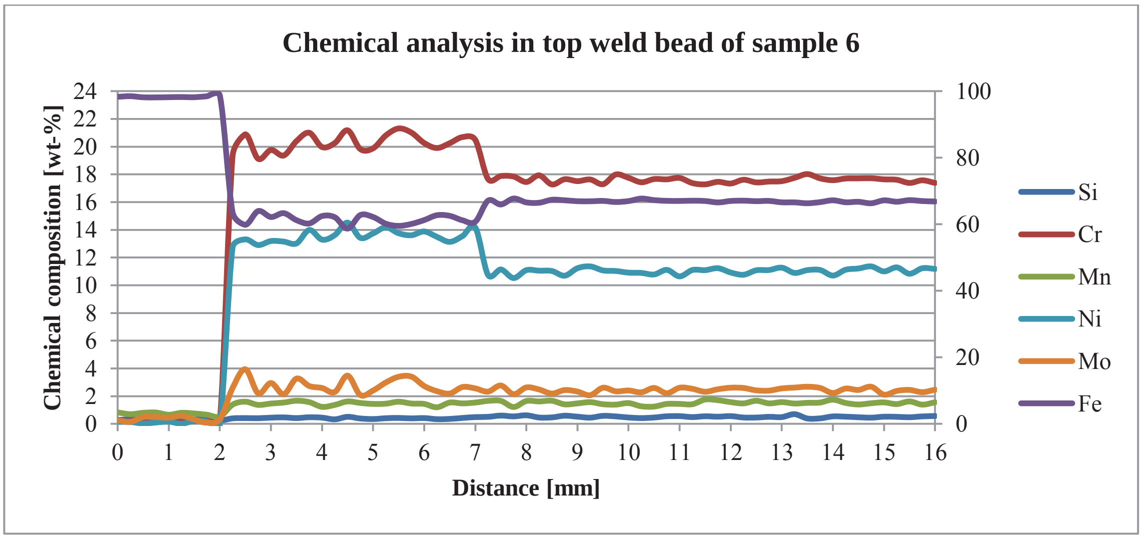


Figure 47, chemical composition in top weld bead of sample 6

6.5 Tensile testing

Tensile tests were performed on the samples with the weld positioned in the center of the specimens. The samples were prepared according to the schematic sketch in figure 48, with the total length of L_{tot}, the width, b, and the waist length, L_c. The exact measurements of the specimens taken from the different samples are specified in table 10. Figure 49 shows the set-up of the tensile test specimen in the machine. The weld was located in the middle of the test specimen, despite that the fracture occurred in the low alloyed steel, see figure 50. The yield strength and the ultimate tensile strength for the specimens from the different samples are listed in table 11. The yield strength has a range from 359-392 MPa and the ultimate tensile strength has a range from 527-536 MPa.

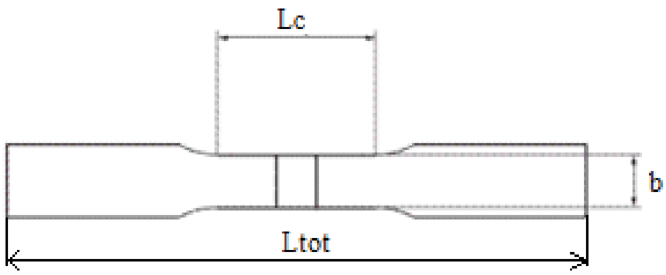


Figure 48, Schematic picture of a test specimen

Table 10, Parameters of tensile tests specimens

Sample	b [mm]	L_{tot} [mm]	L_c [mm]
1	4.95	80.4	32
2	4.99	73.2	32
3	4.96	81.0	32
4	4.94	77.5	32
5	4.98	80.4	32
6	4.96	83.2	32

Figure 49, Set-up of tensile testing

Figure 50, Tensile test specimen after testing

Table 11, Yield strength and ultimate tensile strength of sample 1 to 6

Sample	$R_{p0.2\ \%}$ [MPa]	R_m [MPa]
1	385	530
2	359	527
3	374	532
4	392	536
5	392	529
6	389	536

6.6 Bend test

The bend tests were executed according to standard SS-EN ISO 5173:2009 and evaluated according to standard SS-EN ISO 15614-1:2004 that covers the specification and qualification of welding procedures for metallic materials – Welding procedure test – Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys. In standard SS-EN ISO 15614-1:2004 it is stated that flaws appearing at the corners of the test specimen shall be ignored in the evaluation. It is also stated that flaws larger than 3 mm in any direction is a disapproved test specimen. The approved and disapproved test specimens are listed in table 12. Figures 51 and 52 shows a test specimen during bend testing and figure 53 shows a fully tested specimen. To be able to see if any flaws occurred during the bend test a penetrant test was made on the samples, see appendix H for all details about the penetrant testing procedure. In sample 2 one indication of approximately 16 mm could be detected, see figure 54. In sample 6 two linear indication was detected of approximately 4 mm and 3 mm with a interspace of 2-3 mm between them, see figure 55. The other samples, sample 1, 3, 4 and 5 had no indications occurred during the bend test.

Table 12, Approved and disapproved bend tests

Sample	Approved bend test	Disapproved bend test
1	X	
2		X
3	X	
4	X	
5	X	
6		X

Figure 51, Bend test

Figure 52, Bend test

Figure 53, Bend tested sample

Figure 54, Penetrant testing of sample 2

Figure 55, Penetrant testing of sample 6

6.7 Hardness measurements

Hardness measurements were made at the same places as the chemical analysis, in the root bead, the first weld bead and the top weld. Figure 56 shows the hardness indentations that remain after the measurements. The distances between the measuring points varies, they are closer in the HAZ and the transition from parent metal to weld metal. The graphic illustrations of the hardness in figure 57-62 give a good overview of how the hardness varies over the sample. The highest values are found close to the transition from parent metal to weld metal and in the root bead.

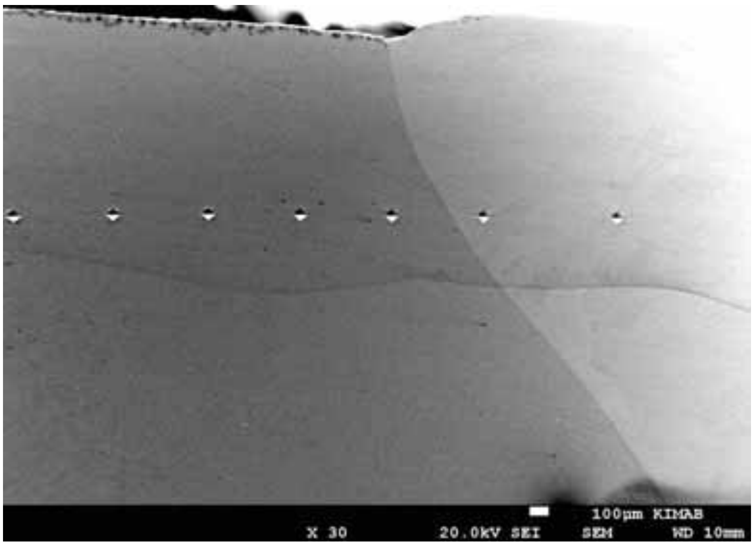


Figure 56, SEM-picture of the hardness indentations.

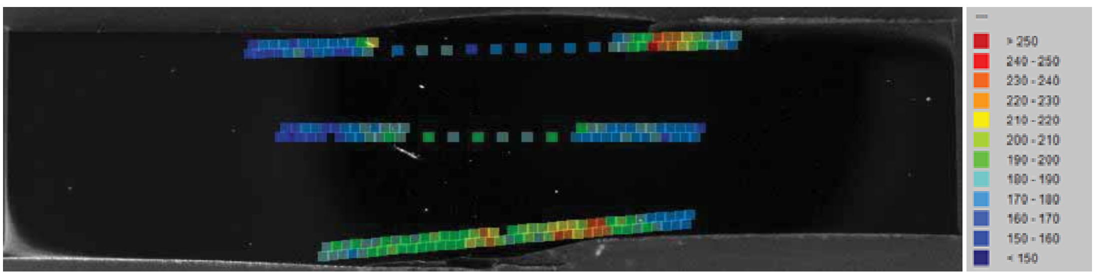


Figure 57, Hardness profile of sample 1

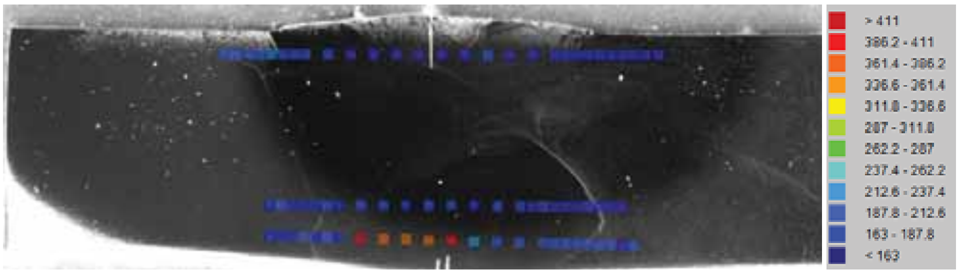


Figure 58, Hardness profile of sample 2

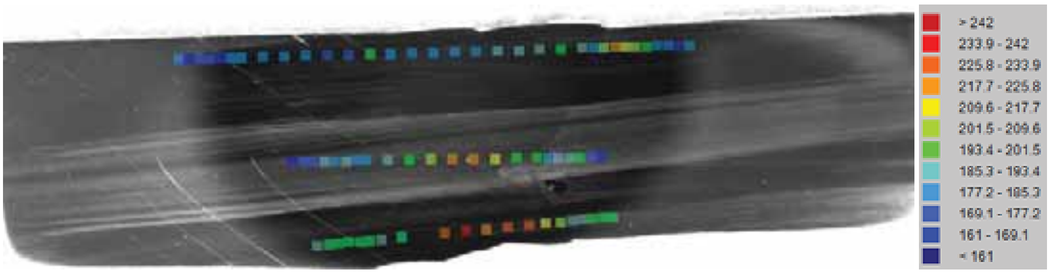


Figure 59, Hardness profile of sample 3

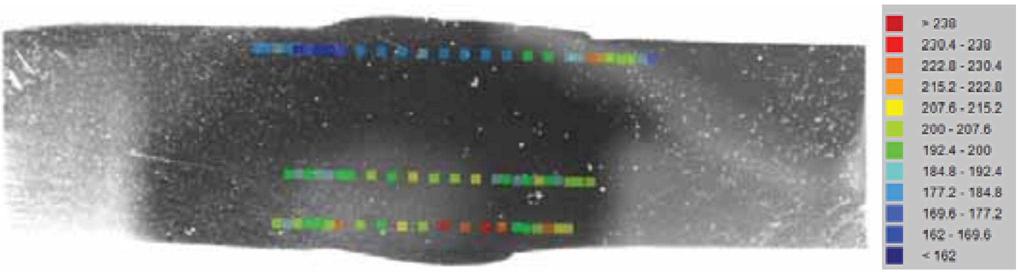


Figure 60, Hardness profile of sample 4

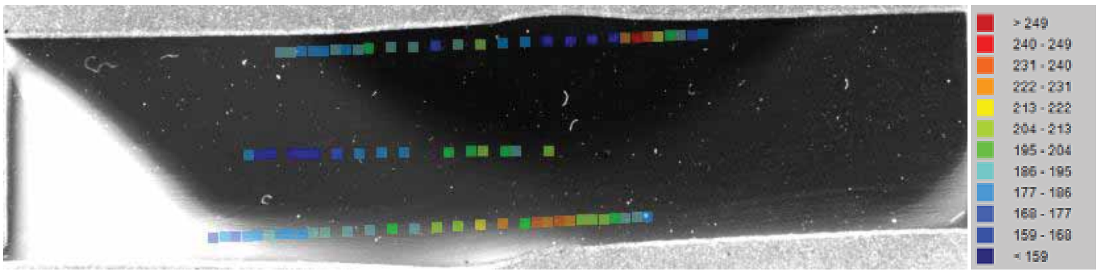


Figure 61, Hardness profile of sample 5

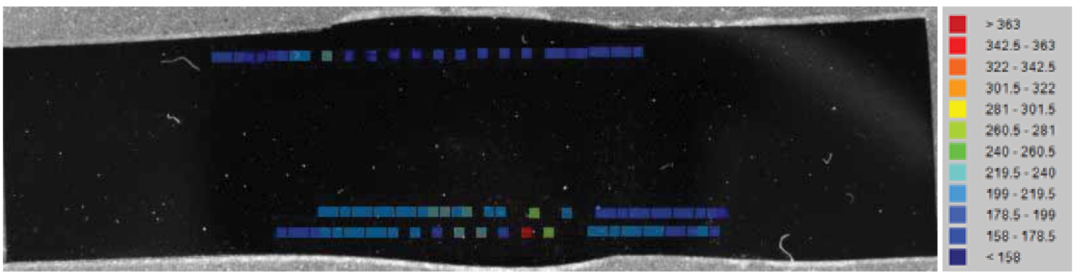


Figure 62, Hardness profile of sample 6

Figure 63-68 shows the hardness values measured at the three different positions of the different samples. The average hardness value in the root bead is between 172-242 HV, with an exception for sample 2 and sample 6 that has increased hardness in the root bead to 411 HV respectively 363 HV.

In the first weld bead the average hardness is 150-230 HV, slightly lower than in the root bead. Sample 6 has an increased hardness of 266 HV in the first weld bead.

In the top weld of the samples, the average hardness is 160-249 HV. Sample 6 have a peak in hardness that is 363 HV in the top weld. Since the hardness measurements were outsourced to SWEREA KIMAB it is not possible to say which side of figures 63-68 that belongs to the low alloyed steel versus the stainless steel.

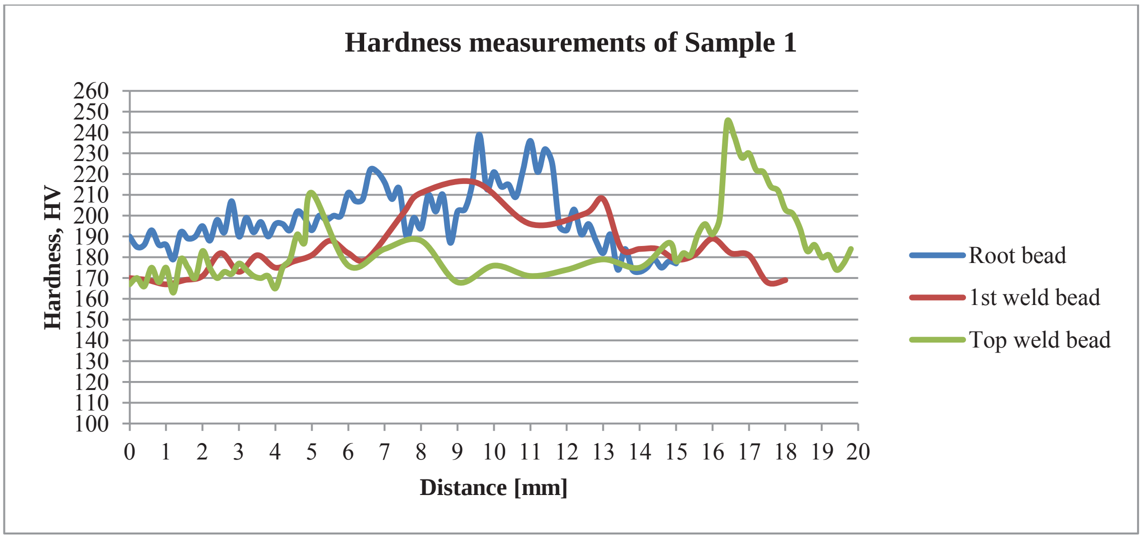


Figure 63, Hardness profile of sample 1

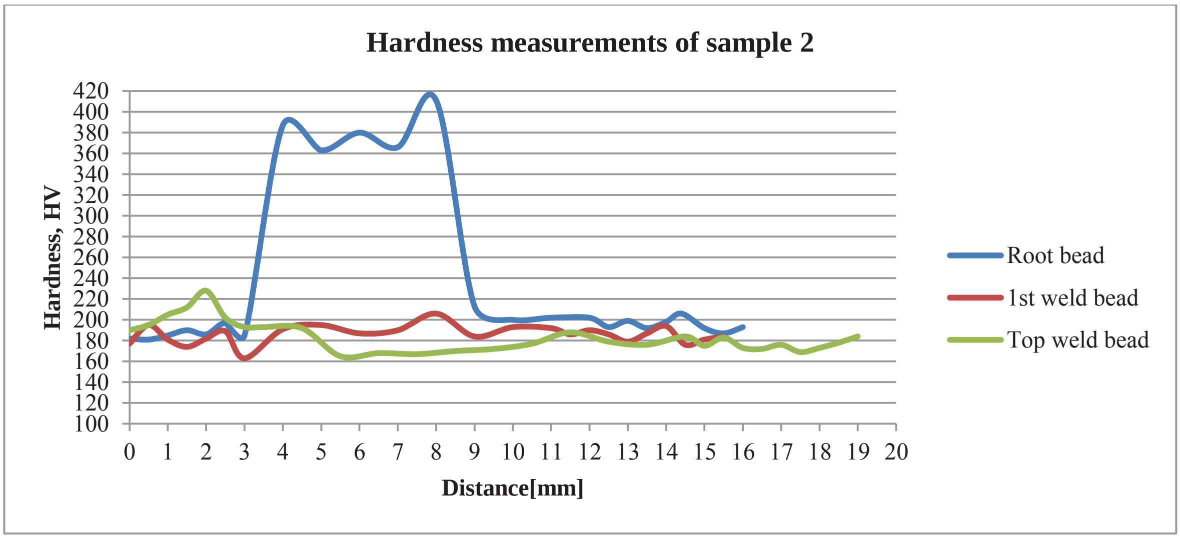


Figure 64, Hardness profile of sample 2

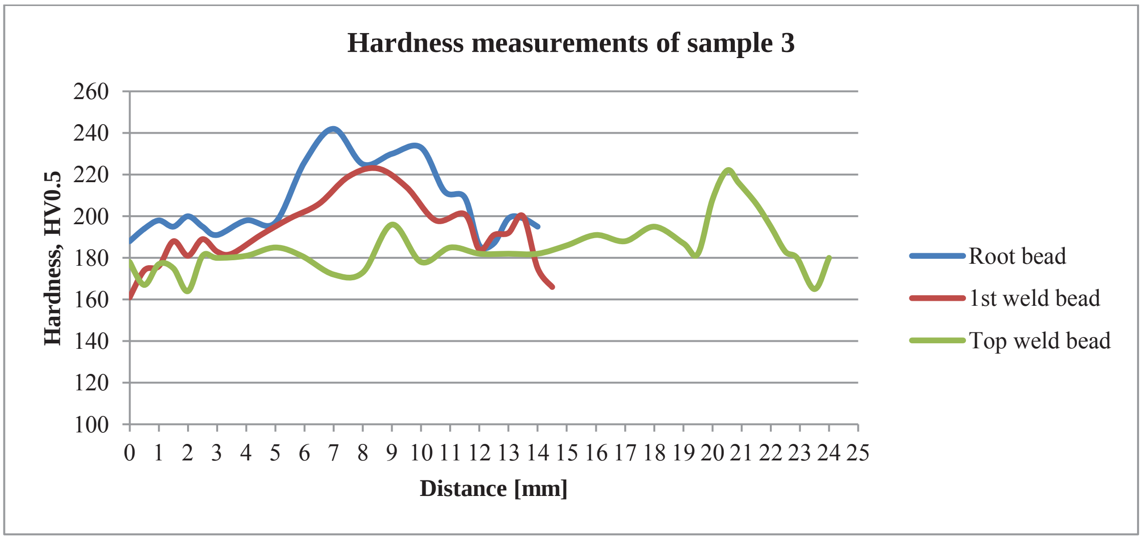


Figure 65, Hardness profile of sample 3

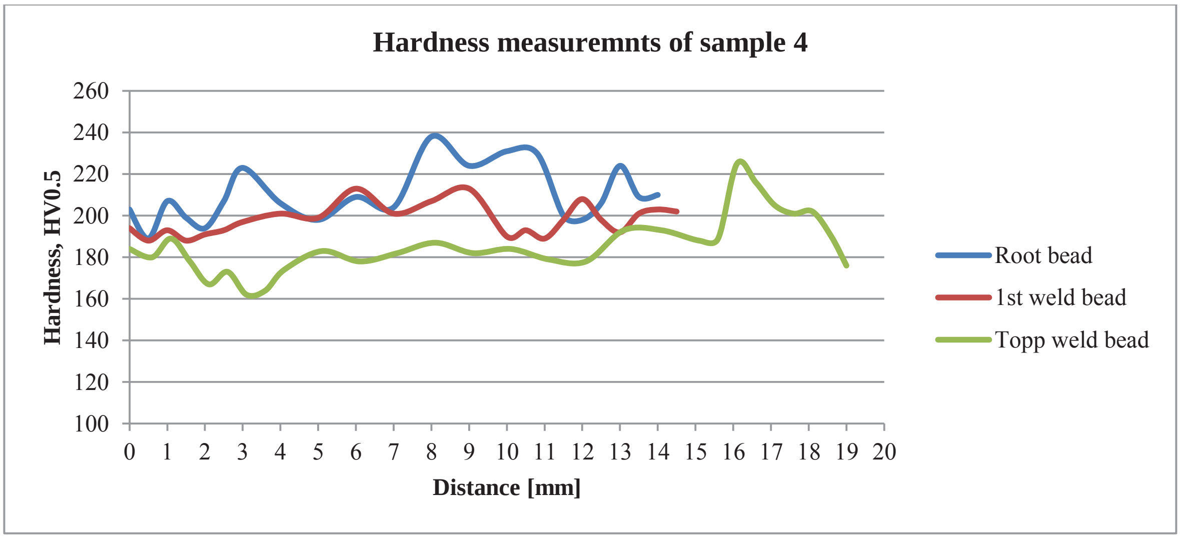


Figure 66, Hardness profile of sample 4

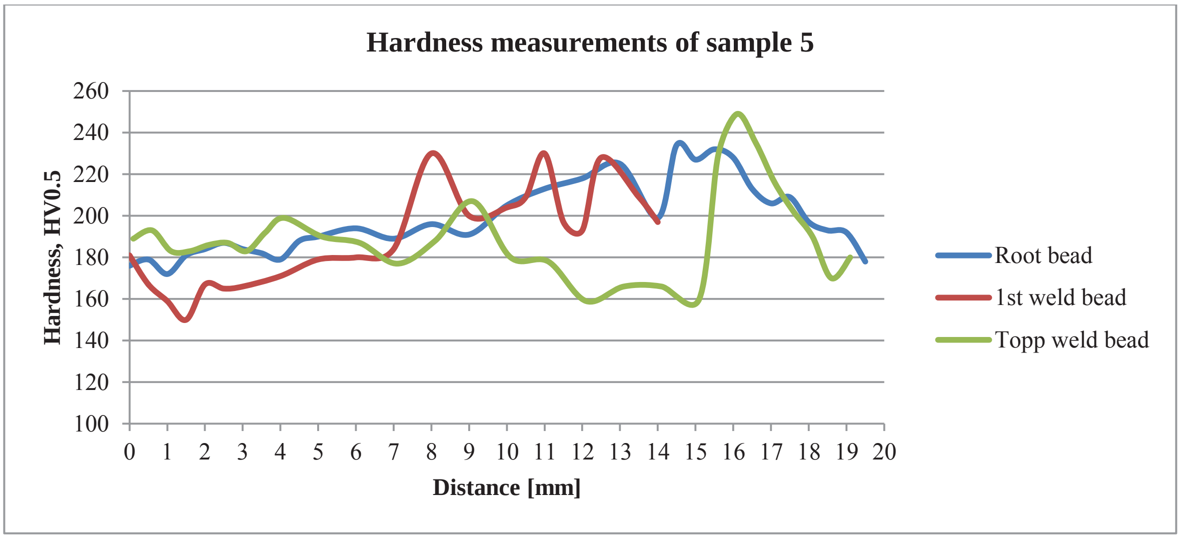


Figure 67, Hardness profile of sample 5

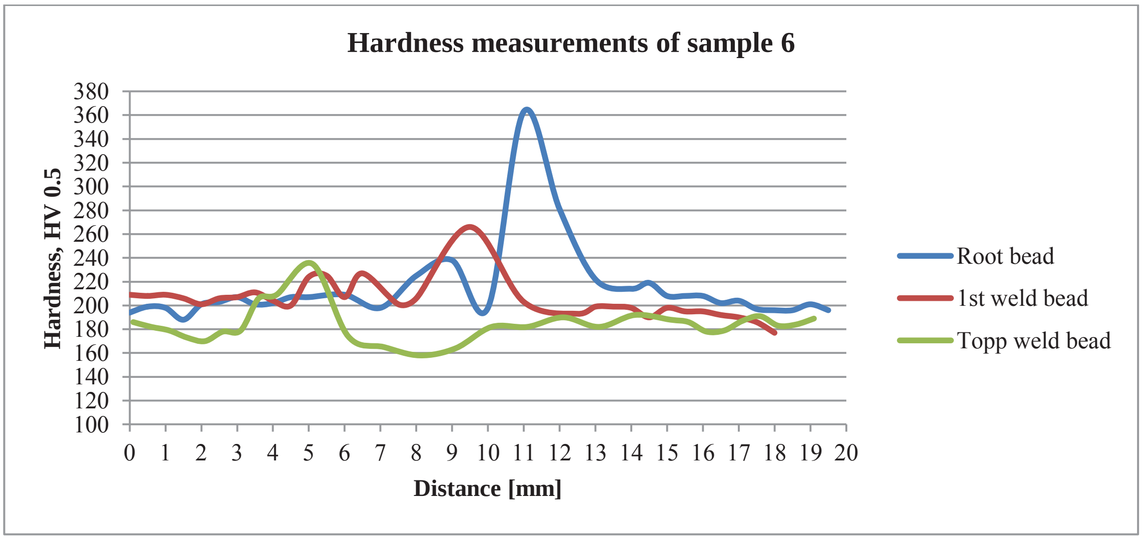


Figure 68, Hardness profile of sample 6

7. DISCUSSION

The preparations before welding are important such as the structure in the weld metal. Therefore, a discussion will be made about the use of the Schaeffler diagram and the importance in the choice of filler metal. The welded samples are evaluated and therefore the following are discussed; the structure in the samples, the chemical analysis and the mechanical properties of the welded samples.

7.1 The use of the Scheffler diagram

The Schaeffler diagram [12] gives a good indication on how the microstructure in a weld metal develops, especially for dissimilar metal welds. As in this case, if the dilution with the filler metal is not sufficient the structure will most likely end up in the martensitic or martensitic and austenitic area instead of the desired austenitic and ferritic area, see figure 16. The root bead and the transition from low alloyed steel to weld metal are the most likely places to find an unwanted structure like martensite.

The technical regulations for mechanical equipment [5] have the requirement of at least 1.5 mm gap to ensure that enough filler metal is diluted in the root bead, see page 1. So the samples welded without gap (sample 2, 4 and 6) has an increased risk of ending up with an unwanted structure in the root bead. In the transition from low alloyed steel to weld metal, carbon from the low alloyed steel could accumulate enough to create martensite.

7.2 The choice of filler metal

As Hajiannia et al. [21] shows in their study, a nickel base filler metal has advantages when welding a dissimilar metal weld between low alloyed steel and stainless steel. However, the nickel based filler metal also has some disadvantages, which are the cost, the risk for hot cracks and IGSCC. Therefore, at the Swedish nuclear power plants, the nickel based filler metal 182 is not permitted without approval from the licensee according to TBM. [5] So in cases where the nickel based filler metal is not necessary the austenitic stainless steel filler metal like 309LMo is a better choice.

7.3 Structure in the samples

The optical microscopy, see figure 20-28, shows that all welds are free from martensitic areas, but small pieces of un-melted low alloyed steel are found adjacent to the transition from low alloyed steel to weld metal, see figure 24. The un-melted parts of low alloyed steel should not affect the strength of the welds. However, only one cross section of each sample is evaluated which makes it possible to have other microstructures on other places in the sample.

7.4 Chemical analysis of the samples

The chemical analysis, see figure 29-47, shows that at several places in several samples an increased chromium and molybdenum content and the same time a decrease of nickel content, which indicates that the measurements are made inside a ferritic area. The element that stabilizes ferrite is chromium, molybdenum, silicon, niobium and titanium. The element that stabilizes austenite is nickel, carbon and manganese as one can see in the Schaeffler diagram, figure 16. According to the Schaeffler diagram

[12] the weld metal should contain around 7 % ferrite, so the possibility to end up in a ferritic area is rather big.

However, the results from the chemical analysis can be questioned if they belong to the right position or the right sample. The length of the measurements does not correspond to the actual length of the weld. Since the chemical analysis is made by KIMAB can the results not be verified any closer.

7.5 Connections between the mechanical properties

The fact that the fracture in the tensile tests occurred in the low alloyed steel and outside the heat affected zone also indicates of a weld metal and heat affected zoned with desirable mechanical properties, see figure 50. A weld with an unwanted structure in the root bead or the transition zone to parent metal would have the fracture there instead. However, the entire cross section of the weld was not tested in the tensile testing due to the shape of the tensile test specimens. Therefore, a root bead with insufficient dilution with the weld metal is not possible to test with these kinds of tensile testing. Instead bend tests were performed on all the samples, both to test the root and the top side of the weld, see page 45-46. Two of the specimens in the transverse root bend test were not approved, see figure 54-55, the two specimens were welded without gap so the conclusion is that there was not enough dilution with the weld metal. Even though that the welds without gap is a U-joint instead of a V-joint. An increased hardness in the root bead can occur due to the faster cooling rate in the root bead compared to the other welds in a multi-pass weld.

A connection to the disapproved bend tests could be drawn to the hardness measurements, the hardness in the root bead of the two disapproved bend tests are unacceptable high with 411 HV and 363 HV respectively in sample 2 and sample 6, see figure 61 and 65. In comparison to the other samples, an increased hardness can be seen in the root bead as well as in the transition zone from parent meal (most likely low alloyed steel) to weld metal, see figure 54-59. Other fluctuations in the hardness can have occurred due to the mixed structure of austenite and ferrite or other particles in the weld metal. No connection between the hardness measurements of sample 2 and 6 can be drawn to the chemical analyses of the samples. The transition from parent metals to weld metal is very sharp, but that is the case for all six samples see figure 26-44.

8. CONCLUSIONS

One important conclusion that can be drawn from this study that the welding position does not affect the structure and mechanical properties of the weld metal in any noticeable way. This means that the criterion in the technical regulations for mechanical equipment that welding should be made in horizontal position is not that necessary. One other important conclusion is that the criteria of a 1.5 mm gap seem to be very important, which can be seen from the results of the bend testing and hardness measurements. The samples welded without gap was a U-joint to increase the dilution with the filler metal in the root bead, but that appeared to not be enough to get a good dilution. A suggestion to the new version of the technical regulations for mechanical equipment could be something like this; *”For dissimilar joints, there shall be a gap of at least 1.5 mm between the weld ends before start of the welding.”*

The conclusions from the study could be summarized to:

- The welding position, horizontal, vertical or reversed vertical does not affect the weld in any noticeable way.
- The gap and a good dilution with the filler metal are extremely important.

9. ACKNOWLEDGEMENTS

I would like to thank my supervisors Bengt Bengtsson at OKG AB and Professor Pål Efsing at KTH for their inputs and support of this project. I would also like to thank OKG AB to making this project possible.

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[26] SS-EN ISO 6947:2011
[27] Dekra Industrial, Repslagaregatan 28, 572 32 Oskarshamn

APPENDIX A: MATERIAL CERTIFICATE 316L

OKG AKTIEBOLAG
– ett företag i Sydkraftkoncernen

OKG Dokumentnr: K015456

Sammanfattningsintyg lagermaterial, rör och rördelar

940415

Artikelnummer	OKG beställningsnummer	Intygsnummer	Revision
67 010 114. CR	32290 pos. E	3093 V	–

Benämning	Dimension	Charge nr.
Sömlösa rör	ø 114,3 x 10 mm	469167

Märkning förutom intygnummer	Kontrollplan + rev
SCHOLLER BLECKMANN SBS – ASTM – A312/ASME – SA312 – TP316L – 114.3 x 10 MM – 469167 – SEAMLESS PIPE No xx. 50	16/2/93 Rev. –

Utgångsmaterial enligt	NGS - nr.	Specifikation slutprodukt
ASTM A312 TP316L	678	

Övrigt Rör nr. 1 – 12
SA-PC 512285-14/5 dat. 93.06.08

Följande provning har utförts i enlighet med KSU - KBM 1 moment enligt nedan

Nr		Provning		Nr		Provning	
1	X	Granskning av OFP procedur	QC-4 3.2	11 2)	X	Tryck - och täthetsprovning	EP 2 - 14
2.	X	Granskning av OFP behörighet	QC-4 3.6	12		RT	EP 2 - 27 / EP 3 - 38
3	X	Chargeanalys 1)	EP 2 - 01	13	X	UT	EP 2 - ~~20/21~~ / 22
4	X	Dragprovning	EP 2 -02	14		MT / PT	EP 2 - 16 / 17, 3 - 16 / 17
5	X	Varmdragprovning 300 °C	EP 2 - 03	15	X	Märkning o identifiering	EP 2 - 09 / ~~4 - 09~~
6		Slagseghetsprovning °C	EP 2 - 04	16	X	Okulär - o dim. kontroll	EP 2 - 13 / ~~4 - 13~~
7		Hårdhetsprovning	EP 2 - 05	17	X	Granskning av slutdok.	EP 190
8	X	Annan teknologisk provning	EP 2 - 06	18			
9	X	Korngränsfrätningsprov gr 1	EP 2 -07	19			
10	X	Värmebehandling	EP 2 - 10	20			

Begränsningar för användande:

Max beräkningstryck – MPa / bar(a) Styrkefaktor –
Max beräkningstemp. – °C

Övriga anmärkningar 1) C = 0,016 , Co = 0,089
2) 143 bar

~~Materialet~~ / rör / ~~rördelar~~ enligt ovan är godkänd för kvalitetsklass 1

OKG QC	Datum	SA - ~~godkännande~~	Datum
[signature] QC/5	950422	Gunnar Edman	950424

Shop Inspection CERTIFICATE
Nuclear Component, Code FTKA

Identification

SA-Client	Manufacturer	Certificate No
OKG AB order 32290 pos. E Oskarshamnsveket 57093 Figeholm Schweden	Schoeller-Bleckmann Edelstahlrohr Ges.m.b.H. Ternitz Österrike	512285-14/5 Plant/Position Oskarshamn 1
Product Nahtlose Rohre kaltgeformt Ø 114,3 x 10 mm	Identification marking Schoeller-Bleckmann SB-SBS-ASTM-312/ASME SA312 TP316L 114,3 x 10 mm 469167 Seamless Pipe No. 1-12	Quality class 1 Material ASTM 316L Grade 1
Quantity 12 St.	Year of manufacturing 1993	Design pressure –
Inspection plan No 16/2/93 Issue –	Drawing No – Issue –	Design temperature –

Inspection

Pos	Checkpoint	Checked (X)	Pos	Remarks
1.0	Quality auditing	–		
1.1	Inspection program	X		
1.2	Design review	–		
1.3	NDT-qualification records	X		
2.1	Material certificates	X		
2.2	NDT-material	X		
3.0	Heat treatment qualification records	–		
3.1	Welding/welders' qualification records	–		
3.2	Welding material	–		
3.3	Welding operations	–		
3.4	NDT-welds	–		
3.5	Heat treatment	–		
4.1	Dimensions	X		
4.2	Visual inspection	X		
4.3	Marking/identification	X		
4.4	Pressure/tightness test	X		
4.5	Performance test (pressure-/temp.-limitations)	–		

Result

[X] Requirements fulfilled	[ ] Requirements fulfilled with remarks

AB SVENSK ANLÄGGNINGSPROVNING - The Swedish Plant Inspectorate

Date	Inspector	Sign	Stamp
93.06.08	B.Jennefors	[signature]	SA 1347

SA 188.1 40blx25 92.01 Datex 08-80 63 15

FINAL INSPECTION DOCUMENTATION

for

SCANDINOX AB S-30241 HALMSTAD SWEDEN

Customer Order No.: SF 550/93 / OKG/32290

Item: 05 Lot No.: 67767 X

Dimension: 114,3 mm OD x 10,00 mm WT

Quantity : 12 pieces 87,51 metres

Table of Contents:

1. CMTR No.10/93
2. Enclosure to CMTR No. 10/93
3. Ultrasonic testing report A
4. Certificate of hydraulic tests No. Wi 93M 073 Stej
5. Heat treatment report No. 118/93
6. Dimensional inspection report (2 pages)
7. NDE personnel names and qualifications (2 pages)
8. Q-Plan No. 16/2/93 Rev. 0 (2 pages)

Confirmation:

According to the requirements of inspection procedure KSU-KBM/EP-190, Edition 1 we Schoeller-Bleckmann Edelstahlrohr G.m.b.H. confirm that the inspection and testing stipulated in the detailed inspection plan (Q-Plan No. 16/2/93 Rev. 0) has been carried out with approved results.

SCHOELLER BLECKMANN
Edelstahlrohr
Gesellschaft m.b.H.
Qualitätssicherung
A-2630 Ternitz

(Ing.Preißler)
QA Manager

AB SVENSK ANLÄGGNINGSPROVNING	
Övervakat ☐	Delvis övervakat ☐
Granskat ☒	Se avv. rapp. ☐
Namn	
Datum 93.06.08	

OKG/93.06.08.

SCHOELLER-BLECKMANN
EDELSTAHLROHR GES.M.B.H

MATERIALPRÜFBERICHT
CERTIFIED MATERIAL TEST REPORT

CMTR - No. 10 / 93

Seite / Page 1 von / of 2

Kunde / Customer: SCANDINOX AB S-30241 HALMSTAD SWEDEN

Kundenbestellung / Customer Order No.: SF 550/93 / OKG 32290 / OKG PROJECT 1-93.087

Werksauftrag Nr. / Works Order No.: 709170/S

Werkstoff/Material (ASME Material Specification, Type and Grade)

TP316L to ASME Sect. II Part A SA-312/SA-312M
1989 Edition up to and including A91 Addendum

Vattenfall Materialspecification No.1.31E Rev.3 Nuclear Quality Class 1

SA approved Q-Plan No. 16 /2/93 Rev.0

Produkt/Abmessung/Stück / Product/Dimension/Piece: Seamless coldformed pipes
solution annealed at 1085 °C. pickled
Item 05: 114.3 mm OD x 10.00 mm Wall 12 pcs 87.51 metres

Los Nr. / Lot No.: 67767

Schmelze Nr. / Heat No.: 469167

Kennzeichnung, Markierung / Identification, Marking: SBS ASTM A312/ASME SA312 TP316L dimension heat no. seamless
pipe no. 1 (till 12) ZFP

Beigelegte Dokumente / Attached Documents: Ultrasonic Testing Report

Nicht durchgeführte Analysen und Prüfungen / Not performed Analyses, Examinations and Tests: none

Chemische Analyse / Chemical Composition

Schmelze Nr. Heat No.	C	Si	Mn	P	S	Cr	Mo	Ni	N	Co
469167	0.016	0.40	1.42	0.024	0.008	16.78	2.03	11.17	0.057	0.089
Product Analysis from each pre-material bar:										
No. 959	0.020	0.40	1.38	0.025	0.009	16.75	2.02	11.27	0.059	0.080
No. 960	0.020	0.40	1.40	0.025	0.008	16.75	2.02	11.30	0.058	0.080
No. 961	0.019	0.40	1.37	0.024	0.008	16.75	2.01	11.18	0.057	0.080
No. 962	0.022	0.40	1.39	0.025	0.009	16.73	2.02	11.30	0.059	0.080
No. 963	0.022	0.40	1.38	0.025	0.009	16.74	2.02	11.23	0.059	0.080

SCHOELLER-BLECKMANN
EDELSTAHLROHR GES.M.B.H

MATERIALPRÜFBERICHT
CERTIFIED MATERIAL TEST REPORT

CMTR - No. 10 / 93

Seite 2 von 2
Page 2 of 2

Ergebnis der mechanischen Prüfungen / Mechanical Test Results

Prüf-Nr. Test-Nr.	Dehngrenze Yield strenght (0.2% offset) MPa	Streckgrenze Yield point MPa	Zugfestigkeit Tensile strenght MPa	Dehnung Elongation L = A4/A5 %	Einschnürung Reduction %	~~Kerbschlagzähigk. Impact Test~~ Test Temperature
67767	262		562	60/55	78	RT
67767	148		430	47/42	78	300°C

AB SVENSK ANLÄGGNINGSPROVNING
Övervakat ☒ Delvis övervakat ☐
Granskat ☒ Se avv. rapp. ☐
Namn
Datum 93.06.03

Weitere Prüfungen
Further Examinations and Tests:

Flattening test from one end of each pipe: ok

Intergranular corrosion test to KSU-KBM/EP-2-07 Group 1
Samples sensitized at 740°C for 30 minutes, boiling practice as per ASTM A262/E:
Not any signs of corrosion are present.

Ultrasonic Examination to KSU-KBM/EP-2-22: ok

Hydrostatic pressure test at 143 bar: ok

QUALITÄTSSICHERUNGS ZERTIFIKAT(MATERIAL) No. QSC-539 **Auslaufdatum:**
QUALITY SYSTEM CERTIFICAT(MATERIAL) **Expires** November 10,1995

Wir bestätigen, daß der Inhalt des Materialprüfberichtes (CMTR) richtig und genau ist und daß alle Prüfergebnisse und Tätigkeiten, die von SB oder von Unterlieferanten durchgeführt wurden, mit den Forderungen der Materialspezifikation und den anwendbaren Materialanforderungen des Code, wie vom Kunden angegeben, übereinstimmen.

We affirm, that the contents of the CMTR are correct and accurate and that all test results and operations performed by SB or SB vendors are in compliance with the requirements of the material specification and the applicable material requirements of the Code as designated by the Customer.

	Ort/Place	Unterschrift/Signature	Datum/date
Leiter der Abnahme **Certification Manager**	Ternitz/Austria	W.Mohr	08/06/93
QS-Leiter QA Manager	Ternitz, Hauptstr.2 Österreich/Austria	P.Preißler	8.6.93

SCHOELLER-BLECKMANN
EDELSTAHLROHR AKTIENGESELLSCHAFT

Enclosure to CMTR No. 10/93

Further Examinations are performed with satisfactory result:

- Visual inspection and dimensional checking
- Inspection of cleanliness and surface finish
- Inspection of packaging and preservation
- Check of marking and indentification

SCHOELLER-BLECKMANN
Edelstahlrohr
Gesellschaft m. b. H.
Abnahme
A-2630 Ternitz

08/06/93

W. Mohr
Certification Manager

SCHOELLER-BLECKMANN
Edelstahlrohr
Gesellschaft m.b.H.
Qualitätssicherung
A-2630 Ternitz

8.6.93

P. Preißler
Q A Manager

TELEFON
TELEPHONE
(0 26 30) 311
DVR 0648078

SCHOELLER-BLECKMANN EDELSTAHLROHR AKTIENGESELLSCHAFT. HAUPTSTRASSE 2, A-2630 TERNITZ, AUSTRIA
HANDELSRECHTLICHER SITZ/COMP. REG. OFFICE. HAUPTSTRASSE 2, A-2630 TERNITZ, AUSTRIA
RECHTSFORM: AKTIENGESELLSCHAFT.
FIRMENBUCH-NR./COMMERCIAL REGISTER NO.: HRB 3083, FIRMENBUCHGERICHT/REGISTER COURT: WR. NEUSTADT
BANKVERBINDUNGEN/BANK ACCOUNT: CREDITANSTALT-BANKVEREIN, BLZ 11000, KTO 0324-05722700,
BANK AUSTRIA AG, BLZ 12000, KTO 108.108.957/00, PSK, BLZ 60000, KTO 7376.696

171.801/R

Verteiler: Distribution: TQT/ABA, TQW/ZFP, TPA	
R-TQW/ZFP 6 /93	**ULTRASCHALL PRÜFUNG / ULTRASONIC TESTING** UT — **PRÜFBERICHT A / REPORT A**
Werks-Auftrag / Works-order: 709.170/ S	Pos. / Item: 05
EKK (FP/WP) Nr. / Traveller (FP/WP) No.: 67767 X	
Nr. / No.: Wi 93 M 073 / Stej	Seite / page 1 von / of 1
Schritt/Prüf-Nr. / Step/Test no.: 290/330	Schweißplan-Nr. / Welding-schedule-No.: –
Prüfobjekt / Test object: seamless tubes	Rahmenvorschrift / Main specification: ASME SA 312/ SA 312M 89 ED, VATTENFALL 1.31E Rev. 3 Nuclear Class 1
Besteller / Purchaser: Scandinox AB, Kristinebergsvaegen 24 S 30241 Halmstad, Sweden	Prüfvorschrift / Specification: KSU-KBM/ FP2-22 KSU-KBM/ QA - 6 and TELEFAX from 3.5.1993 from 1. January 1988
Bestell-Nr. / Order No.: SF 550/93 from 27.4.93	ZfP-Arbeitsvorschrift / NDE-procedure: AV 098/74 Rev 1
Stückzahl / Quantity: 12 (No 1 - 12) — Gewicht / Weight: – kg	Beurteilungsstandard / Evaluation standard: AV 098/74 Rev.1
Kennzeichnung / Identification: ZFP (T 2)	Prüfbereich / Inspect. area: full length of tube
Abmessung / Dimension: ø 114,30 x 10,00 x appr. (7300 -7500) mm appr. 90 m	Prüfumfang / Insp. coverage: Producer: 100 % — TÜV-Austria: at random Tube-no.: 3, 8
Werkstoff / Material: TP 316 L	Oberflächenzustand / Surface condition: cold formed, heat treated and pickled
Schmelze-Nr. / Heat-No.: 469 167	Anmerkungen / Remarks: Test-method: Immersion-technique
Wärmebehandlung / Heat treatment: heat treated	
Fertigungszustand / Stage of production: finished (production length)	
Zeichnungs-Nr. / Drawing No.:	
Fabrikat und Type des Prüfgerätes / Equipment, producer and type: Messrs. TRC designation TRC 8000	Registriergrenze / Recording level: Indication hight of reference notches
Prüfanlage Nr. / Test equipment-no: –	Prüfköpfe / Probes: Messrs. TRC
Prüftechnik / Test method: pulse-echo-method	Type / Type: line-focussed
Testrohr-Nr. / Test tube-no: 1367	Frequenz / Frequency: 4 MHz
Einstelldaten / Calibration data: –	Einschallrichtungen / Scanning directions: both circumferential-and both longitudinal directions
Verschubgeschwindigkeit / Test speed: 2,41 m/min	Koppelmittel / Couplant: water
Drehzahl / Revolutions: 100 rpm	Referenzfehler / Referencereflector: longitudinal notches outside/inside) — Transverse notches outside/inside)
Impulsfolgefrequenz / Pulse-repetition-frequency: 700 Hz	Length: 25,00 mm — 25,00 mm; Width: 1,42/1,46mm — 1,41/1,39mm
Impulsdichte / Pulse-density: 0,86 mm/pulse	Depth: 0,46/0,53mm — 0,48/0,48mm
Prüfort / Place of exam.: Ternitz/TPA — Datum / Date: 1993-06-07	Prüfer/Stufe / Operator/Level: [signature] III 1993-06-07
Prüfergebnis: Entspricht /-~~entspricht nicht der~~ Vorschrift*) / Test result: Within /-~~not within~~ specification *)	Prüfverantwortlicher/Stufe / Supervisor/Level: [signature] III 1993-06-07
	Kunde / Customer:
	Gutachter/Sachverst. / Authorized Inspector: 07.06.1993 [signature]

*) Nichtzutreffendes streichen / erase incorrect statement

CEOC/B - 7/72 e/d

C. E. O. C.

(Colloque Européen des Organismes de Contrôle)

CERTIFICATE OF HYDRAULIC TESTS
ZEUGNIS ÜBER WASSERDRUCKPRÜFUNGEN

Certificate
Zeugnis
No. Wi93M 073 Stej

NAME AND ADDRESS OF INSPECTION ORGANIZATION
NOM ET ADRESSE DE L'ORGANISME DE CONTROLE

Technischer Überwachungs-Verein Österreich
A-1015 Wien, Krugerstraße 16

Member of the
Mitglied des COLLOQUE EUROPEEN DES ORGANISMES DE CONTROLE (CEOC)

Works Order No.: 709.170/S
Herstell No.

Year of manufacture: 1993
Herstelljahr:

Maker: Schoeller-Bleckmann Edelstahlrohr GmbH., Ternitz/Austria
Hersteller:

Dimension: 114.3 x 10.0 mm
Abmessung:

Lot No.: 67767
No. of pieces: 12

Date and place of tests: 08/06/93 Ternitz/Austria
Druckprüfung: Datum—Ort:

Name of inspecting engineer: Mr. Göppert
Name des Sachverständigen:

The pipes whose identification details are stated above has been hydraulically tested under the conditions specified below:

Die oben bezeichnete Rohre wurde einer Wasserdruckprüfung unter folgenden Bedingungen unterzogen:

Test pressure: 143 bar
Prüfdruck:

Duration: 5 seconds minimum
Dauer:

Type of gauge: DP 11 / DP 50
Manometer:

Results: within specification
Befund:

Date
Datum 08/06/1993

Technischer Überwachungs-Verein Österreich

Signature
Unterschrift

SCHOELLER-BLECKMANN EDELSTAHLROHR GES.M.B.H	S	WÄRMEBEHANDLUNGS - PROTOKOLL (Durchlaufofen) HEAT TREATMENT - REPORT (Continuous furnace) No.: 118/93	Seite von Page 1 of 1

Kunde Customer	Kundenauftrag Customer Order	Projekt Project	Werksauftrag Works Order	Pos. No. Item
Scandinot AB	57550 /93 OKG 32290 /OKG	1-93.087	909170/S	05/01

Qualität Quality	Schmelze No. Heat	Erzeugnis Product	Abmessung Dimension
A200	469167	nahtl. Edelstahlrohre	114,30 x 1900

Stück/Gewicht Piece/Weight	WÄRMEBEHANDLUNGSVORSCHRIFT HEAT TREATMENT PROCEDURE			Laufkarte No. Traveler	Schritt No. Connect.
12 Stk 2464 kg	AV 093/30, Rev.2			67767/X	250
	Temperatur Temperature	Haltezeit Holding time	Abkühlmedium Cooling medium		
	1050-1100°C	10 min	Wasser		

WÄRMEBEHANDLUNGS - DURCHFÜHRUNG / HEAT TREATMENT - PERFORMANCE

Wärmebehandlungsbetrieb : Heat treatment shop	TPK/GL
Wärmebehandlungsbeginn / Datum / Uhrzeit : Heat treatment start / Date / Time	93-05-26 6Uhr55
Wärmebehandlungs - Aggregat : Heat treatment - Furnace	RoDR 6000
Art der Wärmebehandlung : Type of heat treatment	Abschrecken
Aufheizgeschwindigkeit : (K/h) Heat up speed	———
Ofen-oder Stücktemperatur in der Ausgleichszone : Furnace-or piece temperature in equalizing zone	1085°C
Durchlaufgeschwindigkeit :(m/h) Travel speed	48 m/h
Haltezeit : (min) Holding time	10 min
Abkühlmedium : Cooling medium	Wasser

Anmerkung / Remark	Es wird bestätigt, daß die Durchführung der Wärmebehandlung anhand der Ofen - Temperaturstreifen mit der oben genannten Vorschrift (AV) verglichen wurde und mit dieser übereinstimmt. This certified heat performance of heat treatment was compared with the procedure (AV) against the time temperature chart and is in accordance with it.

Erstellt/Prepared		Genehmigt/Approved	
Betrieb/Shop	TPK/GL	Abteilung/Department	TQT
Datum/Date	93-06-02	Datum/Date	03/06/93
Unterschrift/Signature	[signature]	Unterschrift/Signature	[signature]

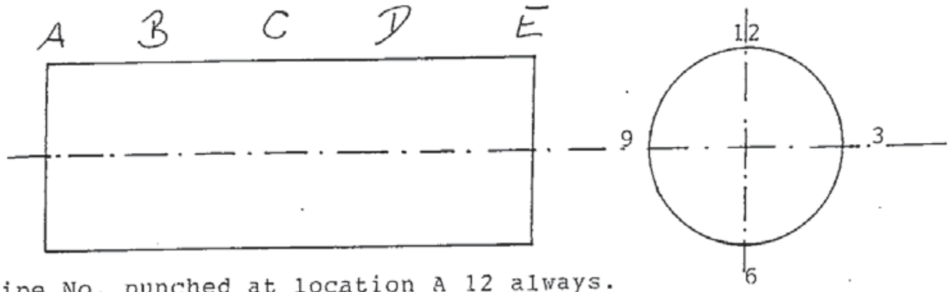
SCHOELLER-BLECKMANN

DIMENSIONAL CHECK LIST

SHEET 1 OF 2

Lot No.: 67767X

Size No.: 114,3 x 10 mm



Pipe No. punched at location A 12 always.

Pipe No.	Length (mm)		WALL THICKNESS AT LOCATION (mm) A	B	C	D	E
7	7360	12	10,6	10,7	10,8	11,0	11,0
		3	10,8	11,0	11,0	11,0	11,2
		6	11,1	10,8	10,6	10,7	10,7
		9	10,7	10,8	10,7	10,8	10,6
1	7360	12	11,0	10,8	10,6	10,6	10,5
		3	11,0	11,2	11,3	11,2	11,2
		6	10,8	10,8	11,0	10,8	11,0
		9	10,8	10,5	10,4	10,4	10,4
2	7340	12	10,8				11,2
		3		10,8			
		6			11,0		
		9				10,6	
12	7140	12	10,8				11,0
		3		10,8			
		6			11,2		
		9				10,6	
10	7120	12	11,0				11,2
		3		11,2			
		6			10,8		
		9				10,8	
9.	7280	12	10,8				11,0
		3		11,2			
		6			11,0		
		9				10,4	

1993 -06- 08 [signature]
Date / Signature

AB SVENSK ANLÄGGNINGSPRO...
Övervakat ☑ Delvis övervakat ☐
Granskat ☐ Se avv. rapp. ☐
Namn [signature]
Datum 93.06.03-08

200.013 SB Druckerei Horrmann

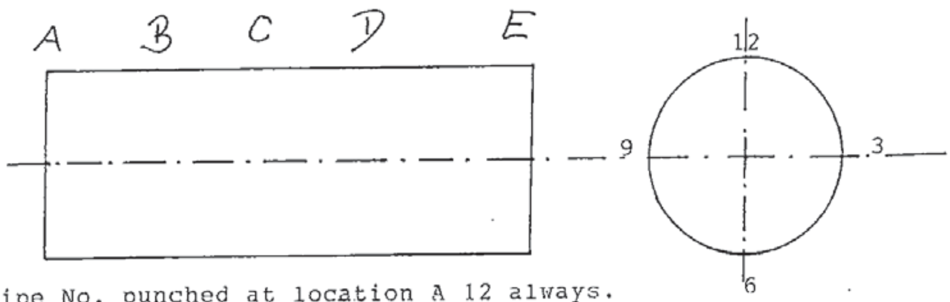
SCHOELLER-BLECKMANN

DIMENSIONAL CHECK LIST

SHEET 2 OF 2

Lot No.: 67767X

Size No.: 114,3 x 10 mm



Pipe No. punched at location A 12 always.

Pipe No.	Length(mm)		WALL THICKNESS AT LOCATION (mm) A	B	C	D	E
6.	7230	12	10,8				11,2
		3		11,0			
		6			10,8		
		9				10,8	
4	7430	12	11,2				11,2
		3		11,2			
		6			10,6		
		9				11,0	
3	7410	12	10,9				11,2
		3		11,0			
		6			11,0		
		9				10,5	
5	7400	12	10.8				10.8
		3		10.8			
		6			10.8		
		9				10.7	
8	7340	12	10.8				10.8
		3		10.8			
		6			11.1		
		9				10.9	
11	7180	12	10.9				11.1
		3		10.8			
		6			10.7		
		9				10.8	

1993 -06- 08 Lecher

Date / Signature

AB SVENSK ANLÄGGNINGSPROVNING
Övervakat ☒ Delvis övervakat ☐
Granskat ☐ Se avv. rapp. ☐
Namn [signature]
Datum 93.06.03 - 08

200.013 SB Druckerei Herrmann

Erneuerungen der Prüfberechtigung
Recertifications

Die Erneuerung erfolgt gemäß SNT-TC-1A, ÖNORM M 3040 und SB -ZfP Ausbildungs- und Zertifizierungshandbuch aufgrund ununterbrochener, zufriedenstellender Prüftätigkeit.

Recertification in accordance with SNT-TC-1A, ÖNORM M 3040 and SB -NDE Training and Certification manual on the basis of continuing satisfactory performance.

Verfahren / Method	Stufe / Level	Datum der Erneuerung / Date of recertification	Unterschriften / Signatures	
UT	III	05.06.1992	Dr.Stiebellehner	Dr.Wedl
ET	III	05.06.1992	Mag.Trebsche	
MT	III	07.12.1992	Dr.Stiebellehner	Dr.Wedl
PT	III	07.12.1992	Mag.Trebsche	
VT	III	07.12.1992		

Die Prüfberechtigung und deren Erneuerung sind auf einen Zeitraum von jeweils 3 Jahren begrenzt.

Certification and recertification are limited to a period of 3 years.

SCHOELLER-BLECKMANN

PRÜFBERECHTIGUNG

für Prüfpersonal in
der zerstörungsfreien
Werkstoffprüfung

NDE PERSONNEL CERTIFICATE

Name / Name :

Ing. POSCH Franz

Verfahren / Method +)	UT			RT			MT			PT			ET			VT		
Stufe / Level +)	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III

+) Nichtzutreffende Verfahren und Stufen streichen
Erase non applicable methods and levels

ÖGfZP
NDT
ÖSTERREICHISCHE GESELLSCHAFT FÜR ZERSTÖRUNGSFREIE PRÜFUNG

A-1015 WIEN, KRUGERSTRASSE 16, TELEFON (0222) 512 18 07

UJ-II / 12324

ZEUGNIS

Herrn
BLEYER Ludwig

GEB. AM 11.11.1963 IN Neunkirchen
HAT DEN FACHKURS ZUR QUALIFIKATIONSSTUFE II
FÜR Ultraschall
IN DER ZEIT VOM 17.09.90 BIS 05.10.90
AN DER AUSBILDUNGSSTELLE
Voest Alpine Stahl Linz Ges.m.b.H.
BESUCHT UND DIE FACHPRÜFUNG MIT ERFOLG ABGELEGT.
AUSBILDUNGSZEIT UND ERFOLG DER EINZELNEN PRÜFUNGSABSCHNITTE
ENTSPRECHEN DER ÖNORM M 3040.

VORSITZENDER: Ing. Balas

PRÜFER: Ing. Moser

WIEN, AM 05.10.90

FERTIGUNGS- UND PRÜFFOLGEPLAN

FABRICATION- AND TESTING PLAN

Q-PLAN No. 16/2/93

KUNDE: SCANDINOX AB
CUSTOMER:

KUNDENAUFTRAG: SF 550/93
CUSTOMER ORDER:

PROJEKT: OKG PROJECT NO. 1.-93.087
PROJECT: OKG P.O. 32290

PRODUKT: Nahtlose Rohre kaltgeformt
PRODUCT: seamless tubes cold formed

WERKSTOFF: TP 316L NUCLEAR GRADE 1
MATERIAL:

SPEZIFIKATION: VATTENFALL Mat.Spec.No.1.31E Rev.3 NC1- ASTM A312/A312M-91b
SPEZIFICATION: ASME II Part.A SA312/SA312M-1989Ed. A91Add.

WERKSAUFTRAG: 709.170/S
WORKS ORDER:

POS. NR.: 05 114,3 x 10,00 mm
POS. NO.:

ABNAHME:
INSPECTION:

1 Betrieb/Manufacturer
2 Qualitätsstelle/Quality Controll Department
3 Kunde/Customer
4 Third Party Inspection "SA"
KSU-KBM QC-1-Symbols acc. spec.1.31E Rev.3
5 Be performed at OKG

BEMERKUNGEN:
NOTES:

H Hold Point
W Witness Point
R Review

GENEHMIGUNG DURCH KUNDEN: 29.04 93
CUSTOMERS APPROVAL:

SA Rev. 0 Approved 1993-04-29 SA 3533

SEITE: 1 VON 2
PAGE: OF

0	93/04/28	TQT	TQT	TQS
REV.:	DATUM: DATE:	ERSTELLT: PREPARED:	GEPRÜFT: REVIEWED:	FREIGEGEBEN: APPROVED:

171.745 R

SCHOELLER - BLECKMANN
EDELSTAHLROHR GES.M.B.H

Q-PLAN NO.: 16/2/93

SCHR.NR. SEQ. NR.	BESCHREIBUNG DESCRIPTION	SPEZIFIKATION SPECIFICATION	ATTESTE CERTIFICATES	ABNAHME / INSPECTION				
				1	2	3	4	5
	Review of NDE-procedures	KSU-KBM/QC-4 Ed.1		X		R	R	
	Review of NDE-competence	KSU-KBM/QC-4 Ed.1		X		R	R	
1.	**Starting Material**							
	Stock material (forged bars)							
1.1	Receiving inspection			X	X			
2.	**Pipe Production**							
2.1	Preparing of billets	QA-Manual, Sect.15		X				
2.2	Hotforming (piercing, extrusion to pipes)	QA-Manual, Sect.15		X				
2.3	Cold forming to final dimension	QA-Manual, Sect.15		X				
2.4	Final heat treatment	KSU-KBM EP-2-10 Ed.1 AV 043/30 Rev.2	CMTR	X	X			
2.5	Straightening	QA-Manual,Sect.15		X				
2.6	Pickling	AV 112/44 Rev.1		X				
2.7	Sampling	QA-Manual,Sect.13 KSU-KBM EP-2-09		X			H	
2.8	Mechanical and metallurgical tests				X			
	A Tensile test	KSU-KBM EP-2-02 Ed.1	CMTR		X		H	
	B Hot tensile test at 300°C	KSU-KBM EP-2-03 Ed.1	CMTR		X		H	
	C Corrosion test (ASTM A262 Pract. E) temp./time for senzitizing 740+/-5°C/30 min.	KSU-KBM EP-2-07(Gr.1) Ed.1	CMTR		X			
	D Flattening test	KSU-KBM EP-2-06 Ed.1	CMTR		X		H	
	E Charge analysis	KSU-KBM EP-2-01 Ed.1	CMTR		X			
2.9	Ultrasonic test at random	KSU-KBM EP-2-22 Ed.1 AV 098/74 Rev.1	CMTR / UT-Report		X		H	
2.10	Hydrostatic test (143 bar)	KSU-KBM EP-2-14 Ed.1	CMTR	X	X		H	
2.11	Cleanliness			X				
2.12	Marking	KSU-KBM EP-2-09/4-09 Ed.1			X	H	H	H
2.13	Inspection	KSU-KBM EP-2-13/4-13 Ed.1			X	H	H	H
2.14	Certification	KSU-KBM EP-190 Ed.1	CMTR		X	H	H	
2.15	Packing	QA-Manual, Sect.18 KSU-KBM EP-435 Ed.1		X				
2.16	Dispatch	QA-Manual, Sect.18		X				

APPENDIX B: MATERIAL CERTIFICATE 15Mo3

OKG

Art nr 71010 114 BR

SAMMANFATTNINGSINTYG LAGERMATERIAL, RÖR OCH RÖRDELAR	Intygsnummer: 2524 F

Benämning ≈ 31 m	Dimension	Charge No
Sömlösa rör	ϕ 114,3 × 10,0	529473

Material/leveransspecifikation + rev		Kontrollplan + rev
DIN 17175 05 79		2006 5
Utgångsmaterial enligt	**NGS-nummer**	**Specifikation slutprodukt**
15 MO3/III	413	
Övrigt		**Datum för utförd/redovisad provning vid tillverkning**

Följande provning har utförts: KSU-KBM 1

			moment				moment
1	[X]	Granskning av OFP proc. ..	QC4 3.2	*) 11	[X]	Tryck- och täthetsprovn...	EP 2-14
2	[X]	Granskning av OFP kval. ..	QC4 3.6	12	[ ]	RT	EP 2-27/3-28
3	[X]	Analys	EP 2-01	13	[X]	UT	EP 2-20/21/22
4	[X]	Dragprovning	EP 2-02	14	[ ]	MT/PT	EP 2-16/17, 3-16/17
5	[X]	Varmdragprovning +300 °C	EP 2-03	15	[X]	Materialidentifiering	EP 2-09/4-09
6	[X]	Slagseghetsprovning −10	EP 2-04	16	[X]	Okulär- och dim kontroll...	EP 2-13
7	[ ]	Hårdhetsprovning	EP 2-05	17	[X]	Granskning av slutdok	EP 1-90
8	[X]	Annan teknisk provning ..	EP 2-06	18	[ ]	....	
9	[ ]	Korngränsfrätningsprov ..	EP 2-07	19	[ ]	....	
10	[X]	Värmebehandling	EP 2-10	20	[ ]	....	

Begränsningar för användande:

Max ber. tryck .... Styrkefaktor ....

Max ber. temp .... Övriga upplysningar ....

Övriga anmärkningar: *) Enl. S.E.P 1925

Materialet/rör/rördelen är godkänd enligt ovan för kvalitetsklass 1

Simpevarp 900708	Simpevarp 900122
[signature]	[signature]
OKG AB, TLK	AB Statens Anläggningsprovning

AB Statens Anläggningsprovning
The Swedish Plant Inspectorate

INTYG över produktkontroll – Kärnkraft
Shop Inspection CERTIFICATE – Nuclear Component

Identifikationsuppgifter/Identifications

Uppdragsgivare/SA-Customer: OKG AB Auftrag 83702 Oskarshamusverket	X 1:a kontr/1st inspection Omkontroll/Reinspection		Intygsnr/Certificate no: 765081-03
Objekt/Component: Nahtl.Rohre 114,3 x 10,0	Objekttyp/Comp type[1]: R	Kontr.kl/Insp.class: 1	Material/Material[1]: 15Mo3/III
	Antal/Number of: 6	Märkning/Identification marking: 529473	
Tillverkare/Manufacturer: Benteler Werke AG 4220 Dinslaken	Ber tryck/Design pressure: ------ bar		Ber temp/Design temp: ------ °C
	Tillv nr/Serial no: Rohr-Nr.1;12;14;13;9		Tillv år/Year: 1989
Avsett för (anläggning och platsbet)/Destinated for: Oskarshamn block 1;2;3	Kontrollplan nr/Insp plan no: OKG 2006		Rev/Issue: 5
	Ritning nr/Drawing no: ------		Rev/Issue: -----

Kontroll/Inspection

Pos	Kontrollpunkt/Inspection point	Check (X)	Pos	Anmärkningar/Remarks	Kod[3] Code
1.1	Kontrollplan/Inspection plan	X			
1.2	Ritning/Drawing	--			
2.1	Materialintyg/Material certificate	X			
2.2	Ofp, material/NDE, material	X			
3.1	Svetslic, svetsarprövn/Welding qualific.	--			
3.2	Ofp, svets/NDE, welds	--			
3.3	Värmebehandling/Heat treatment	--			
4.1	Dimensionskontroll/Dimensions	X			
4.2	Okulärkontroll/Visual inspection	X			
4.3	Materialident/Material identification	X			
4.4	Tryckprov/Pressure test bar medium	--			

US-Prüfung R 5 wird bei OKG wiederholt.

Resultat/Result

X Motsvarar ställda krav/Conforming to requirements

☐ Motsvarar ej ställda krav/Not conforming to requirements

AB Statens Anläggningsprovning
Kärnkraftavdelningen, Stockholm

Datum/Date	Namn/Name	Anställningsnr/No	Signatur
89-05-24	H.Detmer	570	

1) 2) 3) Se omstående/See overleaf

SA 237 2 000/++ 85.02 ZATA A 50884

CEOC

CONFEDERATION EUROPEENNE D'ORGANISMES DE CONTROLE

Rheinisch-Westfälischer
Technischer Überwachungs-Verein e. V.

Abnahmeprüfzeugnis
Inspection Certificate
Certificat de Réception
Certificato Collaudo Materiali

(DIN 50049-3.1 A)

Prüf-Nr. – Inspection No – Certificat N° – N° di collaudo: 2/22003050/2
Teil – Part – Partie – Parte: 001
Blatt-Nr. – Sheet No. – Page-N° – Pag-N°: 1

Bestell-Nr. – Order No – N° de la commande – N° dell'ordine: 4-3659
vom – dated – date – in data: 12.12.88
Werks-Nr. – Works-No – N° usine – Commessa N°: 39-2472

Besteller – Customer – Acheteur – Committente:
ROEHRENGROSSHANDLUNG L. BARTHEL KG.
4000 DUESSELDORF HAMBURGER STR. 8

Hersteller – Manufacturer – Fabricant – Produttore:
BENTELER-WERKE AG
4220 DINSLAKEN LUISENSTR. 117

Prüfgegenstand – Article – Produit – Prodotto:
NAHTLOSES ROHR

Prüfgrundlagen/Anforderungen – Technical requirements/Demand – Spécifications techniques/Exigences – Norma di controllo/Requisiti:
TRB 100 / TRD 102 / AD-MERKBL. W4.

Werkstoff – Material – Matière – Materiale: 15MO3
entsprechend – according to – suivant – secondo: (1.5415) DIN 17175
Ausgabe – Edition – Edizione: 05.79

Lieferzustand – State of delivery – Etat de livraison – Stato di fornitura: NORMALISIEREND UMGEFORMT
Erschmelzungsart – Melting process – Procédé d'élaboration – Procedimento di elaborazione: ELEKTRO-VERFAHREN (E)

Kennzeichnung – Marking – Marquage – Punzonature:
15MO3
ROHR-NR.
US

Herstellerzeichen – Brand of the manufacturer – Marque du fabricant – Marchio del produttore: B3

(3) Stempel des Sachverständigen – Inspector's stamp – Poinçon de l'expert – Punzone dell'ispettore: T4U

Pos.-Nr. Item-No Poste-N° N° pos.	Stückzahl No of pieces Qté Numero pezzi	Gegenstand – Article – Désignation du produit – Tipo di prodotto	Schmelze-Nr. Heat No N° Coulée N° Colata	Probe-Nr. Test No N° d'éprouvette N° di prova
003	235	NAHTLOSES ROHR AD=31,80MM S=3,20MM GL=1545,30M IN TL VON 5-7 M. GRUPPEN-NR.: 1 -127	529638	00026 03
003		-"-	529638	00074 03
015	31	NAHTLOSES ROHR AD=114,30MM S=10,00MM GL=165,68M IN TL VON 5-7 M GRUPPEN-NR.: 1 -16	529473	00007 15
015		-"-	529473	00013 15

Zusätzliche Angaben – Additional remarks – Autres remarques – Osservazione:

Die gestellten Anforderungen sind lt. Anlagen erfüllt. – The requirements are fulfilled acc. to Annex. – Les conditions imposées sont satisfaites suivant annexes. – I risultati sono conformi ai requisiti richiesti come da allegati.

DUISBURG
(Ort – Location – Lieu – Località)

10.02.1989
(Datum – Date – Data)

Technische Überwachung Bezirk 4 TÜ 4

(Der Sachverständige – Inspector – L'expert / L'ispettore)

Anlagen – Annexes – Annexes – Allegati:
1) Ergebnis der Prüfungen – Test results – Résultats des essais – Risultati delle prove

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CEOC
CONFEDERATION EUROPEENNE D'ORGANISMES DE CONTROLE

Ergebnis der Prüfungen
Test Results
Résultats des Essais
Risultati delle Prove

Rheinisch-Westfälischer
Technischer Überwachungs-Verein e. V.

Anlage – Annex – Annexe – Allegato: 1

Prüf-Nr. – Inspection No – Certificat N° – N° di collaudo: 2/22003050/2
Teil – Part – Partie – Parte: 001
Blatt-Nr. – Sheet-No – Page N° – Pag N°: 2

Mechanische Prüfungen – Mechanical tests – Essais mecaniques – Prove meccaniche

Prüfart – Test type – Type d'essai – Tipo di prova:
Probenart – Specimen type – Type de l'éprouvette – Tipo di provetta: ZUGVERSUCH. ZUGPROBE
Probenzustand – specimen condition – Etat d'éprouvette – Stato delle provette:

Probe-Nr. / Test No / N° d'éprouvette / N° di prova; Schmelze-Nr. / Heat No / N° Coulée / Colata N°	Probenabmessung – Dicke / Thickness / Epaisseur / Spessore mm	Probenabmessung – Breite, Ø / Width, Ø / Largeur, Ø / Largh., Ø mm	Probenentnahme – Ort – Location / Lieu – Zona	Richtung / Direction – Senso	Lage – Position / Posizione	Prüftemperatur / Test temperature / Température d'essai / Temperatura di prova °C	Streck-/Dehngrenze / Yield point / Proof stress / Limite d'élasticité / Lim. di snervamento REH N/mm²	Zugfestigkeit / Tensile strength / Résistance à la traction / Carico di rottura Rm N/mm²	Bruchdehnung / Elongation / Allongement / Allungamento A Lo = 5DO %	Brucheinschnürung / Reduction of area / Striction / Strizione Z %		Werte – Values – Valeurs – Valori 1	2	3	Σ/n	Bemerkung / Remarks / Remarques / Osservazioni
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
ANFORDERUNGEN =============																
				NORMALGEGLUEHT												
DICKE	> 3-	10		02		20	285	450/	22							
DURCHM.	>	0						500								
				ZUGVERSUCH ROHRSTREIFENPROBE NORMALISIEREND UMGEFORMT			REH		5DO							
*00007 15	1080	1990	05	02	01	20	302	490	31							
*00013 15	1000	1990	05	02	01	20	322	501	30							
				ROHRABSCHNITTSPROBE												
*00026 03	330	3180	05	02	14	20	333	548	30							
*00074 03	330	3180	05	02	14	20	332	520	28							

05= ENDE
02= LAENGS
01= GESAMTDICKE
14= GESAMTQUERSCHNITT

AUSSAGEN ZU WEITEREN PRUEFUNGEN
===============================

1. BESICHTIGUNG
   OHNE BEANSTANDUNG

Technischer Überwachung TÜ 4 Bezirk 4

DUISBURG
(Ort – Location – Lieu – Località)

10.02.1989
(Datum – Date – Data)

(Der Sachverständige – Inspector – L'expert – L'Ispettore)

-003-

CEOC

CONFEDERATION EUROPEENNE D'ORGANISMES DE CONTROLE

Ergebnis der Prüfungen
Test Results
Résultats des Essais
Risultati delle Prove

Rheinisch-Westfälischer Technischer Überwachungs-Verein e. V.

Anlage – Annex – Annexe – Allegato: 1

Prüf-Nr. / Inspection No / Certificat N° / N° di collaudo: 2/22003050/2
Teil / Part / Partie / Parte: 001
Blatt-Nr. / Sheet-No / Page N° / Pag N°: 3

Mechanische Prüfungen – Mechanical tests – Essais mecaniques – Prove meccaniche

Prüfart – Test type – Type d'essai – Tipo di prova:
Probenart – Specimen type – Type de l'éprouvette – Tipo di provette:
Probenzustand – specimen condition – Etat d'éprouvette – Stato delle provette:

Probe-Nr. / Test No / N° d'éprouvette / N° di prova / Schmelze-Nr. / Heat No / N° Coulée / Colata N°	Probenabmessung Dicke / Thickness / Epaisseur / Spessore mm	Breite, Ø / Width, Ø / Largeur, Ø / Largh, Ø mm	Ort – Location / Lieu – Zona	Richtung / Direction – Senso	Lage – Position / Posizione	Prüftemperatur / Test temperature / Température d'essai / Temperatura di prova °C	Streck-/Dehngrenze / Yield point / Proof stress / Limite d'élasticité / Lim. di snervamento N/mm²	Zugfestigkeit / Tensile strength / Résistance à la traction / Carico di rottura Rm N/mm²	Bruchdehnung / Elongation / Allongement / Allungamento A Lo = %	Brucheinschnürung / Reduction of area / Striction / Strizione Z %		Werte – Values – Valeurs – Valori 1	2	3	Σ/n	Bemerkung / Remarks / Remarques / Osservazioni
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

1 = [J] Schlagarbeit – Energy of impact – Energie de rupture – Energia di rottura
2 = [J/cm²] Kerbschlagzähigkeit – Impact strength – Résilience – Resilienza
3 = [%] Krist. Bruchanteil – Cryst. proportion – Partie cristalline – Proporzione cristallina
4 = [mm 10⁻²] Breitung – Expansion – Expansion
5 = [%] Flangissement – Espansione
6 = Härte (Einheiten) – Hardness – Dureté – Durezza

AUSSAGEN ZU WEITEREN PRUEFUNGEN
================================

2. MASSKONTROLLE
OHNE BEANSTANDUNG

3. ABNAHMEPRUEFZEUGNIS B
SIEHE ANLAGE ...

4. WERKSSEITIG DURCHGEFUEHRTE PRUEFUNGEN: 1 ANLAGE

5. RINGAUFDORNVERSUCH 020% AN EINEM ENDE DER HERSTELLUNGSLG.
EINSCHNUERUNG U. BRUCHGEF.O.BEANSTANDG POS.003

6. RINGAUFDORNVERSUCH 100% AN EINEM ENDE DER HERSTELLUNGSLG.
EINSCHNUERUNG U. BRUCHGEF.O.BEANSTANDG POS.015

Technische Überwachung Bezirk 4 TÜ 4

DUISBURG
(Ort – Location – Lieu – Località)

10.02.1989
(Datum – Date – Data)

(Der Sachverständige – Inspector – L'expert – L'ispettore)

CEOC

CONFEDERATION EUROPEENNE D'ORGANISMES DE CONTROLE

Rheinisch-Westfälischer
Technischer Überwachungs-Verein e. V.

Abnahmeprüfzeugnis
Inspection Certificate
Certificat de Réception
Certificato Collaudo Materiali

(DIN 50049-3.1 A)

Prüf-Nr. – Inspection No – Certificat N° – N° di collaudo: 2/22003050/2
Teil – Part – Partie – Parte: 001
Blatt-Nr. – Sheet No – Page-N° – Pag-N°: 1

Besteller – Customer – Acheteur – Committente:
ROEHRENGROSSHANDLUNG L. BARTHEL KG
4000 DUESSELDORF HAMBURGER STR. 8

Bestell-Nr. – Order No – N° de la commande – N° dell'ordine: 4-3659
vom – dated – date – in data: 12.12.88

Hersteller – Manufacturer – Fabricant – Produttore:
BENTELER-WERKE AG
4220 DINSLAKEN LUISENSTR. 117

Werks-Nr. – Works-No – N° usine – Commessa N°: 39-2472

Prüfgegenstand – Article – Produit – Prodotto:
SEAMLESS TUBE

Prüfgrundlagen/Anforderungen – Technical requirements/Demand – Spécifications techniques/Exigences – Norma di controllo/Requisiti:
TRB 100 / TRD 102 / AD-MERKBL. W4

Werkstoff – Material – Matière – Materiale: 15MO3
entsprechend – according to – suivant – secondo: (1.5415) DIN 17175
Ausgabe – Edition – Edizione: 05.79

Lieferzustand – State of delivery – Etat de livraison – Stato di fornitura: CONTROLLED ROLLED
Erschmelzungsart – Melting process – Procédé d'élaboration – Procedimento di elaborazione: ELECTRIC-FURNACE PROCESS (E)

Kennzeichnung – Marking – Marquage – Punzonatura:
15MO3
NO.OF TUBE
US

Herstellerzeichen – Brand of the manufacturer – Marque du fabricant – Marchio del produttore: V3

(3) Stempel des Sachverständigen – Inspector's stamp – Poinçon de l'expert – Punzone dell'ispettore: T4U

Pos.-Nr. Item-No Poste-N° N° pos.	Stückzahl No of pieces Qté Numero pezzi	Gegenstand – Article – Désignation du produit – Tipo di prodotto	Schmelze-Nr. Heat No N° Coulée N° Colata	Probe-Nr. Test No N° d'éprouvette N° di prova
003	235	SEAMLESS TUBE OD=31,80MM THK=3,20MM TL=1545,30M IN TL VON 5-7 M GROUP-NO.: 1 -127	529638	00026 03
003		-"-	529638	00074 03
015	31	SEAMLESS TUBE OD=114,30MM THK=10,00MM TL=165,68M IN TL VON 5-7 M GROUP-NO.: 1 -16	529473	00007 15
015		-"-	529473	00013 15

Zusätzliche Angaben – Additional remarks – Autres remarques – Osservazione:

Die gestellten Anforderungen sind lt. Anlagen erfüllt. – The requirements are fulfilled as per Annex. – Les conditions imposées sont satisfaites suivant annexes. – I risultati sono conformi ai requisiti richiesti come da allegati.

DUISBURG
(Ort – Location – Lieu – Località)

10.02.1989
(Datum – Date – Data)

Technischer Überwachung Bezirk 4 TÜ

(Der Sachverständige – Inspector – L'expert – L'ispettore)

Anlagen – Annexes – Annexes – Allegati:
1) Ergebnis der Prüfungen – Test results – Résultats des essais – Risultati delle prove
Weitere Anlagen in 1) – Other annexes in 1) – Autres annexes en 1) – Altri allegati in 1)

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CEOC

CONFEDERATION EUROPEENNE D'ORGANISMES DE CONTROLE

Ergebnis der Prüfungen
Test Results
Résultats des Essais
Risultati delle Prove

Rheinisch-Westfälischer Technischer Überwachungs-Verein e. V.

Anlage – Annex – Annexe – Allegato: 1

Prüf-Nr. / Inspection No / Certificat N° / N° di collaudo: 2/22003050/2 — Teil / Part / Partie / Parte: 001 — Blatt-Nr. / Sheet-No / Page N° / Pag N°: 2

Mechanische Prüfungen – Mechanical tests – Essais mecaniques – Prove meccaniche

Prüfart – Test type – Type d'essai – Tipo di prova:
Probenart – Specimen type – Type de l'éprouvette – Tipo di provetta: TENSILE TEST
Probenzustand – specimen condition – Etat d'éprouvette – Stato delle provette: TENSILE TEST

Probe-Nr. / Test No / N° d'éprouvette / N° di prova — Schmelze-Nr. / Heat No / N° Coulée / Colata N°	Probenabmessung / Dim. of specimen — Dicke / Thickness / Epaisseur / Spessore mm	Breite, Ø / Width, Ø / Largeur, Ø / Largh., Ø mm	Probenentnahme / Specimen / Prélèvement / Prelevamento — Ort – Location / Lieu – Zona	Richtung / Direction – Senso	Lage – Position / Posizione	Prüftemperatur / Test temperature / Température d'essai / Temperatura di prova °C	Streck-/Dehngrenze / Yield point / Proof stress / Limite d'élasticité / Lim. di snervamento REH N/mm²	Zugfestigkeit / Tensile strength / Résistance à la traction / Carico di rottura Rm N/mm²	Bruchdehnung / Elongation / Allongement / Allungamento A Lo = 5DO %	Brucheinschnürung / Reduction of area / Striction / Strizione Z %	1 = [J] 2 = [J/cm²] 3 = [%] 4 = [mm 10⁻¹] 5 = [%] 6 =	Schlagarbeit – Energy of impact – Energie de rupture – Energia di rottura; Kerbschlagzähigkeit – Impact strength – Résilience – Resilienza; Krist. Bruchanteil – Cryst. proportion – Partie cristalline – Proporzione cristallina; Breitung – Expansion – Elargissement – Espansione; Härte (Einheiten) – Hardness – Dureté – Durezza — Werte – Values – Valeurs – Valori 1	2	3	Σ/n	Bemerkung / Remarks / Remarques / Osservazioni
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
MECHANICAL REQUIREMENTS																
				NORMALIZED												
THICKN. DIAM.	> 3-	100		02		20	285	450/ 600	22							
				TENSILE TEST TUBE STRIP TEST CONTROLLED ROLLED			REH		5DO							
*00007 15	1080	1990	05	02	01	20	302	490	31							
*00013 15	1000	1990	05	02	01	20	322	501	30							
				TUBE SECTION TEST PIECE												
*00026 03	330	3180	05	02	14	20	333	548	30							
00074 03	330	3180	05	02	14	20	332	520	28							

05= END
02= LONGITUDINAL
01= TOTAL THICKNESS
14= TOTAL CROSS SECTION

DECLARATION TO FURTHER TESTS

1. VISUAL INSPECTION
NO OBJECTION

Technische Überwachung TÜ 4 Bezirk 4

DUISBURG
(Ort – Location – Lieu – Località)

10.02.1989
(Datum – Date – Data)

(Der Sachverständige – Inspector – L'expert – L'ispettore)

-003-

CEOC

CONFEDERATION EUROPEENNE D'ORGANISMES DE CONTROLE

Ergebnis der Prüfungen
Test Results
Résultats des Essais
Risultati delle Prove

Rheinisch-Westfälischer
Technischer Überwachungs-Verein e. V.

Anlage – Annex – Annexe – Allegato: 1

Prüf-Nr. / Inspection No / Certificat Nº / Nº di collaudo: 2/22003050/2
Teil / Part / Partie / Parte: 001
Blatt-Nr. / Sheet-No / Page Nº / Pag Nº: 3

Mechanische Prüfungen – Mechanical tests – Essais mecaniques – Prove meccaniche

Prüfart – Test type – Type d'essai – Tipo di prove:
Probenart – Specimen type – Type de l'éprouvette – Tipo di provetta:
Probenzustand – specimen condition – Etat d'éprouvette – Stato delle provette:

Probe-Nr. / Test No / Nº d'éprouvette / Nº di prova; Schmelze-Nr. / Heat No / Nº Coulée / Colata Nº	Probenabmessung / Dim. of specimen / Dim. de l'éprouvette / Dim. della provetta: Dicke / Thickness / Epaisseur / Spessore (mm)	Breite, Ø / Width, Ø / Largeur, Ø / Largh., Ø (mm)	Probenentnahme / Specimen / Prélèvement / Prelevamento: Ort – Location / Lieu – Zona	Richtung / Direction – Senso	Lage – Position / Posizione	Prüftemperatur / Test temperature / Température d'essai / Temperatura di prova (°C)	Streck-/Dehngrenze / Yield point / Proof stress / Limite d'élasticité / Lim. di snervamento (N/mm²)	Zugfestigkeit / Tensile strength / Résistance à la traction / Carico di rottura Rm (N/mm²)	Bruchdehnung / Elongation / Allongement / Allungamento A Lo = (%)	Brucheinschnürung / Reduction of area / Striction/Strizione Z (%)		Werte – Values – Valeurs – Valori 1	2	3	Σ/n	Bemerkung / Remarks / Remarques / Osservazioni
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

1 = [J] Schlagarbeit – Energy of impact – Energie de rupture – Energia di rottura
2 = [J/cm²] Kerbschlagzähigkeit – Impact strength – Résilience – Resilienza
3 = [%] Krist. Bruchanteil – Cryst. proportion – Partie cristalline – Proporzione cristallina
4 = [mm 10⁻¹] Breitung – Expansion – Elargissement – Espansione
5 = [%] Härte (Einheiten) – Hardness – Dureté – Durezza
6 =

DECLARATION TO FURTHER TESTS
==============================

2. DIMENSIONAL CHECK
   NO OBJECTION

3. INSPECTION CERTIFICATE B
   SEE ANNEX...

4. VERIFICATIONS MADE BY MANUFACTURER: 1 ANNEX

5. RING EXPANDING TEST 020 % AT ONE END OF MANUFACTURED LENGTH
   REDUCTION OF AREA AND FRACTURE SURFACE WITHOUTCOMPLAINT ITEM 003

6. RING EXPANDING TEST 100 % AT ONE END OF MANUFACTURED LENGTH
   REDUCTION OF AREA AND FRACTURE SURFACE WITHOUTCOMPLAINT ITEM 015

Technische Überwachung TÜ 4 Bezirk 4 Duisburg

DUISBURG
(Ort – Location – Lieu – Località)

10.02.1989
(Datum – Date – Data)

(Der Sachverständige – Inspector – L'expert – L'ispettore)

BENTELER AKTIENGESELLSCHAFT
Postfach · 4790 Paderborn
Tel. 05254/81-0 · Telex 936866
Teletex 525421 · Telefax 05254/13666

BENTELER AKTIENGESELLSCHAFT

ABNAHMEPRÜFZEUGNIS (DIN 50049-3.1 B)
Inspection Certificate
Certificat de Reception

Prüf-Nr. / Certificate No. / No. du certificat: D 89068

Benteler AG · Postfach · D-4790 Paderborn

L. Barthel KG
Postfach 1608

4000 Düsseldorf

Hersteller: / Producer: / Fabricant: Benteler Aktiengesellschaft Dinslaken

Zeichen des Lieferwerks: / Suppliers trade mark: / Marque de l'usine du fournisseur:

Bestell-Nr.: / Order-No.: / No. d'ordre: 4/3659

Stempel des Sachverständigen: / Inspectors stamp: / Cachet de représentant: T40

Versand-Nr.: / No. of dispatch: / No. del éxpédition:

Werkstoff: / Material: / Acier: 15 Mo 3

Werks-Nr.: / Works No.: / No. d'usine: 41-39-2472/50

Erschmelzungsart: / Steelmaking process: / Mode d'élaboration: E

Kennzeichnung des Erzeugnisses: / Marking of the product: / Identification du produit: 3
15 Mo 3 - Rohr-Nr. - US - T40

Prüfgegenstand: nahtlose Rohre
Test object: seamless tubes
Objet d'essai: tubes sans soudure

Lieferbedingungen: / Standards: / Spécifications:
DIN 17175/79
- Gütest./Grade III -
AD-Merkblatt W 4, TRB 100, TRD 102
~~DIN 2448/81~~

Rohrgruppe/
Tube group No.

Pos. Item No. d'article	Stückzahl Number Quantité	Abmessung mm Dimension mm Dimensions mm	Menge - Quantity - Quantité m	kg	XXXXXXXXX
3	235	31,8 x 3,2 mm Lg. 5-7 m	1.545,30	3.526 (Vorl. 1-111 in 2fch.Lg.	1 - 127
15	31	114,3 x 10,0mm Lg. 5-7 m	165,68	4.468 (Vorl. 1-15 in 2fch.lg.	1 - 16

Ergebnis der Schmelzanalyse in %: Results of ladle analysis: Résultats d'analyse:

Pos. Item No. d'article	Schmelz-Nr. Heat No. No. de coulée	C	Si	Mn	P	S	Cr	Mo		Probe-Nr. Specimen-No.
3	529638	.17	.26	.67	.004	.007		.26		26, 74
15	529473	.18	.20	.66	.004	.003		.28		7, 13

Beizscheibenprüfung am Vormaterial: bestanden
Pickle test on the billets: passed
Materialverwechselungsprüfung: bestanden
Material conformity test: passed

Ergebnis der Prüfungen: Test Results: Résultats des Essais: / siehe Anlage: voir Annexe: see Attachement:

Die Rohre sind auf Dichtheit geprüft. – ~~durch Wasserinnendruckversuch~~ – durch Wirbelstromprüfung gemäß SEP 1925/XXXXXXX
The tubes are tested on tighiness – XXXXXXXXXX by eddy current test acc. to S.E.P. 1925 XXXXXXXX
Les tubes sont eprouvés XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX – par un essai de courant Foucault selon S.E.P. 1925 XXXXXXX

Die Rohre befinden sich über ihre ganze Länge in gleichmäßigem XXXXXXXXXX Zustand. walznormalisiert
The tubes are in a: XXXXXXXXXXXXXXXXXXXX condition over the whole length.
Les tubes sont en bon état de XXXXXXXXXX - sur tout leur longueur.

Die Rohre wurden ultraschallgeprüft gemäß SEP 1915 bestanden
The tubes are us tested according SEP 1915.
Les tubes sont tester us selon SEP 1915. passed / passé

Die Rohre entsprechen den oben angeführten Lieferbedingungen.
The tubes conform to the above mentioned standards.
Les tubes sont conformes aux spécifications mentionné ci-dessus.

4220 Dinslaken, 03.02.1989/wi
Tel. 02134/63383
Telex 8551967

Der Werkssachverständige
Works inspector
L'Expert d'usine

upw werkstoffprüfung g.m.b.h.

Hamburger Str. 6
4000 Düsseldorf-Hafen

Telefon 0211/3900360
Telex 8582107
Telefax 0211/3900339

Abnahmeprüfprotokoll

Auftraggeber		Abnahmegesellschaft
Barthel KG		SA - Abnahme
Auftragnummer		**Abnahmebedingungen**
1/1567 (Nachtrag)		DIN 17175
Werkstoff	**Abmessung**	**Spezifikation/Werkstoffblatt**
15 Mo 3	114,3 x 10,0	OKG 2000, 2006, 2007

Probe Nr. bzw. Rohr-Nr.	Schmelze Nr. ~~Abmessung~~	Probenlage	Zerreißversuche bei RT													Kerbschlagbiegeversuche bei - 10 °C ISO-V, längs									
			Breite mm	Dicke mm	So mm²	Lo mm		Rp 0,2 0,2% Dehngr. KN	Rp 0,2 N/mm²	Rp 1,0 1% Dehngr. KN	Rp 1,0 N/mm²	Rm Zugfestigkeit KN	Rm N/mm²	E Dehn. %	Z Einsch. %	Probenform: Breite mm	Höhe mm	S cm²	Schlagarbeit J Nm	J Nm	J Nm	Zähigkeit J cm²	J cm²	J cm²	Mittel J/cm²
			Anforderungen:					≥ 285				450-600		≥22					≥27						
2	529473	L	12,6	10,6	134	65	RT	49,2	368			66,9	500	26	61	10,0	8,0	0,80	73	69	40				
14	"	L	13,2	10,8	143	70	RT	50,8	356			70,8	496	26	59										
								≥195																	
2	"	L	10,0	RD	78,5	50	+300°	23,3	297			48,8	622	20	47										

Sonstige Prüfungen: Nr. 1, 1, 2, 9, 13, 14 Ringaufdornproben an beiden Enden je Rohr: ohne Beanstandung

24.05.1989
Prüfdatum:

WERKSTOFFPRÜFUNG upw
Gest.
Prüfer:

89-05-24
Sachverständiger:

tpw

2524F

Werkstoffprüfung G.m.b.H.

Hamburger Str. 6
4000 Düsseldorf-Hafen
Telefon 0211/39 00 360

Technische Prüfung metallischer Werkstoffe

tpw · Werkstoffprüfung G.m.b.H · Postfach 1608 · 4000 Düsseldorf 1

Barthel KG
Hamburger Str. 6-12
4000 Düsseldorf

4/518/89

Ultraschall-Prüfprotokoll / Ultrasonic Test Report

Barthel KG	Auftrags-Nr. / Order No. 1/1567 (Stalrör)
Besteller / Client	Bestell-Nr. / P. O. No.
nahtl.Rohre	ganze Rohrlänge
Prüfgegenstand / Subject	Prüfbereich / Test range
USL 32 Krautkrämer	WB 45-N4
Prüfgerät / Instrument	Prüfköpfe / Transducer
glatt	Wasser
Prüfflächenzustand / Coupling condition	Koppelung / Couplant
80 % BSH	SEP 1915/1918
Registriergrenze / Registration level	Gerätejustierung / Calibration

Pos. Item	Werkstoff Quality	Stck. pce	Meter meter	Art und Abmessung Description and dimension	Schmelze-Nr. Heat No.
1	15 MO3	6	31,20	114,3 x 10,0 71010114.BR	529473

Es wurden keine registrierpfl.Anzeigen festgestellt.

Prüfbefund / Results

Bemerkung / Remarks

Düsseldorf, den 30.5.89 Prüfer: Operator Engelhard Prüfaufsicht: Supervisor Weckes

WERKSTOFFPRÜFUNG

Geschäftsführer, Peter Wolff
AG Düsseldorf · HRB 15625

Bankverbindung: Deutsche Bank Düsseldorf (BLZ 300 700 10) Kto.-Nr. 5 187 610 tpw werkstoffprüfung g.m.b.h.

CERTIFICATE ON

ULTRASONIC-EXAMINATION

Acc. To DIN 50049/3.1.B

Client Stalroer 311011	Project	
Purchaser Barthel KG 1/1567	Report 4/518/89	Page 1
Manufacturer	Operator Engelhard Level II	
Object Tubes	Examination 24.05.1989	

Item	Dimension	Piece	Length	Quality/Heat No.
5	114,3 x 10,0	6	31,20	15 Mo 3 529473

Heat Treatment: acc. Works-certificates	Surface Cond.: acc. DIN 17175
US-Procedure Ref.: SEP 1915/1918 KSU-KBM EP2-22	
Acc. Standard: Testsp. OKG 83702	Rep. Level (%): 100% long and tra.
US-Instrument: USL 32	Couplant: water
Probe Type: wb 45-N4	Frequency: 4 (MHZ)
Crystal Size: 20 x 22 (mm)	Scanning Sensit.: + 6 (dB)
Range Calibr.: 0-100 (mm)	Transv. Correction: Without (Calibration On Above Material)

Test Result: (If Necessary enclose Sketches)

The Tubes tested with satisfactory result

Additional Sketches	Approved	Place	Date
	WERKSTOFFPRÜFUNG tpw DÜSSELDORF		24.05.1989

1988-03-17 16:14 Stålrör Halmstad 46 35 130568 06

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Werkstoffprüfung G.m.b.H.

Prüf-Vorschrift / Test Specification / Prescription relatives For OKG		Seite 1 von 4 / Page of / Page sur
für / for / pour: Ultraschallprüfung an Rohren / Ultrasonic Test on tubes / Contrôle Ultrasonore de tubes Best. 83702		AQB-Nr: / AQB No / AQB Nº
Auftrags-Nr: / order No / Nº de la commande	Anf-Stufe: / Nuclear class / Classe nucléaire	
Position: / Item / Poste	FP-Plan Nr: / FP-Plan No / Nº du LOFC	
Inquire Paloon-Impex for OKG	Schritt Nr: / Operation No. / Nº opération	

Erstellt: / Prepared by / Etabli par	Revision: / Revision / Révision	0	
	Datum: / Date / Date	14.3.88	
tpw werkstoffprüfung g.m.b.h. hamburger straße 4, 4000 düsseldorf-hafen, telefon 0211-3900360	Genehmigt: / Approved by / Approuvé par	14.3.88	OKG QA GODKÄND/APPROVED 0 1988-07-21
Datum: / Date / Date 14.3.88			

Spezifikation / Specification / Spécification	Bezeichnung / Title / Désignation	Ausgabe / Edition / Édition	Revision / Revision / Révision	Abschnitt / Section / Titre	Paragraph / Paragraph / Paragraphe	Rev.
SEP 1915 + 1918.		1977		SA Rev. 0 Approved 1988.07.22		
KSU-KBM EP2-22						

Prüfung: / Inspection / Contrôle	Prüfumfang: / Range of inspection / Étendue du contrôle
[X] Längsfehler / Longitudinal inhomogenities / Défauts longitudinaux	[X] jedes / each / tous les — Rohr in beiden Umfangsrichtungen / tube in the two circumferential directions / tube dans les deux directions circonférentielles — [X] ganze Länge / entire length / longueur totale; [ ]
[X] Querfehler / Transverse inhomogenities / Défauts transversaux	[X] jedes / each / tous les — Rohr in beiden axialen Richtungen / tube in the two axial directions / tube dans les deux directions axiales — [X] ganze Länge / entire length / longueur totale; [ ]
[ ] Dopplungen / Laminations / Doublures	[ ] jedes / each / tous les — Rohr / tube / tube
[ ] Abmessungen / Dimensions / Dimensions	[ ] jedes / each / tous les — Rohr / tube / tube
[ ]	

Oberflächenzustand: / Surface condition / État de surface: in accordance with DIN 17175	Rauheit: / Roughness / Rugosité

Träger des Bezugsstandards: / Basis of reference standard / Support du standard de référence

[X] Kontrollkörper-Rohr / Reference tube / Tube de référence
[ ] Teil-Kontrollkörper / Partial reference block / Bloc de référence
[X] Prüfling / Test object / Éprouvette
[ ] Einstell-Normal / Calibration standard / Standard de calibrage

Der Träger des Bezugsstandards besteht aus Material
The solid of reference standard consists of material
Le support du standard de référence se compose du matériel

[X] mit gleichem Nenn-Durchmesser, gleicher Nenn-Wanddicke, gleicher Nenn-Analyse, gleichem Oberflächenzustand und gleichartiger Wärmebehandlung.
with the same nominal diameter, nominal wall thickness, nominal composition, the same surface finish and nominal heat treatment.
avec même diamètre nominal, même épaisseur nominale, même analyse nominale, même état de surface et traitement thermique identique.

[ ] mit gleichen prüftechnisch relevanten Eigenschaften.
with the same relevant properties
avec caractéristiques identiques sur le plan technique.

UPW Werkstoffprüfung G.m.b.H.

Prüf-Vorschrift für Ultraschallprüfung an Rohren
Test Specification for Ultrasonic Test on tubes
Prescription relatives pour Contrôle Ultrasonore de tubes

Revision: Revision Révision	0						

Bezugsstandard / Reference standard / Standard de référence	Längsfehler / Longitudinal / Défauts longitudinaux	Querfehler / Transverse / Défauts transversaux	Dopplungen / Lamination / Dédoublures	Abmessungsprüfung / Dimension test / Dimension contrôle	Rev.
Typ: / Type / Type	Square Notch	Square Notch		☐ Wanddicke / Wall thickness / Epaisseur ☐ Außen-Durchmesser / Outside diameter / Diamètre extérieur ☐ ______	
Lage: / Position / Position	☐ innen / inside / intérieur ☐ außen / outside / extérieur	☐ innen / inside / intérieur ☐ außen / outside / extérieur	☐ innen / inside / intérieur ☐ außen / outside / extérieur		
Abmessung / Dimension / Dimension — Tiefe / Depth / Profondeur	5 % der Nennwand / of nominal w.th. / de l'épaisseur nom.	5 % der Nennwand / of nominal w.th. / de l'épaisseur nom.	— % der Nennwand / of nominal w.th. / de l'épaisseur nom.	Toleranzen entsprechend / Tolerances according to / Tolérances suivant DIN 17175	
	min. 0,1 mm	min. 0,1 mm			
	max. 1,0 mm	max. 1,0 mm			
Breite / Width / Largeur	≤ 1,5 mm	≤ 1,5 mm			
Länge / Length / Longueur	≤ 25 mm	≤ 25 mm			

Soll-Tiefe des Bezugsstandards:
Required depth of reference standard
Profondeur prescrite par la norme de référence

Position / Item / Poste	Abmessung / Dimension / Dimension (mm)	Längsfehler / Longitudinal / Défauts longitudinaux — innen / inside / intérieur + außen / outside / extérieur (mm)	Querfehler / Transverse / Défauts transversaux — innen / inside / intérieur (mm)	Querfehler — außen / outside / extérieur (mm)	Dopplungen / Lamination / Dédoublures — innen / inside / intérieur (mm)	Dopplungen — außen / outside / extérieur (mm)
A	10,2 x 1,8	0,1				
B	13,5 x 2,0	0,1				
C	14 x 2,0	0,1				
D	17,2 x 2,0	0,1				
E	20 x 3,0	0,15				
F	21,3 x 2,9	0,15				
G	30 x 4,0	0,2				
H	33,7 x 2,9	0,15				
I	42,4 x 2,9	0,15				
J	60,3 x 3,2	0,16				
K	60,3 x 6,3	0,31				
L	76,1 x 4,5	0,22				
M	76,1 x 7,1	0,35				
N	88,9 x 5,6	0,28				
O	88,9 x 8,0	0,4				
P	114,3 x 6,3	0,31				
Q	114,3 x 10,0	0,5				
R	139,7 x 8,8	0,4				
S	168,3 x 4,5	0,22				
T	168,3 x 7,1	0,35				
U	168,3 x 12,5	0,62				

the same depth of CL
Longitudinal reference
should be

upw Werkstoffprüfung G.m.b.H. SIDA 1

Prüf-Vorschrift für Ultraschallprüfung an Rohren
Test Specification for Ultrasonic Test on tubes
Prescription relatives pour Contrôle Ultrasonore de tubes

Seite 8 von 4 (Page of / Page sur)

Revision / Revision / Révision	0					

Bezugsstandard / Reference standard / Standard de référence	Längsfehler / Longitudinal / Défauts longitudinaux	Querfehler / Transverse / Défauts transversaux	Dopplungen / Lamination / Dédoublures	Abmessungsprüfung / Dimension test / Dimension contrôle
Typ: / Type / Type	Square Notch	Square Notch		☐ Wanddicke / Wall thickness / Épaisseur ☐ Außen-Durchmesser / Outside diameter / Diamètre extérieur ☐ ______
Lage: / Position / Position	☐ innen / inside / intérieur ☐ außen / outside / extérieur	☐ innen / inside / intérieur ☐ außen / outside / extérieur	☐ innen / inside / intérieur ☐ außen / outside / extérieur	

Abmessung / Dimension / Dimension		Längsfehler	Querfehler	Dopplungen	Toleranzen entsprechend / Tolerances according to / Tolérances suivant
	Tiefe / Depth / Profondeur	5 % der Nennwand / of nominal w.th. / de l'épaisseur nom.	5 % der Nennwand / of nominal w.th. / de l'épaisseur nom.	__ % der Nennwand / of nominal w.th. / de l'épaisseur nom.	
		min. 0,1 mm	min. 0,1 mm		
		max. 1,0 mm	max. 1,0 mm		
	Breite / Width / Largeur	≤ 1,5 mm	≤ 1,5 mm		
	Länge / Length / Longueur	≤ 25 mm	≤ 25 mm		

Soll-Tiefe des Bezugsstandards:
Required depth of reference standard
Profondeur prescrite par la norme de référence

Position / Item / Poste	Abmessung / Dimension / Dimension (mm)	Längsfehler / Longitudinal / Défauts longitudinaux — innen / inside / intérieur, außen / outside / extérieur (mm)	Querfehler / Transverse / Défauts transversaux — innen / inside / intérieur, außen / outside / extérieur (mm)	Dopplungen / Lamination / Dédoublures — innen / inside / intérieur, außen / outside / extérieur (mm)
V	219,1 x 6,3	0,31	the same depth of longitudinal reference standard	
X	219,1 x 12,5	0,62		
Y	219,1 x 6,3	0,31		
Z	219,1 x 12,5	0,62		
Å	219,1 x 16,0	0,8		
Ä	273 x 8,0	0,4		
Ö	273 x 14,0	0,7		
AA	273 x 20,0	1,0		
AB	323,9 x 7,1	0,35		
AC	323,9 x 14,2	0,71		
AD	323,9 x 17,5	0,87		
AE	355,6 x 14,2	0,71		
AF	355,6 x 20,0	1,0		

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Werkstoffprüfung G.m.b.H.

Prüf-Vorschrift für Ultraschallprüfung an Rohren Test Specification for Ultrasonic Test on tubes Prescription relatives pour Contrôle Ultrasonore de tubes						Seite / Page / Page 4 von / of / sur 4
Revision: Revision Révision	0					

Einstellung der Prüfempfindlichkeit: Die Anlage ist so einzustellen, daß klar erkennbare und eindeutig zugeordnete Anzeigen der Bezugsstandards entstehen. Die Anzeigenhöhen sind soweit als möglich anzugleichen; für die Bewertung ist jeweils die kleinere Anzeigenhöhe maßgebend. | Rev.
Setting of sensitivity level
Réglage du niveau de sensibilité du contrôle

Adjust the equipment to produce readily distinguished, clearly identifiable indications from the reference notches. The echo heights should be as nearly equal as possible; for setting the monitoring level the lesser of the two echo heights shall be used.

L'installation doit être réglée de telle façon qu'apparaissent des indications facilement reconnaissables et clairement identifiables sur le standard de référence. Les hauteurs des indications doivent être autant que possible égales; pour établir le niveau du moniteur, on se base sur la hauteur d'indications la plus basse.

Bezugsecho-Aussteuerung 50 % BSH; ___ dB zum Bezugsecho
Setting of reference echo height — screen height — to reference echo height
Réglage de l'écho de référence — de la hauteur de l'écran — de l'écho de référence

Bewertungsschwelle 50 % BSH; ___ dB zum Bezugsecho; ___ mm Schreibstreifen
Monitoring level — screen height — to reference echo height — record width
Seuil d'évaluation — de la hauteur de l'écran — de l'écho de référence — de la bande d'enregistrement

Zulässigkeitsgrenze: Alle Anzeigen von Ungänzen, welche gleich oder größer sind als die Bewertungsschwelle, können der Grund für eine Zurückweisung sein.
Acceptance level
Niveau toléré
All indications of discontinuities which are equal to or greater than the monitoring level may be cause for rejection.
Toutes les indications d'irrégularités qui sont égales ou supérieures au seuil d'évaluation peuvent entraîner le rebut.

Abtastung: lückenlose Prüfung mit min. 10 % Überlappung auf [X] Längsfehler [X] Querfehler
Scanning — 100% coverage inspection with min. — overlap of — longitudinal imperf. — transverse imperf.
Balayage — Contrôle à 100% avec un minimum de — de recouvrement des — défauts longitudinaux — défauts transversaux

Dopplungsprüfung ___ Abmessungsprüfung ___
Inspection of laminations — Dimensional inspection
Contrôle des dédoublures — Contrôle dimensionnel

Einstellkontrolle: Bei Beginn und nach Beendigung der Prüfung jeder Position sowie nach Störungen,
Checking of calibration — At the beginning and at the end of each production run and any malfunctioning,
Contrôle du réglage — Au début et à la fin du contrôle de chaque poste, ainsi qu'après un mauvais fonctionnement,

während der Prüfung jedoch mindestens nach [ ] jedem ___ Prüfling [X] jeweils 240 Minuten.
during the production run but at least after — each — test object — each — minutes
mais pendant le contrôle, au moins — toutes les — éprouvettes — toutes les — minutes

...; bei der Überprüfung festgestellt wurde, daß die Prüfanlage nicht einwandfrei arbeitet, müssen alle Prüflinge, die seit der letzten Funktionsprüfung geprüft wurden, einer Wiederholungsprüfung unterworfen werden, nachdem die Störung beseitigt wurde.
If during any check it is found that the testing equipment is not functioning properly, all the product which has been tested since the last function check shall be retested after the malfunction is corrected.
Si l'examen a permis de constater que l'installation ne fonctionne pas de façon irréprochable, toutes les éprouvettes qui ont été testées depuis le dernier contrôle du fonctionnement doivent être soumises à un nouveau contrôle après réparation de l'installation.

...lerbeseitigung: Stellen mit unzulässigen Anzeigen sind im Rahmen der zulässigen Abmessungs-Toleranzen nachzuarbeiten (z.B. zu schleifen) zurückzuschneiden oder zu teilen. Läßt sich der Fehler nicht beseitigen, sind die Teile zu verwerfen. Reparatur durch Schweißen ist nicht zulässig.
Elimination of defects
Élimination des défauts
Areas with unacceptable indications are to be reworked (e.g. to be grinded), cutted back or to divided provided the acceptable tolerances for the dimensions are met. If the defect couldn't be eliminated, the parts are to be rejected. Repair by welding is not allowed.
Les endroits affectés d'indications inadmissibles doivent être corrigés dans les limites des tolérances sur les dimensions (par ex. meulées), recoupées ou séparées. Si le défaut n'est pas éliminé, les pièces doivent être rebutées. Les réparations par soudage ne sont pas admises.

Nachprüfung der Nacharbeitsstellen:
Checking of reworked areas
Vérification des endroits réparés

[X] durch Ultraschall-Wiederholungsprüfung entsprechend dieser Vorschrift.
by ultrasonic reexamination according to this specification
par nouveau contrôle aux ultrasons suivant cette prescription

[ ] durch Farbeindringprüfung ___ [ ] durch Magnetpulverprüfung ___
by liquid penetrant testing — by magnetic particle testing
par contrôle par ressuage — par contrôle magnétoscopique

Qualifikation des ZfP-Personals:
Qualification of NDT-Personal
Qualification du personnel des contrôles

US - Level I ASTE and Level II G.Z.F.P.

Dokumentation: [X] Protokoll [ ] Schreibstreifen [ ]

Kärnkraftsäkerhet och Utbildning AB

Typ av dokument

Detaljerad ultraljudprocedur - DUP

DUP-nr.	2524 F
Rev.	0
Sida	1/1

Anläggning	Kvalitetsklass	Datum
Oskarshamn Förråd	1	891221

Referensprocedur	Utgåva	Utf.av	Gransk.
KSU-KDM-OFP-22	1	D.D.	CCG

Tillverkare	Objekt	Ritningsnr.	Rev.nr.	Pos.nr.
Benteler Werke AG.	Sömlösa rör	—	—	—

Objektbeskrivning (material, formvara, dimensioner etc.)

Sömlösa rör 114,3×10,0 CS charge 529473.
OKG best. 83702 Pos. E.
Kontrollplan OKG 2006 rev 5.

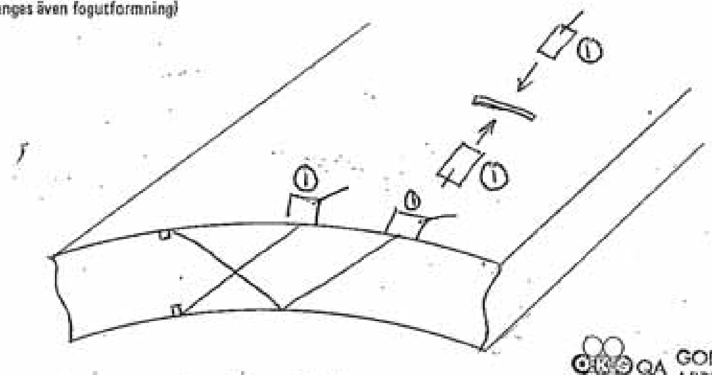
Provningstillfälle/tillverkningsskede

Provningsdata

Kalibreringsmetod:
(referenskropp, referensfel, storlek etc.)

Sökare: 1 KBA 45° 2,25 MHz

Avsökningsriktningar enligt skiss nedan
(för svetsförband anges även fogutformning)



Spår längd 25 mm
bredd 1 mm
djup 0,5 mm

OKG QA GODKÄND/APPROVED 1990-01-11

Acceptansnivå

Se KSU KDM-OFP-22 punkt 9.

SA

SA Rev. 0 Approved 1989-12-21

AB Statens Anläggningsprovning

INTYG ÖVER ULTRALJUDPROVNING. MATERIAL

Sid av/av: 1:1

Uppdragsgivarens ref.: Åke Nilsson
SA-uppdragsnr: 765081
SA-uppdragsgivare: OKG AB

Anläggning: Förråd

Tillverkare: Benteler Werke AG

Tillverkningsnr: —
SA-registreringsnr: —

Objektnamn: Sömlösa rör 114,3 x 10,0 CS
Objektdel: Grundmaterial

Ritningsnr: —
revision:
Materialkvalitet: 15 Mo 3/III
Charge nr: 529473

PROVNINGSTEKNISKA DATA

Provningsomfattning: 10% av levererade rör ≠ 30 m
Rör nr. 9 provat c:a 1 m Nr 14 provat c:a 0,5 m
Nr. 2 provat c:a 0,5 m Nr 13 provat c:a 0,5 m Nr 1A provat c:a 0,5 m

Apparat: USL 31
Kontaktmedel: UL-gel
Ytbeskaffenhet: Acc.

Sökare: KBA 45° 2,25 MHz
Procedur och acceptanskrav enl.: KSU-KBM/OFP-22 DUP 2524 F

Provning: ☐ före värmebehandling ☒ efter värmebehandling
Bilagor: Kalibrerings protokoll

Övriga upplysningar: OKG:s intygs nr. 2524 F

PROVNINGSRESULTAT

U.A
Inga rapporterbara indikationer

Provningen utförd Datum: 891221
Namn: Claes-Göran Göransson

AB Statens Anläggningsprovning

Ort: Simpevarp
Datum: 891221
Signatur: C-GG
Anst.nr: 2642

SA 133 100x50 77.03

AB Statens Anläggningsprovning

Anläggning Förrådet		Provningsform ~~AP/BU~~	1989
Bilaga nr	Blad nr 1	Pärm nr	Sid nr

KALIBRERINGSPROTOKOLL **MANUELL ULTRALJUDPROVNING Kontaktteknik**

Nr CGG 891221-1

Kalibreringsdata

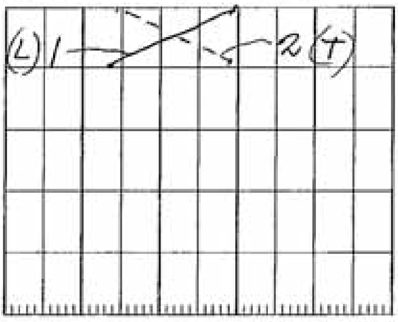
Procedur nr	Ljudvägsritning nr	Kopplingsmedium
KSU-KBM / OFP-22		UL-gel
Kalibreringskropp	**Referenskropp**	**Referensreflektor**
Gut cs R25	Med notcher Rörbit 114,3x 10,0 cs	Notch
Ultraljudprovningsapparat	**SA-nr**	**Storlek**
USL 31	3132288	1,0x 0,5 mm

Sökarinformation

Nr	Sökare	Frekvens MHz	SA-nr	Uppmätt brytn.vinkel	Kristallstorlek	Våg-typ	Anmärkning
1	KBA 45°	2,25	021 941	45,0	Ø6,3	T	
2							
3							
4							

Kalibrering

Nr	Sökare	Avs. typ	Imp. styrka	Mät-område	Referens-förstärkning
1	KBA 45°	L	1	50	44 dB
2	-"-	T	1	50	38 dB
3					
4					



Periodisk kalibreringskontroll

Nr	Sökare	Tid	Kalibrerings-förstärkning	Ref. ekot %	Ref. ekot LV	Kalibr.-kropp	Kalibr.-kontr. reflekt.	Transferkorr. Mätresultat dB	Anmärkning
1	KBA 45°	12⁰⁰	28 dB	80	R25	Gut	R25	0 dB	
2	"	14⁰⁰	"	"	"	"	"		
3									
4									
5									
6									
7									

Kalibreringen utförd av	Datum	Provningsledare
Claes-Göran Göransson	891221	[stamp]

SA 267 100 x 50 83.08

APPENDIX C: MATERIAL CERFTIFICATE AVESTA P5 2.4 mm

okg

Intern med begränsad spridning

OKG Dokumentreg.nr 2009-18180

Materialintyg

Beställningsnummer/ Intygsnummer 4091430-2-1 sid (1/2)

Benämning	TIG-TRÅD
Dimension	ø2,4mm
Material	Avesta P5
Chargenummer	0882
OKG art.nr	106120
Övrigt	Mängd levererat: 40 kg (8 st.á 5kg)
Anmärkning	Fordringar: EN 12072:1999 W 23 12 2 L
	ISO 14343-A:2002 W 23 12 2 L (309LMo)
	Ej check-in provat tillsatsmaterial. För användning i kval.
	klass 1 se KBM EP 3-11.

Slutlig granskning av Q	Datum	Sign/Resursgrupp	Stämpel
Jan Yderland	2009-05-20	JYD/UTP	okg QC/5

D228 2005-09-07 Cas/ES

JYD 4091430 pos 2

Avesta Welding

CERTIFICATE – ZEUGNIS - CERTIFICAT

EN 10204/3.1

QAM, Hans Åström ZC2200000

Buyer ref – Einkauf -Nr – Ref acheteur 4091430/DRE/EI	Date – Datum - Date 2009-03-24	Cert No – Zeugnis Nr – No de cert 333022
Consignee ref – Kunden-Best Nr – Ref destinateur	Our order – Auftrag – Notre référence 1041016019 000010	Pack – Kolli - Colis 1286157
SVETSTEKNIK I KRISTIANSTAD AB 29165 KRISTIANSTAD Sweden	Requirements – Anforderungen – Exigences EN 12072:1999 ISO 14343-A:2002	W 23 12 2 L W 23 12 2 L (309LMo)
Product – Produkt – Produit TIG WIRE ELECTRODES FOR STAINLESS STEEL WELDING		
Brand mark / Herstellerzeichen / Sigle du producteur: Avesta Welding	Inspectors stamp / Abnahmeprüfstempel / Poinçon de l'expert	

Designation – Bezeichnung – Désignation
AVESTA P5

Extent of delivery – Lieferumfang – Etendue de livraison

Pos / Anzahl / Nombre	Weight / Gewicht / Poids	Dimension / Dimension / Dimension	Lot No / Lot Nr / No de lot	Article No / Artikel Nr / No. d'article
	40.00 Kg	2.40 mm	0882	TW8335-240300 65578

Chemical composition – Chemische Zusammensetzung – Composition chimique %

C	Si	Mn	P	S	Cr	Ni	Mo	Nb+Ta	Cu	N	Ferrite according to DeLong	WRC-92
0.012	0.33	1.4	0.020	0.004	21.4	15.0	2.57	0.00	0.10	0.053	10	8

Test results – Prüfergebnisse – Résults d'essai (1N/mm² = 1 MPa)

Temp °C	Rp0.2 N/mm²	Rm N/mm²	A5 %
+ 20	445	626	30

THE ABOVE MECHANICAL PROPERTIES REFER TO PURE WELD METAL. THE VALUES ARE STATISTICAL DATA, OBTAINED FROM OUR CONTINUOUS QUALITY CONTROL SYSTEM.

4091430 Pos. 2
Art.nr. 106/20

BÖHLER WELDING GROUP NORDIC AB
BOX 501
S-774 27 AVESTA
SWEDEN
VAT NR: SE 556017786601
www.avestawelding.com
www.bwgnordic.com

The requirements stipulated are satisfied.
Die gestellten Anforderungen sind erfült.
Les conditions imposes sont satisfaites.

BWG NORDIC AB
QA-DEPARTMENT
Eva Lidström

DNV
SS-EN ISO 9001
Certificate No. 2005-SKM-AQ-2191

APPENDIX D: MATERIAL CERFTIFICATE AVESTA P5 1.6 mm

Status

Frisläppt

Dokumentnamn

K12 Reservdelar/Förrådsmaterial med intygsnr

Reg nr	Utgåva
2012-29529	0

Utfärdad	Gäller fr o m	Gäller t o m
2012-11-05		

Titel

Tig-tråd Ø1,60 mm

Skriv- och språkkontroll

Sakgranskning	**Nej**
Kvalitetsgranskning	**Nej**
Projektgodkänt	**Nej**
Linjegodkänt	**Nej**
Extern granskning	**Nej**
Frisläppt	**Irene Johansson, GAI, 2012-11-29**

Ärende

Distribution

Sekretessklass

Intern med begränsad spridning

enligt lag om skydd för företagshemligheter och i förekommande fall säkerhetsskyddslag 1 § 3 pkt samt 5-7 §

okg

Materialintyg

Beställningsnummer/ Intygsnummer 4122267-1-1 sid (1/2)

Benämning	TIG-TRÅD
Dimension	ø1,60mm
Material	Avesta P5
Chargenummer	8261
OKG art.nr	106119
Övrigt	Mängd levererat:5 kg (delleverans)
Anmärkning	Fordringar:
	EN 12072:1999 W 23 12 2 L
	ISO 14343-A:2002 W 23 12 2 L (309LMo)
	OBS! Ej check-in provat. För användning i kval. klass 1, se
	KBM EP 3-11.

Slutlig granskning av Q	Datum	Sign/Resursgrupp	Stämpel
Jan Yderland	2012-11-05	JYD/UMK	

D228 2005-09-07 Cxo/ES

(36)

Avesta Welding

CERTIFICATE – ZEUGNIS - CERTIFICAT

EN 10204/3.1

QAM, Hans Åström ZC2200000

Buyer ref – Einkauf -Nr – Ref acheteur 3202186	Date – Datum - Date 2012-04-03	Cert No – Zeugnis Nr – No de cert 370206
Consignee ref – Kunden-Best Nr – Ref destinateur	Our order – Auftrag – Notre référence 1041038218 000060	Pack – Kolli - Colis 2342891
SVETSTEKNIK I KRISTIANSTAD AB ESTRIDS VÄG 7B 29165 KRISTIANSTAD Sweden	Requirements – Anforderungen – Exigences EN 12072:1999 ISO 14343-A:2002	W 23 12 2 L W 23 12 2 L (309LMo)
Product – Produkt – Produit TIG WIRE ELECTRODES FOR STAINLESS STEEL WELDING		
Brandmark / Herstellerzeichen / Sigle du producteur: Avesta Welding	Inspectors stamp / Abnahmeprüfstempel / Poinçon de l'expert	

Designation – Bezeichnung – Désignation

AVESTA P5

Extent of delivery – Lieferumfang – Etendue de livraison

Pcs / Anzahl / Nombre	Weight / Gewicht / Poids	Dimension / Dimension / Dimension	Lot No / Lot Nr / No de lot	Article No / Artikel Nr / No. d'article
	5.00 Kg	1.60 mm	8261	TW8335H160000 74322

Chemical composition – Chemische Zusammensetzung – Composition chimique %

C	Si	Mn	P	S	Cr	Ni	Mo	Nb+Ta	Cu	N
0.013	0.40	1.5	0.020	0.004	21.5	15.4	2.59	0.01	0.10	0.051

Ferrite according to

DeLong	WRC-92
9	7

Test results – Prüfergebnisse – Résults d'essai ($1 N/mm^2 = 1 MPa$)

Temp	Rp0.2	Rm	A5
°C	N/mm^2	N/mm^2	%
+ 20	472	642	29

THE ABOVE MECHANICAL PROPERTIES REFER TO PURE WELD METAL. THE VALUES ARE STATISTICAL DATA, OBTAINED FROM OUR CONTINUOUS QUALITY CONTROL SYSTEM.

4122267 Pos-1
Ar.l.nr. 106119

BÖHLER WELDING GROUP NORDIC AB
BOX 501
S-774 27 AVESTA
SWEDEN
VAT NR: SE 556017786601
www.avestawelding.com
www.bwgnordic.com

The requirements stipulated are satisfied.
Die gestellten Anforderungen sind erfüllt.
Les conditions imposées sont satisfaites.

BWG NORDIC AB
QA-DEPARTMENT
Eva Lidström

DNV SWEDAC ACKREDITERING
SS-EN ISO 9001
Certificate No. 2005-SKM-AQ-2191

APPENDIX E: WELDING PROCEDURE SPECIFICATION

okg
- ett företag i E.ON koncernen

Sekretessklass **Intern med begränsad spridning**

WPS: OKG-1.1/8.1-004

Rev: 0 2011-03-29

SVETSDATABLAD ENLIGT SS-EN ISO 15609-1 Kvalificerad enligt WPQR: **PR-BS300-33**

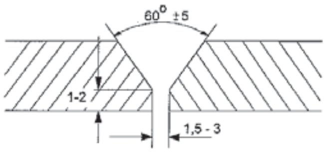
Giltighetsområde

Fogtyp:	BW			
Materialgrupp (ISO 15608):	1.1	mot	8.1	
Ytterdiameter i mm:	109,5	till	Plåt	
Godstjocklek i mm:	3	till	12	
A-mått:	- - -			

Materialspecifikation/Förbehåll

* Svetsning i verkstad och horisontalläge ska eftersträvas.

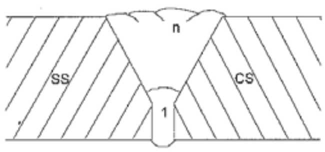
Fogberedning:



Flersträng

Svetsläge:
Alla*, utom fallande svetsning (PG och J-L045).

Svetsplanering:



Förberedelser av fogkantområde: CS blank metall, min. 20 mm. SS rengör. m aceton el. likv.

Strängbredd: Max 3 ggr kärndiametern

Häftsvetsning: Enligt krav i TBM.

Termisk verkningsgrad: Enligt EN 1011-1

Hantering av tillsatsmaterial: Enligt 2005-10388.

Sträng	Metod	Tillsatsmaterial	Dimension mm	Ström A	Spänning V	Strömtyp Polaritet	Hastighet cm/min	Sträckenergi (kJ/mm)
1	141-TIG	P5 Avesta ISO 14343 - W 23 12 2 L	1,6 / 2,0 / 2,4	55-75	10-12	DC -pol	3-3,6	0,6-1,1
n	141-TIG	P5 Avesta ISO 14343 - W 23 12 2 L	1,6 / 2,0 / 2,4	85-115	10,5-12,5	DC -pol	4,3-6,6	0,5-1,2

Anmärkning: Ersätter O-BS3014.

Förhöjd arbetstemp (°C): 15
Mellansträngtemp (°C): Max.100
Wolframelektrod typ/dim: ISO 6848 WTh 20, ø 2,4
Gaslins: Min. 4 ggr wolframdiametern
Svetsgas: AGA Argon, ISO 14175-I1
Gasflöde (l/min): 10±2 l/min
Spoltid: Se tabell i 2005-10388
Rotgas: AGA Formier 10, ISO14175-N5
Rotgasflöde (l/min): Sätts till 5-20 l/min.

VBH enligt: - - -
VBH metod: - - -
Uppkörningshastighet: - - -
VBH temp: - - -
Hålltid: - - -
Avsvalningshastighet: - - -

Upprättad	Granskad	Godkänd	Granskad Ackrediterat kontrollorg.
HDE I.W.E. H. Eriksen 29/3-11	GAA I.W.E. 1/4-11	MHG/UTP 4/4-11	PER-OLA EKLÖF 21 2011-04-13

APPEDIX F: TEST PROTOCOL RADIOGRAPHIC TESTING

PROVNINGPROTOKOLL
Radiografering
Test Report
Radiographic Testing

DEKRA

Dokument nr/Document no	Rev	Bilaga/Appendix	Sida/Page
541113 RT-21	0	0	1(1)

Ritning nr/Drawing No.	Rev	Provningsdatum/Date of testing	Uppdragsgivare/Customer
-	-	2013-07-11	**OKG AB** **Simpevarp** **572 83 Oskarshamn**
Anläggning/Provningsplats/Site/Place of testing: OKG AB			
Objekt information/Object information: Svetsning av blandskarvar 316L mot 15Mo3			Uppdragsgivarens referens/Customer reference: Manfred Olejnik — Order nr/Order No: 4500019230

Provningsprocedur/Testing proc.	Rev	Provning enligt/Examination acc. to	Grundmaterial/Base material	Tillsatsmaterial/Filler	
RT-101	5	SS-EN ISO 17636-1 Klass B	316L/15Mo3	Enl. WPS	
Accept. proc. (nivå)/Accept. proc. (level)	**Rev**	**Acceptans krav/Acceptance criteria**	**Svetsmetod/Welding procedure**	**Fogtyp/Joint design**	**Värmebehandl./Heat treated**
RT-901 (1)	7	SS-EN 12517-1:2006	141	Enl. WPS	Nej
Provningsbeskrivning/Omfattning/ Extent of testing			**Tillverkare/Manufacturer**	**Kontrollplan/Control plan**	**Rev**
100% + HAZ			---	-	-
Övriga uppgifter/Supplementary information					

Strålkälla Id.Nr./Source Id.No.	Märkning på objekt/Marking on object		Exp.data/ Exp.data	Rörsp./Tube voltage [kV]	FFA/FFD [cm]	Exp. tid/ Exp. time [mAmin]	Prov. upps./ Technique	Filmtyp/ Type of film	Trådskala/ Type of IQI	Trådskalans placering/ IQI placement
OCO749	Märkpenna									
Strålkälla typ/Type of source: Röntgen	**Apparat/Märkspänning/Equipment/:** Andrex Smart 225		1	185	40	0,9	2	C4	10 FE EN	Filmsida
Fokusstorlek/Focus size: 2,8x2,8	**Förstärkningsskärmar/Screens:** 0.027mm Pb		2							
Isotop/Aktivitet/Isotope activity: ---	**Totalt antal filmer/No of films:** 54	**Svärtn.krav/Density req.:** 2,3-4,7	3							
Framkalln. process/Dev. teqnique: Automatisk	**Filmplan/Sketch:** -		4							
Övriga uppgifter/Supplementary information: ---										

100 - Spricka Crack | 2011 - Pora Gas pore | 2012 - Jämnt fördelade porer Uniformly distributed porosity | 2013 - Porsamling Clustered porosity | 2014 - Porer på linje Linear porosity | 2015 - Långsträckt blåsa Elongated cavity | 2016 - Maskhål Worm-hole | 202 - Pipe Shrinkage cavity | 301 - Slagginneslutning Slag inclusion | 3041 - Volframinneslutning Tungsten inclusion | 401 - Bindfel Lack of fusion | 402 - Rotfel Lack of penetration | 501 Smältdike - Undercut | 5011 - Fortlöpande smältdike Continuous undercut | 5012 - Intermittent smältdike Intermittent undercut | 5013 - Rotdiken Shrinkage groove | 502 - För hög svetsvulst Excess weld metal | 504 - Genomrinning Excess penetration | 507 - Kantförskjutning Linear misalignment | 510 - Genombränning Burn through | 511 - Ej utfylld svets Incompletely filled groove | 515 - Vals i rot Root concavity | 517 - Startfel Poor restart

Skarv/ Film nr Joint/Film No	Enligt krav/ Acc. to req. Ja/ Yes	Enligt krav/ Acc. to req. Nej/ No	Filmlägen/ Film positions	Anmärkningar /Reparationslägen/ Remarks/Repair positions	Svärtning enl. krav/ Density acc. to req. Ja/ Yes	Svärtning enl. krav/ Density acc. to req. Nej/ No	Hålkval .IQI	Exp. data	Material dimension [mm]	Svetsare/ Welder
prov1	X		1-9-1		X		W14	1	ø114,3x10	2232
prov2	X		1-9-1		X		W14	1	ø114,3x10	2232
prov3	X		1-9-1		X		W14	1	ø114,3x10	2232
prov4	X		1-9-1		X		W14	1	ø114,3x10	2232
prov5	X		1-9-1		X		W14	1	ø114,3x10	2232
prov6	X		1-9-1		X		W14	1	ø114,3x10	2232

Övrigt/Skiss/ Supplementary information/Sketch

DEKRA Industrial AB

Filmgranskare/Evaluator	Operatören/Operators
Fredrik Karlsson Fredrik Karlsson 2013-07-15 SS-EN 473 II A405424	Tobias Persson/ EN473 II

Adress: Gamlestadsvägen 2, Box 13007, SE-402 51 Göteborg
Tel: +46 (0)10 455 10 00 | Fax: +46 (0)10 455 12 99 | www.dekra.se | Org. nr 556033-5977

RT-601 rev 2

APPENDIX G: TEST PROTOCOL PENETRANT TESTING

PROVNINGPROTOKOLL
Penetrantprovning
Test Report
Liquid Penetrant Test

DEKRA

Dokument nr/Document no	Rev	Bilaga/Appendix	Sida/Page
541113 PT-286	0	0	1(1)

Ritning nr/Drawing No.	Rev	Provningsdatum/Date of testing	Uppdragsgivare/Customer	
-	-	2013-07-11	**OKG AB** **Simpevarp** **572 83 Oskarshamn**	
Anläggning/Provningsplats/Site/Place of testing: OKG AB CMV				
Objekt information/Object information: Svetsning av blandskarv 316L mot 15Mo3 (6st)			Uppdragsgivarens referens/Customer reference: Manfred Olejnik	Order nr/Order No: 4500019230

Provningsprocedur/Testing proc.	Rev	Provning enligt/Examination acc. to	Svetsmetod/Welding procedur	Grundmaterial/Base material	Tillsatsmaterial/Filler
PT-101	8	SS-EN 571-1	141 - TIG	316L/15Mo3	4091430-2-1/4122267-1-1

Accept. proc. (nivå)/Accept. proc. (level)	Rev	Acceptans krav/Acceptance criteria	Kontrollplan/Inspection plan	Rev.	Tillverkare/Manufacturer
PT-904 (1)	6	KBM	-	-	Elajo Mek

Provningsbeskrivning/Omfattning/ Extent of testing	Värmebehandlat/Heat treated
100 % penetrant provning av 6 st blandskarvar 114,3x10	Nej

Övriga uppgifter/Supplementary information

Ytkondition/Surface condition	Använd penetrant metod/Used penetrant method	UV-lampa/UV-lamp id-nr/No.
Obearbetad svets	Färgad (röd)	-

	Steg	Metod			Medel	Charge nr./No.
1	Förbehandling/ Pre-Examination	Rengöring/Cleaning method: Lösningsmedel och trasa			Rengörare/Cleaner: Bycotest C10	120708
2	Applicering av penetrant/ Application of penetrant	Appliceringsmetod/Application method: Pensling	Objekt/Object Temp °C: 20	Inträngn.tid/Penetration time: 20 min	Penetrant/Penetrant: Bycotest RP20	120302
3	Borttagning av penetrant/ Removing penetrant	Använd penetrant är borttagen med/ Used penetrant is removed with: Lösningsmedel och trasa		Torktid/Drying time: 5 min	Bortagare/Remover: Bycotest C10	120708
4	Framkallning / Developing	Framkallningstid/Developing time: 0-30 min			Framkallare/Developer: Bycotest D30	120603

Övrigt/Skiss/ Supplementary information/Sketch

Resultat

Uppfyller krav enligt specifikation/Acceptable according to procedure: ☒ Ja/Yes ☐ Nej/No

DEKRA Industrial AB

Ansvarig Operatör/Responsible Operator	Operatörer/Operators
Fredrik Karlsson Fredrik Karlsson 2013-07-16 SS-EN 473 II A405424	Fredrik Karlsson/ SS-EN 473/Nordtest II

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PT-601 rev 2

APPENDIX H: TEST PROTOCOL BEND TESTING

PROVNINGSPROTOKOLL
PENETRANTPROVNING

Återkommande provning vid kärnkraftsverk

SWEDAC ACKREDITERING 4780 EN 17025

DEKRA

Bilaga	Dokumentnummer	Uppdragsnummer	Sida
	-	549038	1/2

Anläggning	Systemnummer	Komponentnummer	Besiktningsområde nr
-	-	-	-

Uppdragsgivare: OKG AB, 572 83 Oskarshamn

Föremål, dimension: 12 st. bockprov.

Ritningsnummer	Rum nr	Detalj nr
-	-	-

Grundmaterial: SS/CS	Tillsatsmaterial: -	Ljusmätare ☒ Vit: ID-nr: 52053	Ljusmätare ☐ UV: ID-nr: -
Svetsmetod: -	Fogtyp: Blandskarv	Belysning vid provytan: >500 lux	Temperaturmätare: ID-nr: -
Värmebehandlat: ☐ Ja ☒ Nej		Bakgrundsbelysning (vid UV-test): Lux:	Temperatur provyta: 23 C

Provningsomfattning A-sida: 100% mm	Provningsbegränsning A-sida: -
Provningsomfattning B-sida: 100% mm	Provningsbegränsning B-sida: -

Procedur nummer: PT01 rev 3

Ytkondition: Acc	Metod: ☒ Färgad penetrant ☐ Fluorescerande penetrant

Förbehandling	Rengöring: C10	Rengörare: C10	Chargenummer: 110605	Penetrant: RP20	Chargenummer: 120712
	Torkningsmetod: Avdunstning	Penetrantborttagare/: C10	Chargenummer: 110605	Framkallare: D30	Chargenummer: 120603
	Torktid: 5 min	Använd penetrant är borttagen med: ☐ Vatten ☒ Lösningsmedel ☐ Vatten + lösningsmedel			

Applicering av indikator	Appliceringsmetod: Pensel	Borttagning	Torkningsmetod: Trasa fuktad med C10
	Inträngningstid: 30 min		Torktid: 3 min
	Temperatur °C: 23	Framkallning	Metod: Sprayning; Temperatur °C: 23

Anmärkning/Skiss

Procedurprov har körts för olika svetslägen, ur dessa har det sedan tagits 12 provbitar som bl.a. genomgått bockprov.

Bitar 1-6 (rotbock)
Bitar 1-6 (toppbock)

Bit nr: 2 och 6 som är rotbockade uppvisar linjära indikationer på den svarta sidan i övergången till svetsen, se bilaga 1.

Rapporterbara indikationer ☒ Ja ☐ Nej

Stråldos: 0,1 mSv

302 rev. 1

DEKRA Industrial AB			**Tillståndshavare**
Datum: 2014-02-27	Operatör: Magnus Strand	Nivå: II	Datum:
Datum: 2014-02-27	Provningsansvarig: Magnus Strand		Underskrift:

RAPPORT utfärdat av ackrediterat provningslaboratorium.