

# Susceptibility to Hydrogen Induced Stress Cracking of centrifugal cast 25Cr Duplex Stainless Steel

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## Preface

As a part of the requirements of the Master's degree program at the Department of Materials Science and Engineering, the present thesis is submitted to the Norwegian University of Science and Technology (NTNU). The supervisors of this work are Professors Roy Johnsen and Mariano Iannuzzi at NTNU in collaboration with Atle Qvale and Anders Jernberg at GE Oil & Gas.

I am very grateful to all my supervisors at both NTNU and GE Oil & Gas for their steady guidance throughout the process of writing this thesis. Professors Roy Johnsen and Mariano Iannuzzi let me employ their expertise in HISC testing, without which this work would not have been the same. I am also grateful to Atle Qvale and Anders Jernberg for their input during discussions as well as for initiating the project and providing the necessary materials. Thank you all.

The engineers and other staff at NTNU and SINTEF must also be mentioned. Especially Nousha Kheramand, Trygve Schanke and Pål Skaret should be thanked for their help with the SEM, laboratory equipment and performing tests needed for the thesis, respectively. Thanks are also extended to Ann-Karin Kvernbråten for performing the hydrogen measurements used in this thesis.

Finally, I am eternally grateful to my co-students at the Department of Materials Science and Technology for making my time at NTNU such a life-changing experience.

Linn Cecilie Gjelseng June 28. 2017, Trondheim

## Abstract

Testing of the susceptibility towards hydrogen induced stress cracking (HISC) for five 25%Cr super duplex stainless steels (SDSS) under cathodic protection (CP) in seawater has been conducted. The materials were from pipes produced through different production methods; hot extrusion with and without subsequent cold drawing, manufactured from a forged bar and centrifugally cast. The testing was carried out in cortest proof rings on three test specimens pre-charged with hydrogen and one reference specimen without hydrogen until fracture occurred. Hydrogen measurements were conducted and the fracture surfaces were examined in a scanning electron microscope (SEM), and the embrittlement through thickness was indexed. The possibility of secondary cracking was also investigated using the SEM. In addition, the microstructures were examined using optical microscopy (OM) and assessed compared to the HISC testing results. The austenite spacing was also measured.

The hydrogen measurements together with the presence of secondary cracking of all test materials confirmed HISC being the fracture mechanism. The test results indicated that all SDSS materials tested are susceptible to HISC, and that the hot extruded material with no cold deformation has a higher HISC resistance while centrifugally cast materials are more prone to HISC than the other production methods. The fracture surfaces of all hydrogen charged test materials showed features indicating a reduction in ductility due to HISC as well as both ductile and brittle fracture characteristics across the surfaces. The placement of the ductile and brittle features varied, and both could be found close to the centre and edges of the fracture surfaces. The fracture surfaces for the reference specimens showed mostly ductile fracture characteristics.

The results from the HISC testing were discussed compared to available literature on the subject of HISC in SDSS, and the susceptibility of the materials from the different materials towards HISC were ranked from lowest to highest based on the overall test performance and measurements conducted. The ranking of production methods is as follows: hot extruded pipes > hot extruded pipes with subsequent cold drawing > forginged pipes > centrifugal cast pipes.

## Sammendrag

Følsomheten mot hydrogenindusert spenningskorrosjon (HISC) for fem 25%Cr super duplex rustfrie stål (SDSS) utsatt for katodisk beskyttelse (CP) i sjøvann har blitt testet. Materialprøvene var fra rør produsert gjennom ulike produksjonsmetoder; varmekstrudering med og uten etterfølgende kalddeformasjon, produsert fra en smidd sylinder og sentrifugalstøping. Testingen ble utført ved stegvis økende last til brudd i cortest testringer ("Cortest proof rings") på tre prøver forladet med hydrogen og én referanseprøve uten hydrogen. Hydrogenmålinger ble gjort og bruddflatene ble undersøkt ved hjelp av et scanning elektronmikroskop (SEM). Forsprøingen grunnet hydrogen gjennom hele prøvetykkelsen ble indeksert og mulige sekundærsprekker ble undersøkt, også dette ved bruk av SEM. Mikrostrukturen til de ulike materialene ble undersøkt ved bruk av lysmikroskopi og vurdert i fohold til resultatene fra testingen for HISC. Austenittavstanden ("austenite spacing") ble også målt for materialene.

HISC ble bekreftet som bruddmekanisme for materialene gjennom hydrogenmålingene samt tilstedeværelsen av sekundærsprekker i alle materialprøvene. Testresultatene indikerer at det varmekstruderte materialet uten kalddeformasjon har høyest motstand mot HISC, mens de sentrifugalstøpte materialene har den laveste motstanden av produksjonsmetodene undersøkt i denne oppgaven. Bruddflatene til alle testmaterialene indikerte reduksjon av duktilitet grunnet HISC, samt både duktile og sprø bruddkarakeristikker ble observert for de forladde prøvene. Plasseringen av de duktile og sprø områdene varierte, og begge ble observert nær midten og mot kanten av prøvene. Referanseprøvenes bruddflater innholdt stort sett duktile bruddkarakteristikker.

Resultatene fra HISC-testingen ble diskutert i forhold til tilgjengelig litteratur om HISC i SDSS, og følsomheten til materialene for denne bruddmekanismen ble rangert fra lavest til høyest basert på den helhetlige prestasjonen i testene og de utførte målingene. Rangeringen for de ulike produksjonsmetodene er som følger: varmekstruderte rør > varmekstruderte rør med påfølgende kalddeformasjon > smidde rør > sentrifugalstøpte rør.

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# Nomenclature

Symbols	Explanation			
α	Ferrite			
$\alpha_m$ , $\alpha_{m+b}$	Allowable SMYS factors			
$\gamma$	Austenite			
$\gamma_{HISC}$	Material quality factor			
E <sub>res</sub>	Residual strain			
$\sigma_m$ , $\sigma_{m+b}$	Stresses: membrane, membrane and bending			
$\sigma_{res}$	Residual stress			
$\sigma_{th}, \sigma_{th,HISC}$	Threshold stress: reference samples, polarised samples			
$A, A_0, A_{min}$	Area: original, minimal			
$(\nabla C)_t$	Concentration gradient at time, t			
D	Diffusion coefficient			
$D_0$	Temperarure-independent pre-exponential for diffusion coefficient			
%DB	Ductile/brittle area ratio			
$d, d_0, d_{min}$	Diameter: original, minimal			
$E, E^{\circ}, E^{rev}, E_{corr}$	Potential: measured, standard half-cell, reversible, corrosion			
<i>e</i> <sup>-</sup>	Electron			
F	Faraday constant			
$ abla G$ , $ abla G_f^\circ$	Sum of free energies of formation: the reaction products, reactants			
8	Gravitational acceleration constant			
$H^+$	Atomised hydrogen			
I, I <sub>corr</sub>	Electric current, rate of corrosion			
$J_x$	Diffusion flux for a specific direction			
$L_{res}$	Distance from centreline of weld			
$M, M^{n+}$	Arbitrary metal and metal ion			
$P_{th}$	Threshold load			
Q	Activities of reactants divided by the activities of products			
$Q_a$	Activation energy for diffusion			
R	Gas constant			

RA	Reduction of area		
RA <sub>air</sub> ,RA <sub>env</sub>	Reduction of area: reference sample, polarised sample		
%RA	Percent relative accuracy		
T	Temperature		
%YS	Yield strength ratio		

Abbreviations	Explanation			
Ag/AgCl	Silver/Silver Chloride Reference Electrode			
AYS	Actual Yield Strength			
BCC	Body Centered Cubic Crystallographic Structure			
BSE	Backscattered Electrons			
CLT	Constant Load Testing			
СР	Cathodic Protection			
DSS	Duplex Stainless Steels			
EDX	Energy-Dispersive X-ray analysis			
FCC	Face Centered Cubic Crystallographic Structure			
HAZ	Heat Affected Zone			
HEDE	Hydrogen Enhanced Decohesion			
HELP	Hydrogen Enhanced Local Plasticity			
HISC	Hydrogen Induced Stress Cracking			
OM	Optical Microscopy			
RA	Reduction in Area			
SD	Standard Deviation			
SDSS	Super Duplex Stainless Steels			
SE	Secondary Electrons			
SEM	Scanning Electron Microscopy			
SMYS	Specified Minimum Yield Stress			
SSRT	Slow Strain Rate Testing			
TLRR	Threshold Load Reduction Ratio			
UTS	Ultimate Tensile Strength			
YS	Yield Strength			

## 1. Introduction

### 1.1. Historical Background

Over the last decades, the use of duplex and super duplex stainless steels (DSS/SDSS) in offshore installations has increased dramatically due to their excellent mechanical and corrosion resistance properties. Applications include line pipe material and manifold pipework, among others. However, in certain applications components made from DSS and SDSS may be connected to carbon steels and other alloys in need of cathodic protection. In such applications, DSS and SDSS may be exposed to cathodic protection (CP) despite having sufficient corrosion resistance. Though the general experience when using duplex stainless steels in such subsea equipment has been good, some failures has occurred as DSS and SDSS materials are susceptible to hydrogen induced stress cracking (HISC) when connected to CP systems [1].

### 1.2. Motivation

The motivation for this Master's thesis is the expressed desire of GE Oil & Gas for investigating whether there is a difference in the susceptibility towards HISC between materials from five of their suppliers. By performing experiments on pipe materials from the different suppliers, which differ in production methods and thus microstructures, they might reduce the risk of HISC occurring in their components by choosing materials with better performance in subsea and offshore conditions.

### 1.3. Aim of This Work

In this thesis, the aim will be to investigate whether there is a difference in the susceptibility towards HISC between the five 25% Cr Super Duplex materials from different production methods provided by GE Oil & Gas. The differences in susceptibility will be documented by investigating the fracture appearance of the test specimens. The investigation will include HISC testing using Cortest Proof Rings and micrographic examination using optical microscopy (OM). Scanning electrode microscopy (SEM) will be used to investigate the fracture surfaces of the test specimens used in the HISC testing.

## 2. Theoretical Background

Hydrogen induced stress cracking (HISC) is a form of hydrogen embrittlement. The typical degradation of a material's properties through HISC is delayed cracking at stresses below fracture strength [2]. The mechanism is caused by the combined effect of three factors, shown in Figure 2.1. These factors are atomic hydrogen, susceptible microstructure and mechanical and/or residual stresses, and they must all be present simultaneously for HISC to occur [3]. The three factors and how they interact will be explained in the first three parts of this chapter. Subsequently, the literature on the subject of HISC studied for this work will be reviewed with focus on previous HISC testing. Previous failures due to HISC will be presented along with standards created for avoiding HISC. Finally a short description of the principles behind the metallographic examination methods used in this thesis is provided.

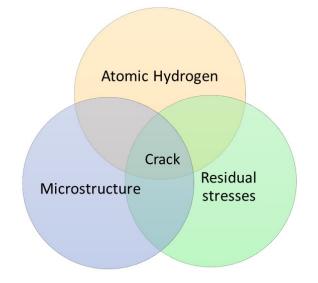


Figure 2.1: Illustration of the necessary factors for HISC to occur.

### 2.1. Sources of Hydrogen

There are several sources of hydrogen, where the main sources are hydrogen from applied cathodic protection (CP) and welding. For the present discussion, the most relevant source

of hydrogen is CP systems [3]. In this section, hydrogen evolution on metal surfaces from CP systems will be explained, along with the electrochemistry behind the phenomenon. Finally, the diffusion of hydrogen is explained.

#### 2.1.1. The electrochemistry of corrosion

When aiming to explain the evolution of hydrogen on a steel surface due to CP systems, one must begin with the electrochemical reactions constituting corrosion. Corrosion is the result of charge transfer reactions occurring simultaneously on a metal surface. The charge transfer reactions, also called half-cell reactions, are the oxidation reaction and the reduction reaction. The oxidation reaction involves a release of negative charge, electrons, while the reduction reactions gains an equal amount of negative charge. Thus, the result of the half-cell reactions is the overall electrochemical reaction. An illustration is presented below, with oxidation, reduction and the overall reaction represented by Equations 2.1, 2.2 and 2.3, respectively. In the equations, M is an arbitrary metal and n is the number of charge equivalents, i.e. number of electrons,  $(e^-)$ , transferred [4].

$$\mathbf{M} \rightleftharpoons \mathbf{M}^{n+} + \mathbf{n}\mathbf{e}^{-} \tag{2.1}$$

$$nH^{+} + ne^{-} \rightleftharpoons nH_{2}(g) \tag{2.2}$$

$$nH^{+} + M \rightleftharpoons nH_{2}(g) \tag{2.3}$$

Whether or not a metal corrodes in a specific environment depends on thermodynamics. Basic thermodynamics states that if the free energy,  $\nabla G$ , is greater than zero, then reaction 2.3 is favoured to the right [4]. Thus, corrosion is possible. To calculate  $\nabla G$ , the Nernst equation is used:

$$\nabla G = \nabla G_f^\circ + RT \cdot lnQ \tag{2.4}$$

Where  $\nabla G_f^{\circ}$  is the sum of free energies of formation of the reaction products minus the sum of free energies of formation of the reactants, R is the gas constant, T is the absolute temperature and Q is the product of the activities of reaction products divided by the product of the reactant's activities.

However, the potential of a corroding metal is not a thermodynamic quantity, but rather a quantity determined by the rates of the electrochemical reactions taking place on the metal[4]. Therefore, a relation between the thermodynamic calculations and electrode potentials is established by comparing measured electrode potentials with the reversible potential of a charge transfer reaction expected to occur. For this to be possible, the thermodynamic quantities  $\nabla G$  and  $\nabla G_f^{\circ}$  must be replaced by  $E^{rev}$  and  $E^{\circ}$ , respectively.  $E^{rev}$  is the reversible potential, and represents a threshold potential that must be overcome for an oxidation process to be thermodynamically possible.  $E^{\circ}$  is the standard half-cell potential. The relations between the potentials and the Gibb's energies are given in Equations 2.5 and 2.6:

$$E^{\rm rev} = -\frac{\nabla G^{\rm rev}}{nF}$$
(2.5)

$$\mathbf{E}^{\circ} = -\frac{\nabla \mathbf{G}_{f}^{\circ}}{\mathbf{nF}}$$
(2.6)

Thus, by substituting the Gibb's energies, the potential analogue of the Nernst equation emerges in Equation 2.7:

$$E^{rev} = E^{\circ} - \frac{RT}{nF} \cdot lnQ \tag{2.7}$$

By comparing measured potentials, *E*, of a metal in solution to the calculated  $E^{rev}$  in the modified Nernst equation the possibility of corrosion can be assessed [4]. The possible results of such a comparison is summarised in Table 2.1. Here, the subscript  $M^{n+}/M$  indicates that the reversible potential pertains to Equation 2.1.

Table 2.1: Possible results of *E* depending on  $E^{rev}$  from [4].

E	Comments concerning the possibility of corrosion		
Less than $E_{M^{n+}/M}^{rev}$	Favoured to the left; corrosion will not occur.		
Equal to $E_{M^{n+}/M}^{rev}$	Equilibrium.		
Greater than $E_{M^{n+}/M}^{rev}$	Favoured to the right; corrosion may occur.		

The possibility of corrosion can also be assessed by using an Evans diagram. In an Evans diagram as shown to the left in Figure 2.2, the range of potentials where the half-cell reactions are possible and the rate of the reactions is shown. The rate is measured in current, I. In the figure, the red line represents metal oxidation and the blue line is the evolution of hydrogen on the metal surface. The intersection between these lines represents the corrosion potential,  $E_{corr}$ , and the corrosion rate,  $I_{corr}$ .

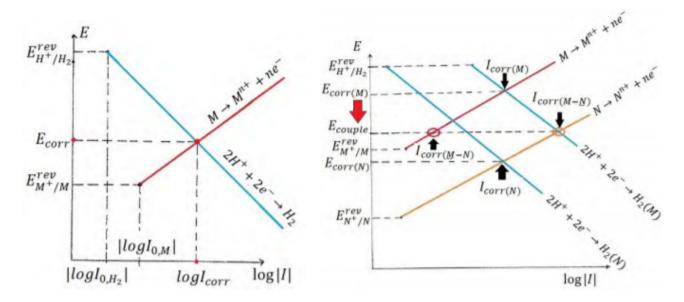


Figure 2.2: Evans diagram from [4] showing corrosion for a single metal (left) and galvanic corrosion (right).

When two metals, one more noble than the other, are in electrical contact, the overall electrochemical reaction consists of four half-cell reactions; two for each metal. In this case, the potential stabilises at an  $E_{couple}$ . At this potential, the rates of oxidation and reduction are equal. This results in the modified Evans diagram for galvanic corrosion to the right in Figure 2.2. If the potential is reduced from  $E_{corr}$  to  $E_{couple}$  as indicated by the arrow in the figure, the corrosion rate of M decreases. This is indicated by the red circle in Figure 2.2. Conversely, the corrosion rate for the less noble metal N and an increase in the corrosion rate occurs for this metal (orange circle). This is what constitutes galvanic corrosion of metals [4].

### 2.1.2. Cathodic protection as hydrogen source

Cathodic protection (CP) is one of the most effective ways of protecting a submerged external steel surface from corrosion. CP utilises the effect of galvanic corrosion in a positive manner by lowering the potential of a metal to a level at which the corrosion rate of the metal is significantly reduced. CP is termed a successful protection method when the rate of corrosion has been reduced to negligible values [5]. This is often achieved by galvanically connecting the surface to be protected to a less noble metal. In the case of steel, Zinc (Zn) or Aluminium (Al) alloys are commonly used. The less noble metal is termed a sacrificial anode, and will corrode in stead of the more noble steel surface.

For protecting carbon and low alloy steels, a potential of -800  $mV_{Ag/AgCl}$  is generally accepted as sufficient [6]. However, the cathodic polarisation varies depending on the distance from the anodes and the anode material. Therefore, when designing CP systems, the protective potential may vary between -800  $mV_{Ag/AgCl}$  and -1100  $mV_{Ag/AgCl}$ . This corresponds to the anode potential. Hydrogen is then formed on the surface due to a cathodic reduction reaction at potentials below -800  $mV_{Ag/AgCl}$ . The reactions occurring at the cathode surface are given in Equations 2.8 and 2.9:

$$2 H_2 O + O_2 + 4 e^- \rightarrow 4 O H^-$$
 (2.8)

$$\mathrm{H}^{+} + \mathrm{e}^{-} \to \mathrm{H}^{0} \tag{2.9}$$

Some of the hydrogen atoms will be absorbed by the steel surface and thus increase the content of dissolved hydrogen in the steel. If the amount of hydrogen absorbed into the steel is sufficiently high and tensile stresses are applied to the material, failure of the material due to HISC may occur. To reduce the amount of hydrogen diffusing into submerged materials, it is generally agreed in the industry that one should avoid polarised potentials more negative than -1050 to -1100  $mV_{Ag/AgCl}$  [7, 8]. However, as hydrogen evolves at -800  $mV_{Ag/AgCl}$ , HISC might still occur even with this precaution.

#### 2.1.3. Hydrogen diffusion

Hydrogen is the smallest element, consisting of only one proton and one electron. In its natural state hydrogen takes the form of  $H_2$  gas, i.e. two hydrogen atoms bonded together. This molecule is too large to diffuse into a solid metal. Therefore, to enter a solid metal lattice, the hydrogen gas must dissociate into single atoms. These atoms are called atomic hydrogen[2]. The main diffusion mechanism for atomic hydrogen is interstitial diffusion, meaning the atoms migrate from an interstitial position in the lattice to an empty, neighbouring interstitial position [9]. In addition to dissolved hydrogen at interstitial positions, hydrogen may also be present in the microstructure at sites associated with crystalline defects, e.g. vacancies, grain boundaries or dislocations. Hydrogen at such structural heterogeneities are termed "trapped hydrogen", and trap sites are either reversible or irreversible depending on their ability to hold a hydrogen atom. At reversible traps the hydrogen may be released and hydrogen in such traps are considered mobile along with the hydrogen at interstitial lattice positions. Irreversible traps, however, hold on to the hydrogen permanently, meaning hydrogen at such sites cannot take further part in the diffusion [3].

### **Fick's Laws**

The diffusion of hydrogen from a region of high concentration to one with a low concentration is described by Fick's first law, given in equation 2.10:

$$J_x = -D \cdot (\nabla C)_t \tag{2.10}$$

Where

$$J_x$$
 = Diffusion flux for a specific direction  $[kg/m^2s]$   
 $D$  = Lattice diffusion coefficient  $[m^2s]$   
 $(\nabla C)_t$  = Concentration gradient at a specific time t

In ideal metals without traps, the hydrogen diffusion follows Fick's second law, equation 2.11, which describes a nonsteady-state diffusion. This law is based on Fick's first law together with the concept of mass conservation. Nonsteady-state implies that the rate decreases as an equilibrium is established[7].

$$\frac{\delta C}{\delta t} = D \left[ \frac{\delta^2 C}{\delta x^2} + \frac{\delta^2 C}{\delta y^2} + \frac{\delta^2 C}{\delta z^2} \right]$$
(2.11)

The lattice diffusion coefficient, D, found in Fick's laws can be described by the relation:

$$D = D_0 \cdot exp\left(-\frac{Q_a}{RT}\right) \tag{2.12}$$

Where

$D_0$	=	Temperature-independent preexponential	$[m^2/s]$
Qa	=	Activation energy for diffusion	[J/mol]
R	=	Gas constant	$[8.31(J/mol \cdot K)]$
Т	=	Temperature	[K]

This coefficient is highly dependent on temperature, as seen from the relation in equation 2.12, indicating that the diffusion of hydrogen for a given concentration is similarly dependent on temperature. An increase in temperature will therefore increase the diffusion rate of hydrogen through a metal.

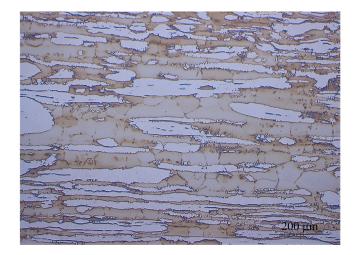
### 2.2. Super Duplex Stainless Steels

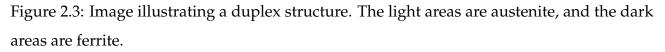
As mentioned in the introduction to this thesis, duplex stainless steels (DSS) and super duplex stainless steels (SDSS) have been used in offshore and subsea applications for some time. Below follows a description of the metallurgy and production methods for these materials.

#### 2.2.1. Metallurgy

Duplex stainless steels are so named due to their characteristic dual phase microstructure consisting of austenite ( $\gamma$ ) islands in a ferrite ( $\alpha$ ) matrix as illustrated in Figure 2.3. This duplex structure combines the strength, corrosion resistance and stress corrosion cracking resistance of ferrite with the toughness and weldability of austenite [10]. The phase distribution of the two phases should be as close to 50/50 as possible to achieve the desired mechanical and corrosion properties. To obtain and maintain the microstructure of duplex stainless steels, both chemical composition and heat treatment is critical [11].

DSS and SDSS contain large amounts of chromium (Cr). Other important alloying elements in DSS and SDSS include nickel (Ni) and molybdenum (Mo). The only stable phase at room temperature in pure iron is ferrite, while austenite is stable at higher temperatures. By adding so-called austenite stabilisers, such as Ni and manganese (Mn), the  $\gamma$ -loop in the iron-carbon phase diagram is extended, and austenite may be preserved at room temperatures. Conversely, Cr and Mo are ferrite stabilisers and addition of these elements will favour the formation of ferrite at greater temperature intervals. However, Cr added to a steel containing Ni will decelerate the kinetics of the austenite to ferrite transformation, and





austenite is easier retained at ambient temperatures. By having the correct balance between  $\gamma$ -forming elements, such as Ni, and the  $\alpha$ -forming elements, such as Cr and Mo, the dual phase ( $\alpha$ + $\gamma$ ) region in the Iron-Carbon phase diagram can be retained down to room temperature. Thus, in combination with heat treatment, a duplex microstructure may be achieved [11].

In addition, the alloying elements also improve the corrosion resistance of DSS and SDSS materials. Stainless steels are created by adding at least 12% of Cr, as this element creates a self-mending passive oxide layer on the steel surface. It is the amount of Cr added that defines the difference between DSS and SDSS; DSS materials contain 22% Cr while SDSS contains 25% Cr. The corrosion resistance is further increased by Mo as it eases the formation of the oxide layer created by the added Cr. The layer is also made more robust by the addition of Mo. Ni makes the oxide layer re-passivate more easily, and increases the steels corrosion resistance in several acidic environments [11].

### 2.2.2. Production methods

There are several possible production methods for DSS and SDSS pipes. The methods relevant for this discussion is presented below.

### Forging

Forging is a manufacturing process involving mechanically deforming a component at elevated temperature. The deformation is accomplished through successive blows to the component or by continous squeezing. The forging process may be either closed or open die. During closed forging operations, a force is applied to two or more die halves, shaping the metal in the gap between them. Two die halves with simple geometric shapes are used in open die forging. Open die is often employed for larger components [9].

### **Centrifugal casting**

One process for manufacturing seamless steel pipes is the horizontal casting process. A schematic of the process is provided in Figure 2.4. In this process, the liquid melt is poured into a preheated and rotated cylindrical, metallic mould. As the mould spins, centrifugal forces is applied as the liquid metal solidifies. The direction of solidification is from the outside diameter inwards, and the molten interior feeds the solidification front continuously. This minimises the solidification porosity and the porosity caused by shrinkage is contained to the inner diameter of the pipe. Solidification impurities such as slag and inclusions are also contained to the inner diameter due to the centrifugal forces. This part of the pipe is normally machined as a part of the manufacturing process, and the impurities will thus be removed from the pipe altogether. The machining also ensures that cast products may be supplied to much stricter tolerances on inner diameters than other products, e.g. wrought seamless pipes. Other advantages of cast products are the isotropic properties and the versatility with respect to composition as the latter can be adjusted to reach specific property requirements [12, 13].

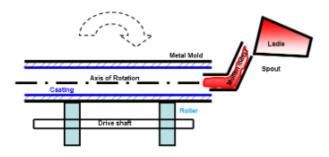


Figure 2.4: Schematic of the centrifugal casting process from [13].

### **Tube extrusion process**

In the process of extruding tubes, the starting material is normally round steel billets. The method may be applied for manufacturing tubes up to an approximate outer diameter of 230mm. The billets may be either rolled, forged or continuously cast, and is first heated to forming temperature before being inserted into the cylindrical recipient of the extruder. Initially, the billet is pierced through the centre by a mandrel. A round-bored die is placed in the end of the recipient, and as the mandrel passes through the die it forms a gap trough which the material is extruded [14]. A schematic of the extrusion process is provided in Figure 2.5.

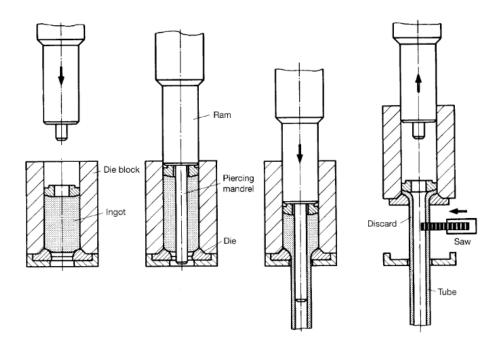


Figure 2.5: Schematic drawing of the extrusion process from [14].

### Cold drawing

A sizable percentage of seamless tubes manufactured through the methods above undergo subsequent cold forming, the purpose of which is to achieve closer wall thickness and diameter tolerances. It also provides an improvement in surface finish and specific mechanical properties in the tube. Another effect of cold forming is to expand the mix of the product toward the lower end of the outer diameter and wall thickness scales. One such process is cold drawing, which may be performed in three different ways: hollow drawing, plug drawing and drawing over a mandrel. In the hollow drawing process, there is no internal tool, meaning only the outside diameter of the tube is reduced. Also, only the outside surface is polished in the die and the reduction in wall thickness is negligible, both in terms of absolute values and tolerances [14]. Figure 2.6 illustrates the cold drawing processes.

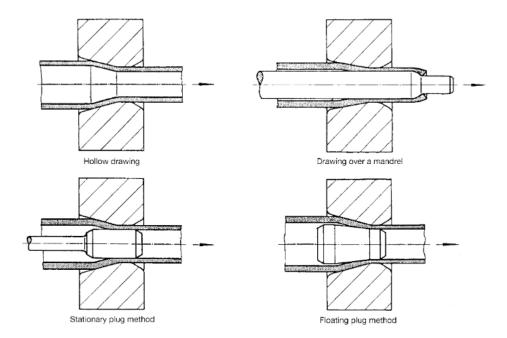


Figure 2.6: Illustration of different cold drawing processes from [14].

In plug drawing, the tube is drawn through a gap formed between a plug and the block die. The result is a reduction in the tolerances of both the outside and inside diameters, and thus also for the wall thickness. Both outside and inside surfaces are also smoothed and polished. When cold drawing over a mandrel, an inserted mandrel bar is employed to pull the tube through the die. As with plug drawing, both inside and outside diameters and the wall thickness undergo reduction. Compared to plug drawing, the possible reductions in area per draw are higher for cold drawing over a mandrel. However, the tube length is restricted by the length of the mandrel bar. In addition, to extract the mandrel the tube must be expanded slightly following the drawing process. As a result, drawing over a mandrel is normally applied for standard sizes and as a preliminary drawing process where the final dimensions are produced is several drawing operations with intermediate heat treatment [14].

When subjected to a cold forming process, the material undergoes strain hardening, meaning the yield and tensile strengths are increased while the elongation and toughness of the material decrease. This might be desirable, but a subsequent heat treatment must be performed prior to any further forming operations to recover some of the lost ductility [14].

### 2.3. HISC in SDSS

This section describes how HISC occurs in SDSS. From this point on, SDSS will be used as a collective term for DSS and SDSS unless otherwise specified as this material is the focus of the present discussion.

### 2.3.1. Hydrogen diffusion in SDSS

For the discussion presented in this work, the dual phase microstructure of DSS and SDSS is important. The ferrite phase has a body centered cubic (BCC) structure, which is an open lattice structure. Austenite, however, has a close-packed face centered cubic (FCC) lattice structure. The open BCC structure of ferrite allows for a high diffusion rate and low solubility of Hydrogen. Conversely, the close-packed FCC structure of austenite results in a decrease of the diffusion rate and increase in the solubility compared to the BCC structure [3]. Diffusion coefficients for ferritic iron and austenitic steel is provided in Table 2.2, along with the coefficients for a low alloy steel, a DSS alloy and a SDSS alloy. From the values, it is clear that the diffusion rate of hydrogen in austenite, represented by the austenitic stainless steel, is much lower than the diffusion rate of hydrogen in ferrite, represented by the pure ferrite iron.

Material	Charging conditions	Test T [C]	Diffusion coeff. $[m^2/s]$
Pure α-iron	-	25	$7.2x10^{-9}$
Low alloy steel (X65)	20 $A/m^2$ in 0.1 M NaOH	25	$1 - 2x10^{-9}$
DSS (SAF 2205)	$1mA/cm^2$ in 0.1 M NaOH	22	$2.8 - 3.0x10^{-15}$
SDSS (SAF 2507)	$1mA/cm^2$ in 0.1 M NaOH	22	$1.1x10^{-15}$
Austenitic stainless steel	-	-	$1.8 - 8.0 x 10^{-16}$

Table 2.2: Diffusion coefficients for hydrogen in different steel types from [3].

This difference in properties between the two lattice structures results in ferrite being more susceptible to hydrogen embrittlement than austenite as ferrite is more readily embrittled by small amounts of hydrogen. Several studies suggest that hydrogen enters SDSS through the ferrite phase due to the higher diffusion rate and embrittles this phase because of its low solubility of hydrogen Thus, HISC is favoured by a higher ferrite content [15, 16]. In addition, HISC is also favoured by higher temperatures. This is due to the temperature dependency of the diffusion coefficient shown in Equation 2.12, meaning that hydrogen will saturate a structure more quickly with increasing temperatures as the diffusion coefficient increases with temperature.

The presence of austenite reduces the diffusion rate of hydrogen in SDSS compared to ferritic stainless steels, as seen in Table 2.2, through several effects. The austenite islands increase the diffusion length, i.e. the distance the hydrogen atoms must travel through the structure. Also, the austenite phase boundaries act as trapping sites, thus decreasing the amount of mobile hydrogen in the material. Both of these retarding effects on hydrogen diffusion are dependent on the shape and spacing of the austenite islands[16]. The finer the grain size, i.e. the size of the islands, the stronger are the effects. This is due to the increase in grain boundary area, and thus trapping sites, with decreasing grain size. Therefore, more hydrogen is trapped at the grain boundaries and the amount of mobile hydrogen is reduced. This in turn reduces the susceptibility of fine grained SDSS materials to HISC [10, 17]. However, one study revealed that for a bimodal distribution of austenite, the fine equiaxed austenite islands appeared to be ineffective towards hindering crack initiation and propagation; the main contribution was then from the elongated grains [18].

### 2.3.2. Deformation and fracture

There are two possible fracture modes for metals, namely ductile or brittle. Ductile metals are characterised by extensive plastic deformation before fracture, and such fractures often exhibit a surface contour termed cup-and-cone. An example of a ductile fracture surface is provided in Figure 2.7 a. In this type of fracture, the interior region of the surface has an irregular and fibrous appearance. A brittle material is characterised by rapid crack propagation and little or no plastic deformation upon fracture. The direction of crack motion is nearly perpendicular to the direction of the applied tensile stress. This yields a fracture surface that is relatively flat, as seen in Figure 2.7 b. For most brittle crystalline materials, crack propagation occurs by cleavage. Cleavage is the process of successive and repeated breaking of atomic bonds along specific crystallographic planes. Such fractures are called transgranular as the cracks propagate through the grains [9].

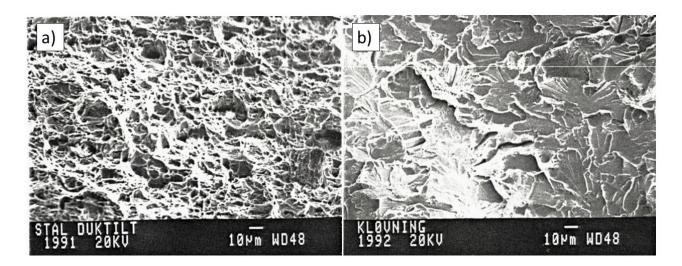


Figure 2.7: Image from [19] depicting a ductile (a) and a brittle (b) fracture surface.

Studies on cracks due to HISC suggest that a typical hydrogen crack in duplex stainless steel is characterised by brittle cleavage type fracture in the {001} plane in the ferrite phase. Under sufficient stress, the crack will overcome the critical stress required for crossing the austenite phase boundaries. This is accompanied by a change in the direction of the crack and stepwise zig-zag micro cracking along the <111> direction when entering the austenite phase [9, 16]. Secondary cracks perpendicular to the stress direction have also been documented by micrographic examination [20, 21]. When hydrogen embrittlement occurs, another fractographic feature is also observed. This feature is termed quasi-cleavage type fracture, and it involves a macroscopically brittle fracture with some local ductile fracture characteristics. It is characterised microscopically by the presence of extended voids, slip ridges and striation marks etc [22].

### 2.3.3. HISC fracture mechanism

When subjecting a crack to a plane opening stress it will, in mechanical terms, be described by a local stress and strain field ahead of the crack tip. The equivalent plastic strain is at its highest at the crack tip, gradually decreasing with increasing distance from this point. The hydrostatic stress field reaches its maximum a short distance ahead of the crack tip. Traditionally, hydrostatic stress is considered the main driving force for hydrogen diffusion from the bulk material towards the crack tip. Thus, hydrogen will diffuse towards the hydrostatic stress field maximum and be trapped there due to dislocation clusters [3]. No complete fracture mechanics model describing both the crack tip stress and strain with the hydrogen affected process zone exists. This is a result of the complexity of the mechanics within this zone, and some assumptions are required for the micromechanical behaviour in front of the HISC crack. The most accredited approaches for these assumptions are the hydrogen enhanced decohesion (HEDE) and the hydrogen enhanced local plasticity (HELP) models [16].

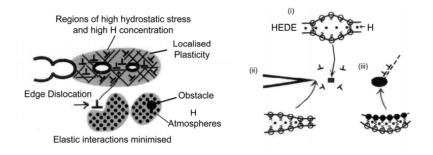


Figure 2.8: Figure from [23] explaining the HELP mechanism (left) and the HEDE mechanism (right).

HEDE is based on the theory that the cohesive strength is lowered by interstitial hydrogen due to an expansion of the metal lattice. In turn, this decreases the fracture energy, implying that the energy barrier for either grain boundary or cleavage plane decohesion is lowered by hydrogen. Fracture is then expected to initiate in the area of maximum hydrostatic stress. To the right in Figure 2.8, the weakened strength of the interatomic bonds due to hydrogen is illustrated by (i) lattice hydrogen, (ii) absorbed hydrogen and (iii) hydrogen at structural heterogeneities. On the other hand, the HELP model suggests that atomic hydrogen enhances the mobility of dislocations at the crack tip through an elastic shielding effect in preferred crystallographic planes. Thus, a fracture based on this model will initiate from slip planes at the crack tip. To the left in Figure 2.8, the HELP mechanism is illustrated by localised plasticity in regions with a high concentration of hydrogen. No matter which model one uses, the crack propagation is promoted by an increased hydrogen concentration at the crack tip [16, 23]. As the FCC crystallographic structure contains more slip planes, i. e. preferred planes, it is hypothesised that the austenite phase fractures through this mechanism, while the fracture mechanism taking place in the BCC structured ferrite phase is HEDE [24].

### 2.4. Previous HISC Testing

In this section, previous testing of several test parameters in relation to HISC is reviewed.

### 2.4.1. Materials and austenite spacing

The microstructure of SDSS materials is highly dependent on production method. Production variables such as heat treatment and cold work are two examples of how the microstructure changes with production method. Improper heat treatment may cause harmful secondary phases, which may decrease the corrosion and mechanical properties. Metallurgical changes such as dislocations, deformation bands and slip steps at the surfaces may be introduced by cold working a SDSS material. Such deformation structures influences the resistance towards hydrogen embrittlement [25]. This is due to alterations in the diffusion characteristics due to changes in the surface topography, as well as changes in the quality of the passive oxide film which may influence the amount of absorbed hydrogen.

A study conducted by Elhoud et. al. [25] found that the presence of detrimental secondary phases due to improper heat treatment weakened the resistance of a SDSS material towards intergranular and pitting corrosion. Whether such secondary phases decreases the resistance towards HISC is debated [20] and should be investigated further to find a more definitive answer. Elhoud et. al. and dos Santos et. al. [26] found that a higher degree of cold work increased the material's susceptibility towards HISC.

As previously mentioned, HISC is favoured by higher ferrite content. It is also favoured by the presence of detrimental phases, e.g. sigma [15]. Sigma phase has the approximate chemical composition FeCr and depletes the microstructure of Cr and Mo, both alloying elements that are vital for SDSS's mechanical and corrosion properties as explained earlier in the chapter. In austenitic stainless steels, sigma phase nucleates at austenite grain boundaries and usually requires ageing for up to 5h at 750°C. However, the presence of ferrite in SDSS accelerates the formation of sigma phase as it nucleates on ferrite/austenite phase boundaries in this material due to higher levels of chromium in the ferrite phase compared to the austenite. Chromium nitrides in SDSS have been investigated, both with respect to the formation of different types of chromium nitrides [27] and to their effect on HISC resistance [20], the latter by Statoil. An analysis performed with energy-dispersive X-ray (EDX)



Figure 2.9: Image showing secondary phases in a SDSS structure.

shows that there are two chromium nitride precipitates that forms in SDSS, namely CrN and  $Cr_2N$ . The former forms on ferrite/austenite interphase regions, and may also form within austenite grains. A lot more is known about  $Cr_2N$  than CrN, e.g. that it tends to form during rapid cooling from elevated temperatures. During such a cooling process the solubility of N in the ferrite decreases, trapping it before it may be redistributed into the austenite phase. The morphology of  $Cr_2N$  is elongated grains, and the precipitates of this phase is generally larger than those of CrN. CrN often forms as an intergranular secondary phase in ferrite, and is often found in clusters here. Both these chromium nitride phases are enriched in Cr, N, Fe and Mo, but *Cr*<sub>2</sub>*N* contains more chromium than, CrN, whilst the opposite holds true for the nitrogen content. This results in  $Cr_2N$  yielding larger chromium depleted regions than CrN. The result of the investigation by Statoil was an observable increase in resistance towards HISC for test specimens without nitrides compared to specimens with nitrides. It was also observed that the material with a high nitride concentration failed at stress levels below yield. Even though this result shows there are reasons for avoiding chromium nitrides, still no common requirement has been established for avoiding it as there is no standardised method for quantification of nitride content [27, 20]. An example of secondary phases in a SDSS structure is shown in Figure 2.9.

Other microstructural features decided by production methods are ferrite content, grain size and austenite spacing. Austenite spacing is the average distance between the austenite islands in the ferrite matrix, or the coarseness of the duplex microstructure [28]. When this parameter decreases the resistance towards HISC increases. This has been observed through several studies, such as Chou et al. [10] and Woolin et al. [18] According to Woolin et al., the risk of HISC may be close to eliminated by reducing the austenite spacing to below  $30\mu$ m. Also, it should be mentioned that the austenite spacing is not a measure of the ferrite grain size, as this is normally substantially larger. A standard for measuring austenite spacing is provided by ASTM E-112 [29]. When relating grain size, ferrite content and austenite spacing to the production method, a ranking of materials from more susceptible to less towards HISC is as follows: forgings > rolled plates > hot isostatically pressed [17].

### 2.4.2. Low temperature creep

When a material is placed under static mechanical stresses it experiences the phenomenon of creep. The definition of creep is "*the time-dependent and permanent deformation of materials when subjected to a constant load or stress*"[9], and it normally occurs at elevated temperatures. When a material experiences creep, it expands in an effort to reduce the plastic strain. In most cases creep is not desired and is the limiting factor for a part's life-time. During constant load testing of environmentally assisted cracking, such as HISC, low temperature creep takes place due to the high mechanical stresses applied to the test material [9, 30].

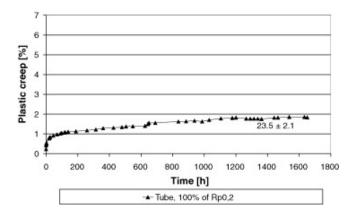


Figure 2.10: Graph from [30] showing the creep curve of an extruded SDSS material at 100% of yield strength.

Kivisäk investigated the influence of low temperature creep on the resistance towards HISC [30]. In the study, SDSS materials with fine and coarse microstructures were subjected to creep testing. A fine microstructure is generally considered to be one with austenite spacing less than  $30\mu$ m, while a coarse structure has values above this limit [28]. The study by Kivisäk concluded that low temperature creep occurs at lower stress levels for materials with

larger austenite spacing. Also, results from the study indicated that strain due to low temperature creep is a prerequisite for HISC to occur although the presence of low temperature creep does not initiate HISC in and of itself [30].

#### Hydrogen content

As hydrogen is a prerequisite for HISC to occur, the presence of hydrogen in the test material is paramount. A study on the effect of hydrogen content on the embrittlement of a DSS material [31] found a direct relation between the two, as shown in Figure 2.11. In the same figure one can also see how the electrolyte used during pre-charging influences the hydrogen content, and thus the level of embrittlement of the test material. In the study, the parameters measured to quantify the degree of embrittlement were the time to failure ratio during slow strain rate testing (SSRT) and the reduction in area ratio (RA).

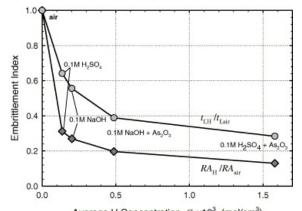


Figure 2.11: Figure from [31] showing the relation between hydrogen content and level of embrittlement for DSS.

The results of the study mentioned above shows the importance of the hydrogen content in specimens when performing HISC testing in simulated operating conditions.

#### **Calcareous deposits**

When using CP as protection against corrosion for steel surfaces in seawater, a calcareous deposit may form on the protected surface. Depending on the chemical composition of the seawater, the deposits may consist of  $CaCO_3$  and  $Mg(OH)_2$ . According to Ou and Wu [32], such deposits reduce the hydrogen absorption of the material due to a barrier effect. For protecting steel surfaces against corrosion, the formation of calcareous deposits is therefore beneficial.

### **Reduction of area**

When testing the influence of hydrogen embrittlement on a material it is helpful to index the amount of embrittlement of test specimens. One such embrittlement index is the reduction of area (RA). As mentioned previously in this section, Zakroczymski et al. used the RA to quantify the level of embrittlement depending on hydrogen content [31]. When investigating the susceptibility towards HISC for a material, the RA of specimens exposed to an environment containing hydrogen should be compared to the RA of specimens in air for the same material [31]. The result is then a reduction in area ratio. The studies conducted by Craidy et al. and Zakroczymski et al. [31, 24] found significant differences in RA between specimens exposed to air and hydrogen. Figure 2.12 shows the RA results from [31].

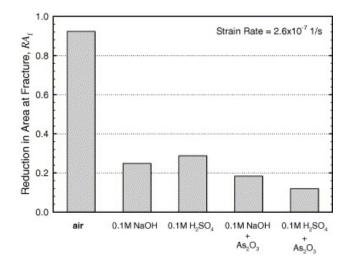


Figure 2.12: Graph from [31] showing the difference in RA between specimens exposed to air and hydrogen containing environments.

#### 2.4.3. Shakedown

Residual stresses from manufacturing processes may be reduced through the process of shakedown. Shakedown occurs when a material is subjected to higher mechanical stress levels than those experienced in operation prior to being put into service. Upon unloading from such high stresses, shakedown causes elastic residual stresses to be lowered and the subsequent behaviour of the material is elastic up to the initial stress level. This will counteract HISC as it lowers the stress levels and thus reduces the level of plastic deformation and delays the occurrence of creep. However, the material will only experience shakedown if the operational stresses are of the same direction and occurs at the same location as the

initial mechanical stress[33].

### 2.5. Reported Failures due to HISC in Literature

Since the oil and gas industry started using DSS and SDSS materials in subsea equipment in the last few decades, there have been several failures attributed to HISC on different subsea components. Some of these are described below to underline the risk posed by HISC in subsea and offshore installations.

### 2.5.1. BP Amoco Foinhaven (1996)

In 1996, BP Amoco installed a total of 181 SDSS subsea hubs on the Foinhaven field in the UK sector. During a routine pressure test of the flowline circuits approximately six months after installation, leaks were discovered in two forged connectors. Cracking was observed in the most highly stressed area of the connectors, and HISC was found to be the cause. Hydrogen had been absorbed into the material due to CP on a non-painted hub surface. A metallurgical investigation found that the failed parts had a coarse microstructure with grain size up to 180  $\mu$ m and containing relatively high levels of carbon nitrides. The ferrite content was measured to approximately 50% [33].

### 2.5.2. Shell Garn West (2003)

Hubs constructed in a non-painted SDSS material were used to connect a manifold pipeline with the transport flowlines. The structure was protected by sacrificial anodes producing typical protection potentials of  $-1050 \ mV_{Ag/AgCl}$ . As one hub connection were restarted after a planned shutdown, it failed close to the weld to the manifold pipe. In an element close to the exposed surface of the hub, the hydrogen content was measured to 300 ppm The cracking was attributed to HISC due to presence of the three necessary factors; susceptible microstructure, access to hydrogen and sufficient stresses [1].

### 2.5.3. Statoil case 1 (published 2013)

An inspection of a forged SDSS subsea module that had been in service for approximately three years revealed a large crack close to the weld between two forged tee components. The failure investigation found that the crack had initiated at the weld toe, propagated throughthickness in the HAZ and base material and continued almost 180 ° circumferential before being arrested. The crack exhibited brittle, cleavage type fracture mode characteristics, and the crack propagation was mainly through the ferrite matrix. Secondary cracking was also observed and was considered indicative of HISC. The hydrogen content close to the crack initiation site was measured to approximately 10 ppm, which is a relatively low value. Further micrographic investigation revealed a relatively coarse microstructure with a ferrite content of 56%. The austenite spacing was measured to 45  $\mu$ m. The investigation concluded that the failure most likely was a result of either brittle impact/overload fracture or HISC [20]. In addition, high levels of chromium nitride precipitates were present in the microstructure, which prompted the Statoil study on chromium nitride's influence on HISC previously mentioned in this work.

#### 2.5.4. Statoil case 2 (published 2013)

Cold formed DSS and SDSS couplings for subsea umbilical hoses installed in sets of 15 were found to fail after a relatively short time in service. One coupling failed after 1,5 years, and when recovering the full set after 3 years in service, seven out of the 15 couplings contained cracks or fractures. All the failed couplings exhibited HISC fracture characteristics, such as crack initiation from multiple sites along the outer surface of the components with brittle crack propagation through the ferrite matrix. The hydrogen content was measured to approximately 40 ppm after three years in service, and approximately 50-60 ppm after five years. Even though the couplings had a fine microstructure with an austenite spacing less than 20  $\mu$ m, the method for attaching them to the hoses included a swaging process. This swaging process introduced considerable cold deformation into the material as well as residual stresses [20].

#### 2.5.5. Statoil case 3 (published 2013)

Multiple partially submerged DSS and SDSS flanges used on vertical column pipes for seawater service under CP failed in a nearly identical manner. Cracking was observed in the flange in the area close to the weld. All the cracks were detected before a complete fracture had occurred. Failure investigations revealed that all cracks exhibited brittle fracture mode characteristics with secondary cracking and propagation in the ferrite matrix. This indicated HISC as the failure mode. The hydrogen content was measured to approximately 100 ppm, which is high value. Other common factors included intermetallic phases in some of the flanges, crack initiation occurring close to the weld start/stop area or in areas with weld repair and cracking occurring on the flange side of the weld [20].

### 2.6. Design Against HISC

Following the major failure on the BP Amoco Foinhaven Field, awareness of the risk HISC posed in the subsea and offshore industries was raised. To prevent HISC from occurring in subsea and offshore installations, several standards have been developed. As preveiously mentioned, HISC occurs when a susceptible material is subjected to mechanical stresses in the presence of atomic hydrogen. By removing either one of these factors, HISC may be avoided. Due to the good corrosion and mechanical properties of SDSS materials, it is not desirable to avoid using these materials and CP systems are necessary to protect components made from other materials. This results in standards focusing on the stress levels of SDSS components used offshore and subsea.

### 2.6.1. Result of investigation into the Foinhaven failure case

As mentioned above, the failure of two SDSS manifold hubs on the Foinhaven Field in 1996 initiated the first large investigation into HISC in the offshore industry. The investigation resulted in the development of a set of acceptance criteria for SDSS components on the field based on a material properties study and stress analyses. These criteria became the starting point for further investigations and more recent guidelines for design of SDSS components for use offshore and subsea. The acceptance criteria set by the Foinhaven investigation were as follows:

- 1. The critical areas of the hub can be shielded from the CP system
- 2. The maximum stresses during any future operational condition will not exceed the threshold for crack initiation
- 3. The hydrostatic strength test has caused sufficient "shakedown"

It was stated that cracking du to hydrogen embrittlement would not occur if one or more of the criteria were followed. In addition to the criteria, a long-term pressure test was developed [33].

#### 2.6.2. DNV Recommended Practice F112

The aim of the DNV-RP-F112 is to provide the offshore and subsea industries with a "best practice" developed on the basis of the knowledge and experience at the time [28]. The standard covers all SDSS materials installed subsea with CP. In addition to recommendations on stress levels and conditions, the standard defines parameters such as CP potentials, temperature and surface characteristics and provides stress/strain design criteria. Recommendations are given on manufacturing, fabrication and testing where these factors are believed to impact the resistance towards HISC directly. As the design criteria are the most relevant for the present work, only these will be reviewed here. These criteria are divided into stress and strain criteria [28]. For both of these, materials produced through the following methods are classified as having microstructures with fine austenite spacing:

- 1. HIP materials.
- 2. Weld metal (heat affected zone, HAZ, excluded).
- 3. Tubes and pipes from extrusion, seamless rolling or drawing operations.
- 4. Rolled plates with wall thickness less than 25mm.

A fine austenite spacing is defined in this standard as less than  $30\mu$ m. All other materials are classified as coarse grained with respect to austenite spacing unless the austenite spacing is measured for each component in question. The two classifications of materials are graded with a material quality factor,  $\gamma_{HISC}$ , which is different for the two:

Fine grained:  $\gamma_{HISC} = 100\%$ Coarse grained:  $\gamma_{HISC} = 85\%$ 

If a component contains girth welds, the residual stresses must be evaluated close to these unless a complete heat treatment has been performed. Estimations of the residual stresses are given within a distance  $L_{res}$  from the centreline of the weld and at weld toes, as shown below:

Girth welds:  $\epsilon_{res} = 0.25\%$ Weld toes:  $\epsilon_{res} = 0.15\%$ 

#### Linear elastic stress criteria

There are two limits for linear stress in this standard, and both are expressed as a percentage of the specified minimum yield strength (SMYS). Both must be met when designing a component for avoiding HISC. The two limits are for membrane stresses,  $\sigma_m$ , and membrane and bending stresses,  $\sigma_{m+b}$ , and are given in Equations 2.13 and 2.14.

$$\sigma_m < \alpha_m \times \gamma_{HISC} \times SMYS \tag{2.13}$$

$$\sigma_{m+b} < \alpha_{m+b} \times \gamma_{HISC} \times SMYS \tag{2.14}$$

(2.15)

In the equations above,  $\alpha_m$  and  $\alpha_{m+b}$  are the allowable SMYS factors for SDSS components. The former equals 80% over the entire area of the component, while the latter varies depending on which part of the component the stress limits are calculated for, as seen in Table 2.3.

Table 2.3: Allowable SMYS factor for component sections

$\alpha_{m+b} = 100\%$	Smooth sections outside <i>L</i> <sub>res</sub>
$\alpha_{m+b} = 90\%$	Smooth sections within <i>L</i> <sub>res</sub>
$\alpha_{m+b} = 90\%$	Weld toe and stress raiser outside $L_{res}$
$\alpha_{m+b} = 80\%$	Within $L_{res}$ for weld toes and stress raisers

#### Non-linear stress criteria

The non-linear strain criteria depends on the distance from welds, as the linear stress criteria do. In addition, the non-linear strain criteria depend on the distance from the surface of the material and the material quality. For the areas outside of  $L_{res}$ , the allowable strain is 0,30% within 5% of the wall thickness. Outside of the 5%, the allowable strain is 1% for fine grained materials and 0,60% for coarse grained materials [28].

# 2.7. Microstructural Examination

### 2.7.1. Optical microscopy

Optical microscopes (OM) are helpful when investigating the microstructure of a material. OMs develop images of a material surface by transferring a magnified image to the eye through a series of lenses that solve the details of the surface [34].

### 2.7.2. Scanning electron microscope

Scanning electron microscopes (SEM) are widely used for microscopical examinations of materials and surfaces. A focused electron beam is used to develop images of the chosen material or surface of interest. Upon impacting the surface of the specimen, several signals may be detected e.g. secondary electrons (SE), backscattered electrons (BSE) and characteristic X-ray radiation. These signals may be used to obtain information on the chemical composition and topography, among others, of the specimen. For fractorgraphical investigations, the topography is of importance. As the electron beam move over the specimen, SE emissions vary as a function of the specimen topography. The quality of the depth of field for SEMs is high enough that the images acquired through this method appear to be three dimensional [19].

Most materials can be investigated using SEM. Some prerequisites for specimens are conductivity and cleanliness. If the specimen has low or no electrical conductivity, the electrons in the beam will be absorbed into the material and accumulate on the surface. The charging of the surface bends the beam, resulting in poor image quality. Methods for circumventing this problem exist, but will not be discussed here as the materials in this thesis are electrical conductors. The other prerequisite, cleanliness is paramount. If there are oily substances on the specimen surface, these may evaporate due to the low pressure in the specimen chamber of SEMs and may contaminate the specimen and/or the apertures [19].

# 3. Materials and Experimental Methods

## 3.1. Test Materials

To perform the experimental work of this thesis, five different SDSS materials were provided by GE Oil & Gas. The materials are manufactured by different suppliers and are obtained through different production methods. The suppliers are Nippon Steel & Sumitomo Metal Co., Fondinox S.P.S., Tubacex Tubos Inoxidables S.A., IBF S.P.A. and Kuhn Special Steel, and the materials from each supplier will from here on be referred to as materials A, B, C, D and E, respectively. Below is provided a short description of each material, and documentation provided by the suppliers such as material certificates and heat treatment procedures are included in Appendix F.However, these material certificates are not complete; for example, not all include values such as the ferrite content of the materials. The rest of this chapter is dedicated to descriptions of the experimental methods used in the present discussion.

### 3.1.1. Material A

The test specimens from material A, manufactured by Nippon Steel & Sumitomo Metal Co. are from a UNS S39274 25% Cr Super Duplex Stainless Steel pipe which is obtained through hot extrusion, followed by cold drawing and subsequent heat treatment. The heat treatment is performed during the extrution process, and the temperature was 1100°C. It is directly followed by quenching in water. The chemical composition of the material is provided in Table 3.1. The ferrite content was not provided by the supplier.

	С	Si	Mn	Р	S	Ni	Cr	Мо	N	Cu	W
Min	0.000	0.000	0.000	0.000	0.000	6.000	24.000	2.500	0.240	0.200	1.500
Max	0.030	0.800	1.000	0.030	0.020	8.000	26.000	3.500	0.320	0.800	2.500
Comp.	0.016	0.250	0.680	0.024	0.0002	6.200	25.100	3.200	0.290	0.530	2.100

Table 3.1: Chemical composition in wt% of test material A.

### 3.1.2. Material B

The second set of test specimens is from material B, manufactured by Fondinox S.P.S. The pipe from which the specimen where machined is seamless and vertically centrifugal cast

UNS S32750 25%Cr SDSS. After casting, the pipe was heat treated by solution annealing at 1130 °C followed by quenching in water. The chemical composition is given in Table 3.2. The ferrite content was reported to be 49,5% by the supplier.

	С	Si	Mn	Р	S	Ni	Cr	Мо	N	Cu	W
Min	0.000	0.000	0.000	0.000	0.000	6.000	24.00	4.000	0.100	-	-
Max	0.030	1.000	1.500	0.040	0.040	8.000	26.00	5.000	0.300	-	-
Comp.	0.023	0.564	0,755	0.023	0.005	7.507	25.124	4.149	0.242	-	-

Table 3.2: Chemical composition in wt% of test material B.

### 3.1.3. Material C

Material C is manufactured by Tubacex Tubos Inoxidables S.A. and is a UNS S32760 25% Cr SDSS from a seamless pipe. The pipe was manufactured through hot extrusion over a mandrel followed by direct quenching in water after extrusion. The extrusion was performed at 1100°C, and thus, the extrusion also acts as a solution annealing. The ferrite content is reported as 54% by the supplier, and Table 3.3 shows the chemical composition of this material.

Table 3.3: Chemical composition in wt% of test material C.

	С	Si	Mn	Р	S	Ni	Cr	Мо	N	Cu	W
Min	0.000	0.000	0.000	0.000	0.000	6.000	24.00	4.000	0.100	0.200	1.500
Max	0.030	1.000	1.500	0.040	0.040	8.000	26.00	5.000	0.300	0.800	2.500
Comp.	0.014	0.390	0,740	0.024	0.0005	6.750	25.700	3.590	0.257	0.66	0.590

### 3.1.4. Material D

The specimens from material D is from a UNS S 32760 25% Cr SDSS seamless pipe, with chemical composition as given in Table 3.4. The pipe was manufactured by IBF S.P.A. from a forged bar, where the bar was bored followed by honing of both inner and outer surface of the pipe. The honing step involves grinding and/or machining to achieve acceptable dimensions and surface finish. Finally, the pipe is heat treated by solution annealing at 1100°C and quenched in water. The supplier provided the ferrite content measurements, and the result of this was 49%.

	С	Si	Mn	Р	S	Ni	Cr	Мо	N	Cu	W
Min	0.000	0.000	0.000	0.000	0.000	6.000	24.00	4.000	0.100	0.200	1.500
Max	0.030	1.000	1.500	0.040	0.040	8.000	26.00	5.000	0.300	0.800	2.500
Comp.	0.016	0.490	0,550	0.025	0.0002	7.000	25.500	3.670	0.245	0.540	0.650

Table 3.4: Chemical composition in wt% for material D

### 3.1.5. Material E

The pipe from which test material E was procured is a centrifugal cast 25% Cr SDSS seamless pipe. The supplier of this material is Kuhn Special Steel. The steel grade of the material is SEW 410 Grade 1.4471.02, which is a modification of UNS S32760 and the chemical composition of the material is provided in Table 3.5. The heat treatment performed for this material was not described in the material certificate from the supplier.

Table 3.5: Chemical composition in wt% of material from E.

	С	Si	Mn	Р	S	Ni	Cr	Мо	Ν	Cu	W
Min	0.000	0.000	0.000	0.000	0.000	5.500	25.50	3.000	0.150	0.800	0.900
Max	0.030	1.000	2.000	0.030	0.020	8.000	28.00	4.000	0.280	1.300	1.100
Comp.	0.018	0.440	0,470	0.015	0.006	7.210	27.260	3.720	0.224	1.090	1.040

# 3.2. Tensile Testing

The HISC testing performed in this thesis is related to the yield strength (YS) of the test materials. Thus, it was necessary to assess the mechanical properties of each test material. Material suppliers are required to perform mechanical and chemical testing before delivering materials to their customers, so data for the materials used in this thesis was available. However, it was determined to obtain new data as the test specimens used by the supplier is of unknown location in the test materials. The dimensions of the test specimens are also unknown. In addition, to obtain all necessary data from the mechanical testing, values from the stress-strain curve is needed.



Figure 3.1: Location in test material from which test specimens were cut.

All the tensile test specimens used for obtaining stress-strain curves were cut from similar locations of the pipe materials provided, as shown in Figure 3.1. The tensile test specimens are the two smaller specimens shown in the figure. The dimensions of the tensile test specimens are provided in Figure 3.2. The cutting and machining was performed by Nomek AS in Trondheim and the tensile testing was performed by staff at the Department of Material Science and Engineering at NTNU. Two tensile tests was performed for each material, and the average value for the actual yield strength, AYS, found by the tensile test performed for this thesis was used during the subsequent HISC testing.

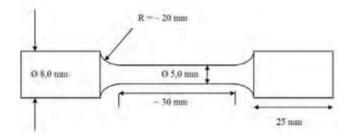


Figure 3.2: Illustration of the dimensions for the tensile test specimens.

## 3.3. Micrographic Examination

For examining the microstructure, suitable pieces were cut out of the test materials. Two test pieces were cut for each material; one in the direction parallel to the pipe length and one in the direction normal to the pipe length. The test pieces were then cast into an epoxy to be more manageable before being ground and polished until a mirror-like surface is achieved. The grinding and polishing procedure was performed in four steps, provided in Table 3.6.

Step no.	Grinding/polishing disk and lubricant	Time
1	Piatto 220 grinding disk w/water	Until plane
2	Allegran 3 polishing disk w/DiaMax 6 $\mu$ m Poly	10 min.
3	Daran 3 $\mu$ m polishing disk w/DiaMax 3 $\mu$ m Poly	8 min.
4	Chemal 1 $\mu$ m polishing disk w/DiaMax 1 $\mu$ m Poly	4 min.

Table 3.6: Overview of the grinding and polishing procedure used to prepare the specimens.

Following the grinding and polishing, the specimens were etched electrolytically in two steps, as recommended for DSS and SDSS by Statoil in their standard for metallographic etching of DSS and SDSS [35]. The first step involves etching the specimens electrolytically with 20% Oxalic acid for 5 to 10 seconds with an applied potential of 5.5*V*. The Oxalic acid etch makes secondary phases such as chromium nitrides visible in the structure. The second step is an electrolytical etch for 6 seconds using 20% NaOH with an applied potential of 2.5*V*. This etch increases the contrast between the ferrite and austenite phases, making them visible in OM images.

## 3.4. Austenite Spacing

For determining the austenite spacing of the test materials, the ASTM E112 standard was applied. The austenite spacing is measured by measuring the mean length of the ferrite grains. This measurement is obtained through superimposing five parallel lines over representative micrographical image of the test material and measuring the length of the ferrite grains. For each material, four randomly selected areas were investigated, and the austenite spacing determined in this thesis is the average of those four areas. The calculation of the austenite spacing, or mean intercept length,  $\overline{\ell_{\alpha}}$ , was obtained through regular calculations of a mean value. If not otherwise specified, the austenite spacing should be measured in the through thickness direction. For the test materials in the present thesis, that is the direction normal to the pipe length.

The accuracy of the measurements are determined through statistical analysis. For the analysis, several values were calculated, the standard deviation, *SD*, the 95% confidence interval, 95%*CI*, and the percent relative accuracy, %*RA*. The equations used for calculating the two latter values are provided in Equations **??** to 3.2 below.

$$95\,\%\text{CI} = \frac{\mathbf{t}\cdot\text{SD}}{\sqrt{n}}\tag{3.1}$$

$$\% RA = \frac{95 \% CI}{\overline{\ell}} \cdot_{100}$$
(3.2)

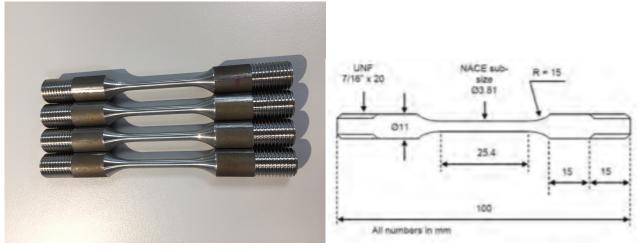
In the equations the parameters explained below are taken from ASTM E112 [29];

- n = Number of measurements
- t = Confidence internal multiplier as a function of n

## 3.5. HISC Testing

#### 3.5.1. Experimental set up

For performing the HISC testing, four test specimens were machined from each material at similar locations as the tensile test specimens. The location from which the specimens were cut can be seen from Figure 3.1. In the figure, the HISC specimens are the larger ones. An image of the HISC specimens is provided in Figure 3.3a, and the dimensions are provided in Figure 3.3b. The specimens were exposed to a HISC favouring environment and put under mechanical stress with subsequent incremental increase in applied load. The HISC testing was performed in three consecutive steps. During all three steps, the the test materials were exposed to a 3,5% NaCl solution with an impressed current of -1050  $mV_{Ag/AgCl}$ . NaCl was chosen as the electrolyte, not artificial seawater, due to the latter containing  $Ca^{2+}$  and/or  $Mg^{2+}$ . Thus, possible calcareous deposits were avoided.

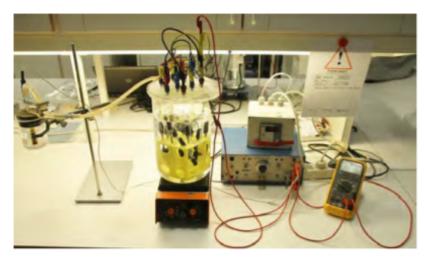


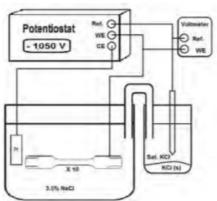


(b) Dimensions of HISC test specimens.

Figure 3.3: Illustrations of the HISC test specimens.

The first step of the HISC testing was pre-charging three of the test specimens with hydrogen at an elevated temperature for at least 10 days to ensure the presence of hydrogen in the material during the testing. The temperature was held constant at 80°C, and the water level was adjusted daily to ensure the correct concentration of 3,5% NaCl in the solution. Figure 3.4a from [36] depicts equipment and electrical set-up used for the pre-charging. The equipment and electrical set-up used in this thesis is identical to that in the thesis by K. Andersen [36]. The fourth test specimen for each test material was not pre-charged with hydrogen as these specimens were to be the reference specimens for each material.





(a) Image showing the equipment used for pre-charging.

(b) Illustration of the electrical set-up for the pre-charging.

Figure 3.4: Figures from [36] showing the equipment and electrical set-up used for the precharging of the HISC test specimens.

After completing the pre-charging, the three specimens were mounted in individual containers and exposed to similar conditions as in the previous step, although at room temperature. The electrical set-up was similar to that of the previous step. The reference specimen for each material was also mounted in a container, only without electrolyte and polarisation. All of the test specimens were then exposed to an applied tensile load of 86% of their respective material's AYS. They were held in this state of tension for seven days.

The final step of the HISC testing involved increasing the applied tensile load incrementally. The load was increased by 4% of AYS daily from the constant load of 86% in the previous step. The incremental increase in applied load continued until fracture. Figure 3.5 shows the equipment used for the second and the final steps of the HISC testing.

### 3.5.2. Cortest proof rings

The equipment used for the HISC testing in this thesis is called Cortest proof rings [37]. This equipment is designed for testing of stress corrosion cracking in environments containing  $H_2S$  and HISC testing, and an image is provided in Figure 3.5.

The rings are compressed manually using the tools marked as b) and c) in Figure 3.6 while the test specimen is inserted in the individual containers. When the ring is compressed, it



Figure 3.5: Image of Cortest proof rings used for HISC testing.

exerts a stress state of uniaxial tension and the deflection in the ring determines the load applied to the test specimen. The deflection-to-load is a linear relation and each ring is accompanied by an individual calibrated conversion chart used to calculate the ring deflection. The conversion calculations were based on the area of the most narrow cross-section.

## **Incidents during testing**

There were some incidents during testing that should be mentioned. When pre-charging the test specimens from material C and D, two specimens went out of the electrical circuit, causing these specimens to corrode. When this was discovered, the charging process was interrupted for a short period of time to replace the corroded specimens. Upon finishing this step, the replacement specimens were left to pre-charge for the correct number of days, while the other specimens for these materials were taken out after 10 days.

Another incident occurred during the last step of testing for material D, the elongation of the reference specimen was too large with respect to the Cortest proof ring it was placed it. This caused the specimen not being able to go to fracture due to lack of room in the test ring.

## 3.5.3. Obtaining results from HISC testing

From the HISC testing, three values were obtained; the threshold load reduction ratio, the percentage of yield strength at fracture and the reduction in area. Below, all three are described and the calculations for all of them are explained.



Figure 3.6: Image of load cell used for obtaining results from HISC testing.

#### Threshold load reduction ratio

The outer diameter of the Cortest proof rings were measured for each increase in load. Upon fracture, the individual containers where removed from the rings and replaced by a load cell, marked as a) in Figure 3.6. By inserting the load cell and compressing the ring to the same level as was held by the test specimens by using the tools shown in the figure, the load applied to the rings at any given increment was obtained. The outer diameter of interest in this thesis is the diameter to which the ring was compressed one step before fracture. This corresponds to the last load the test specimen withstood for 24 hours, or the threshold load,  $P_{th}$  in [kg] [38]. The value for  $P_{th}$  given by the load cell was converted to the threshold stress,  $\sigma_{th}$  [38], for the reference specimen and the HISC threshold stress,  $\sigma_{th,HISC}$ , for the polarised specimens using Equation 3.3. In the equation, *g* represents the gravitational constant equal to 9.81  $m/s^2$ .

$$\sigma_{th} / \sigma_{th,HISC} = \frac{P_{th} \cdot g}{A_0} \tag{3.3}$$

 $\sigma_{th,HISC}$  was then compared to  $\sigma_{th}$  for each material. This gives the threshold load reduction ratio (TLRR), a measure for each material's susceptibility to hydrogen embrittlement in percentage. The comparison was performed by implementing Equation 3.4.

$$TLRR = 100 \cdot \left[ 1 - \left( \frac{\sigma_{th,HISC}}{\sigma_{th}} \right) \right]$$
(3.4)

#### Yield strength ratio

The yield strength ratio, %*YS*, is the ratio between  $\sigma_{th,HISC}$  and the AYS from the stress-strain curves for each material, and the value is given as a percentage of the AYS. The calculation of %YS is provided in Equation 3.5.

$$\% YS = 100 \cdot \left[ 1 - \left( \frac{\sigma_{th,HISC}}{YS} \right) \right]$$
(3.5)

#### **Reduction in area**

RA values are obtained by comparing the original smallest cross-section of a test specimen, i.e. the smallest cross-section before testing, with the smallest cross-section of the specimen after testing. The cross-sections used for calculating the RA are obtained by measuring the diameters of the test specimens before and after testing,  $d_0$  and  $d_{min}$  respectively, and calculating the areas  $A_0$  and  $A_{min}$ . Finally, the areas are inserted into Equation 3.6 [24]:

$$RA = \frac{A_0 - A_{min}}{A_0} \tag{3.6}$$

As this thesis investigates the susceptibility to HISC for different materials, the RA will be reported as the RA ratio, which is the  $RA_{env}$ , for the polarised test specimens from each test material compared to the RA of the reference specimen,  $RA_{air}$ , for the same material. The resulting RA ratio for each polarised specimen will then be a relative value compared to the reference specimen for the respective material. This ratio is obtained through equation 3.7.

$$RAratio = 100 \cdot \left(1 - \frac{RA_{env}}{RA_{air}}\right)$$
(3.7)

#### 3.6. Hydrogen Measurements

The hydrogen content in the test specimen where tested by staff at SINTEF Materials and Chemistry. One specimen from each test material was tested using the melt extraction technique with the H-mat 225 equipment from JUWE Laborgeräte GMbH. The test specimens were taken from the fractured samples previously used for the HISC testing. To avoid the hydrogen diffusing out of the specimens, they were contained in a freezer holding approximately  $-19 \cdot C$  after fracture.

## 3.7. Fractography

To characterise the fracture surfaces of the test materials, all specimens from the HISC testing were investigated using a Scanning Electron Microscope (SEM). The SEM used for the examination was a FEI Quanta FEG 650 Environmental SEM. The method of preparation involved an ultrasonic bath for 5 minutes using acetone as the medium followed by rinsing with ethanol and air drying. During the inspection, the secondary electron detector was utilised, and the operating voltage and working distance were 20kV and 10mm, respectively.

In addition to obtaining fracture surface images, the SEM was used to measure the radius of the brittle areas of the polarised specimens. The measurements were performed to quantify the embrittlement of the specimens due to hydrogen, and the results were used for estimating the brittle area of the specimens. Three measurements for each polarised specimen were performed, and the average value for each specimen was calculated. These average values were used in further calculations. For further calculations, the reduced diameter of the specimens after HISC testing were also used. Once an estimate of the brittle area was obtained, the results were used to calculate the ratio between the ductile and brittle areas (%DB) for each specimen. The estimations for the brittle areas were also compared to the threshold load reduction ratio (TLRR) and the austenite spacing to investigate whether there was any correlation between the parameters.

Finally, the SEM was used for documentation of secondary cracking on the surfaces close to the fracture surfaces of all samples. Due to the specimen holder in the SEM, the working distance during image acquisition of secondary cracks was approximately 20mm.

# 4. Results

# 4.1. Tensile Testing

From the tensile testing, stress-strain curves for the different test materials were obtained. The stress-strain curve for material A is shown in Figure 4.1 as an example. All stress-strain curves are provided in Appendix B. Table 4.1 contains all the measured YS values for the test materials, as well as the average value used for the subsequent HISC testing. Also included in the table are ultimate tensile strength (UTS) values and the UTS/YS ratio for each material. The strain at fracture is not reported in this thesis. This is due to this test parameter not being included in the documentation obtained from the tensile testing.

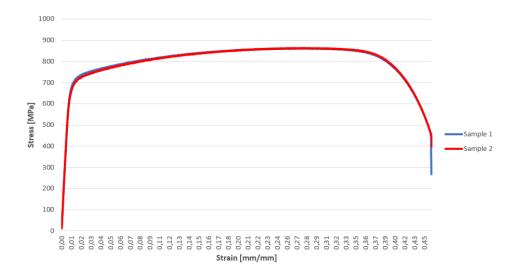


Figure 4.1: Stress-strain curve for material A.

Material	specimen no.	Yield strength	Ultimate tensile strength	UTS/YS
		YS [Mpa]	UTS [Mpa]	[%]
	1	670,7	864,4	128,9
	2	656,9	864,1	131,5
A	Average	663,8	864,3	130,2
	SD	9,76	0,22	1,84
	1	574,0	820,6	143,0
	2	571,2	815,3	142,7
В	Average	572,6	818,0	142,9
	SD	1,98	3,75	0,22
	1	616,5	833,9	135,3
	2	611,5	826,7	135,2
C	Average	614,0	830,3	135,2
	SD	3,54	5,09	0,10
	1	634,7	820,7	129,3
	2	650,0	830,7	127,8
D	Average	642,4	825,7	128,6
	SD	10,82	7,07	14,63
	1	648,4	814,7	125,6
	2	617,6	813,6	131,7
E	Average	633,0	814,2	128,7
	SD	21,78	1,12	4,31

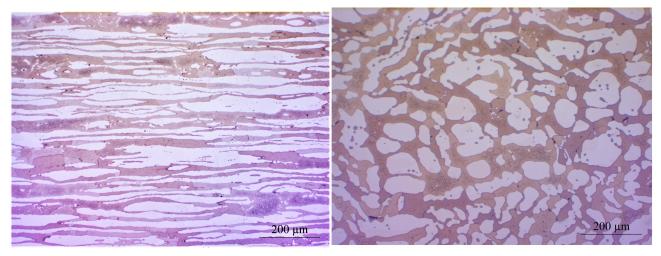
Table 4.1: Tensile test results

# 4.2. Micrographic Examination

In this section, images from the micrographic examination by optical microscopy will be presented for all test materials along with a short description of the microstructure visible from the images. In all OM images presented in this thesis, the light areas represent austenite, while the dark areas represent ferrite. After the micrographical examination, the austenite spacing results are presented.

### 4.2.1. Material A

Figure 4.2 shows the microstructure for test material A. The image in Figure 4.2a is from the direction parallel to the pipe length at 100X magnification. From the image, a duplex structure with elongated austenite islands in a ferrite matrix is clearly visible. In addition, possible clusters of secondary phases are visible as dark clouds in some areas of the ferrite matrix, mainly in larger ferrite grains. Micrographs were also taken for the normal to pipe length direction. As seen in Figure 4.2b taken at 200X magnification, in this plane the austenite islands are more rounded. Possible secondary phases are also visible in the ferrite phase of this plane.

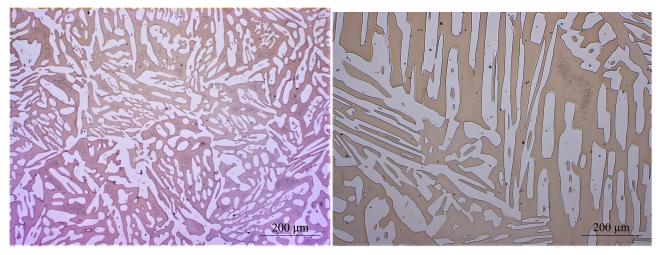


(a) Om image showing the microstructure in the paral-(b) OM image taken in the direction normal to pipe lel to pipe length direction. length

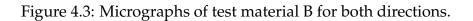
Figure 4.2: Micrographs of test material A for different directions.

### 4.2.2. Material B

Below, the microstructure for test material B in the direction parallel to pipe length is shown in Figure 4.3a. The structure consists of both somewhat elongated and more circular austenite islands in a ferrite matrix. In this material, as for material A, some possible secondary phases are visible in some of the larger ferrite grains.



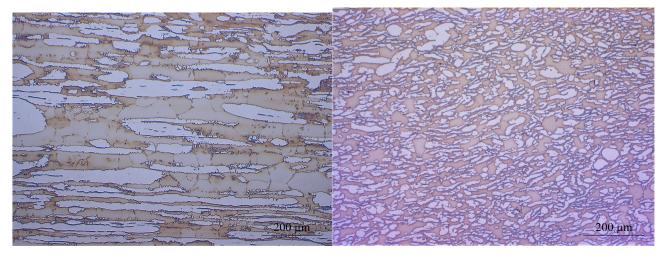
(a) Om image showing the microstructure in the paral-(b) OM image taken in the direction normal to pipe lel to pipe length direction. length



For the direction normal to pipe length of test material B (Figure 4.3b), the austenite islands are more elongated, and the microstructure is more needle shaped. Also in this plane, the larger ferrite grains contain some possible secondary phases.

### 4.2.3. Material C

Figure 4.4a depicts an image of the microstructure of test material C in the plane parallel to the pipe length, while Figure 4.4b is of the direction normal to the pipe length. The magnification of the former is 200X and 100X for the latter. The austenite islands are elongated in the parallel direction and circular in the normal direction. No secondary phases are visible in the ferrite matrix of both directions.

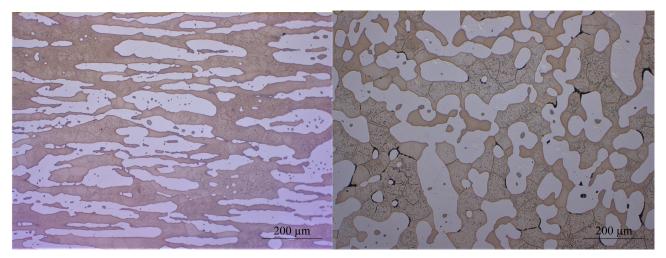


(a) Micrograph of the direction parallel to the pipe(b) OM image taken in the direction normal to pipe length taken at 200X magnification. length

Figure 4.4: Micrographs of test material C for both directions at different magnifications.

#### 4.2.4. Material D

OM images of test material D are provided in Figures 4.5a and 4.5b, both taken at 100X magnification. The images are of the planar direction parallel and normal to the pipe length, respectively. For the parallel direction, the austenite islands are elongated, but somewhat rounded. The duplex structure is also slightly bimodal with some clusters of smaller austenite islands between the larger, more elongated ones. As for the planar direction normal to the pipe length, the austenite islands are less elongated and more rounded. Secondary phases in the ferrite matrix are visible for both directions.

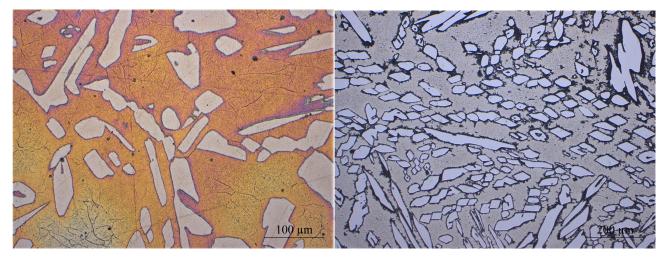


(a) Microstructure of the direction parallel to pipe(b) Microstructure of the direction normal to pipe length.

Figure 4.5: Micrographs of test material D for both directions at different magnifications.

### 4.2.5. Material E

Figure 4.6 depicts OM images of the microstructure of test material E. As can be seen in Figure 4.6a, the microstructure in the direction parallel to the pipe length consists of both elongated and rounded austenite grains of different sizes. The ferrite grains between them are quite large. The direction normal to the pipe length has the same microstructure, as can be seen in Figure 4.6b. From this figure, secondary phases are visible on the ferrite/austenite grain boundaries as black areas.



(a) Microstructure of the direction parallel to pipe(b) Microstructure of the direction normal to pipe length at 200X magnification. length at 100X magnification.

Figure 4.6: Micrographs depicting the microstructure of test material E.

### 4.2.6. Austenite Spacing

The results of the austenite spacing measurements are provided in Table 4.2. From the table and Figure 4.7, material E has the highest average austenite spacing value at  $51,36\mu$ m, while material C has the lowest value at  $24,95\mu$ m. The results for each of the four fields used for calculating the austenite spacing for each test material is provided in Appendix C.

	Material A	Material B	Material C	Material D	Material E
Mean	27,13	26,66	24,95	47,49	51,36
SD	20,71	21,39	14,79	38,55	72,21
95%CI	9,69	10,01	6,92	18,04	33,80
%RA	35,74	37,54	27,73	37,99	65,80

Table 4.2: Austenite spacing results

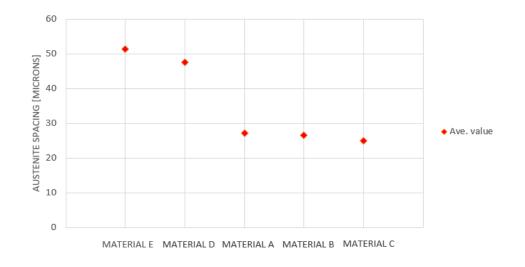


Figure 4.7: Diagram comparing the austenite spacing results sorted from highest to lowest average value.

# 4.3. HISC Testing

As explained in the previous chapter the HISC testing resulted in data for three different testing parameters, namely the threshold load reduction ratio (TLRR), fracture/yield strength ratio (%YS) and reduction in area. The results for these are presented below. As mentioned in the previous chapter, the reference specimen for test material D did not fracture due to lack of room in the Cortest proof ring. How this might have influenced the results will be discussed in the next chapter.

#### 4.3.1. Threshold load reduction ratio

The TLRR values for all polarised specimens from the test materials are presented in Table 4.3. The data used for calculating the values are given in Appendix D. In Figure 4.8 the minimum, maximum and average TLRR values for the test materials are compared. As can be seen in the figure, test material C has the lowest average value or the TLRR at 7,98%. The average values for materials A and D are slightly higher at 11,50% and 10,34%, respectively, while materials B and E are quite high. The latter have average values at 23,46% and 26,10%, respectively. The standard deviation is low for all test materials. However, it is slightly higher for test material D than for the other materials.

specimen no.	Material A	Material B	Material C	Material D	Material E
1	10,00	21,03	7,07	5,00	23,90
2	10,50	23,90	8,89	12,08	25,20
3	14,00	25,44	-	13,95	29,20
Average	11,50	23,46	7,98	10,34	26,10
SD	2,18	2,24	1,29	4,72	2,26

Table 4.3: TLRR values for all polarised specimens [%].

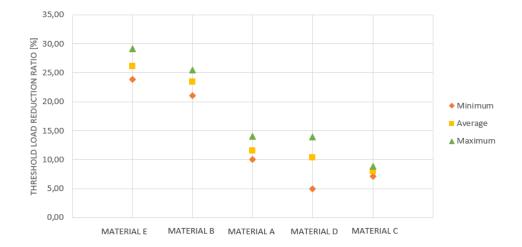


Figure 4.8: Diagram comparing the TLRR values for all test materials sorted from highest to lowest average value.

### 4.3.2. Yield strength ratio

The results for the %YS are given in Table 4.4. The values for  $\sigma_{th,HISC}$  used for obtaining these results can be found in Appendix D under the section pertaining to the TLRR calculations. From the table, it is clear that test material E has the lowest %YS value at 94,40%. This indicates that the test specimens fractured at stress levels lower than the AYS found from the tensile tests. The highest %YS value was found for material C at 132,20%. With the exception of material D, all materials have standard deviations at 3,58 or lower, showing little variation in the results. Test material has a slightly higher SD at 6,10, which is still quite low. Figure 4.9 compares the maximum, minimum and average %YS values for the different test materials.

specimen no.	Material A	Material B	Material C	Material D	Material E
1	119,10	115,76	133,50	122,81	90,40
2	123,90	120,13	130,90	113,67	95,50
3	124,70	113,42	-	111,25	97,30
Average	122,57	116,44	132,20	115,91	94,40
SD	3,03	3,41	1,84	6,10	3,58

Table 4.4: %YS values for all polarised specimens [%].

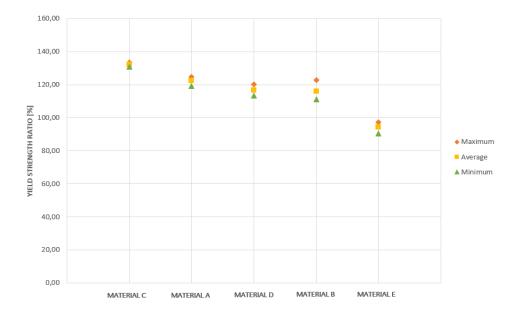


Figure 4.9: Diagram comparing the %YS values for all test materials sorted from highest to lowest average value.

### 4.3.3. Reduction in area

The results from the RA measurements of interest in this thesis are the relative  $RA_{env}/RA_{air}$  values. Therefore, only these values will are presented in Table 4.5. The RA values for all test specimens and the necessary variables for the calculation can be found in Appendix D. Figure 4.10 shows a diagram comparing the RA results for the different test materials. In the figure, the results are sorted by highest average value.

specimen no.	Material A	Material B	Material C	Material D	Material E
1	72,53	85,56	59,30	9,40	94,33
2	82,18	86,32	89,30	11,85	88,34
3	85,72	87,09		12,26	96,06
Average	80,14	86,32	74,30	11,17	92,91
SD	6,83	0,77	21,21	1,55	4,05

Table 4.5: Reduction of area ratio results [%].

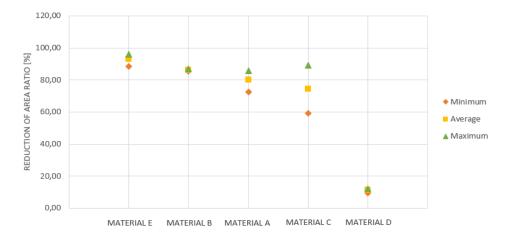


Figure 4.10: Diagram comparing the RA results.

# 4.4. Hydrogen Content

As mentioned in the "Materials and Experimental Methods" chapter, the hydrogen content of the materials after HISC testing was obtained by employing the melt extraction technique using the H-mat 225 equipment from JUWE Laborgeräte GMbH. The results are provided in Figure 4.11 and Table 4.6 below. From the figure, it is evident that test material C has the highest hydrogen content at 82,17ppm, while the lowest value is found for material D at 48,98ppm.

Table 4.6:	Hydrogen	content results
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	Material A	Material B	Material C	Material D	Material E
specimen weight [g]	0,4073	0,4919	0,4216	0,4096	0,4372
Hydrogen content [ppm]	60,06	67,58	82,17	48,98	50,40

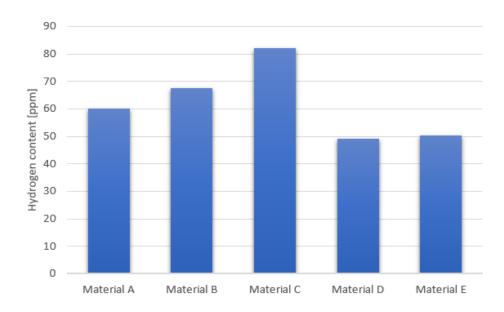


Figure 4.11: Graphical illustration of hydrogen content in the test materials.

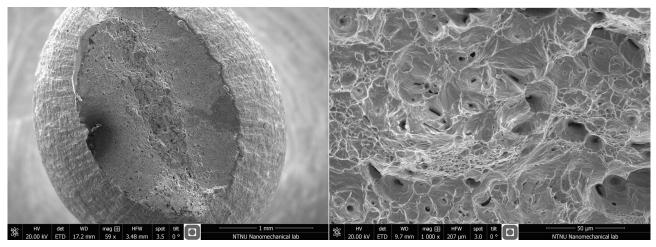
# 4.5. Fractography

For the fractography, the results are obtained through the use of SEM as described in the previous chapter. In this section, SEM images of the specimens are provided along with a short description. Firstly, fracture surface examination images are provided, followed by brittle area estimation results. Finally, SEM images documenting secondary cracking are shown.

### 4.5.1. Fracture surface examination

### Material A

In Figure 4.12, SEM images of the reference specimen for material A is shown at different magnifications. The image to the left is an overview taken at low magnification. In the image, extensive deformation of the specimen before fracture is visible as ridges in the material close to the fracture surface. Cup-and-cone characteristics, or dimples, are visible in the image to the right, which is from the center of the specimen and taken at higher magnification.



(a) Overview image of the test specimen.

(b) Visible dimples in fracture surface.

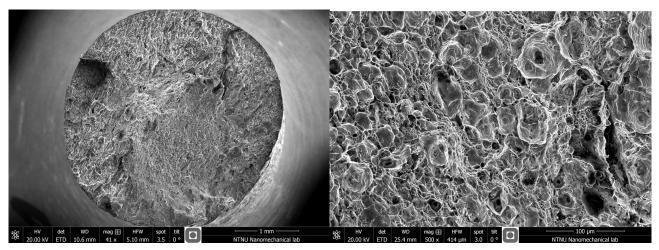
Figure 4.12: Images showing the fracture surface of the reference specimen for material A.

Images of the fracture surface of the first polarised specimen from material A are provided in Figure 4.13. The upper left image, Figure 4.13a, shows the fracture surface at lower magnification. From this image, a ductile surface characteristic is visible towards the lower right edge of the specimen, while a more brittle cleavage-type characteristic is visible to the upper left. Figure 4.13b is of the ductile area, showing the cup-and-cone structure at higher magnification, and Figure 4.13c shows the brittle area at a higher magnification. In the latter, a cleavage in the surface is circled in red.

For the second and third polarised specimens, images taken at different magnifications are provided in Figure 4.14. The two upper images in the figure are from polarised specimen 2, while the bottom two are from polarised specimen 3. From Figures 4.14a and 4.14b, a mostly ductile fracture surface is shown for the second polarised specimen. specimen 3, Figure 4.14c, has a more mixed fracture surface character, with ductile characteristics to the left and brittle to the right of the surface. In the brittle area, a cleavage is circled in red (Figure 4.14d).

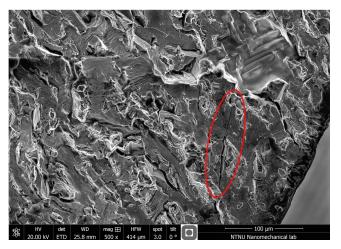
### **Material B**

For the reference specimen for test material B, images of the fracture surface are given in Figures 4.15a and 4.15b. As for material A, the fracture surface of the reference specimen exhibit cup-and-cone characteristics. This is clearly visible from the latter figure. Evidence of



(a) Overview image of the specimen.

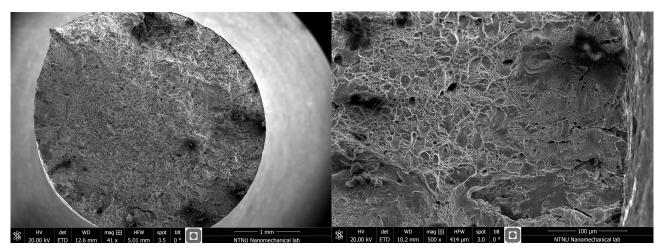
(b) Image showing the dimples in the specimen.



(c) Image taken at the edge of the specimen.

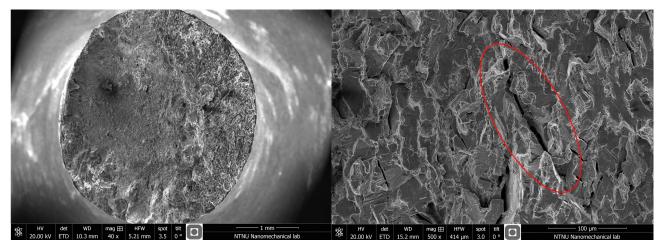
Figure 4.13: Images showing the fracture surface of polarised specimen 1 for material A.

deformation of the specimen before fracture can be seen from the striations on the specimen close to the fracture surface in Figure 4.15a.



(a) Overview image of polarised specimen 2.

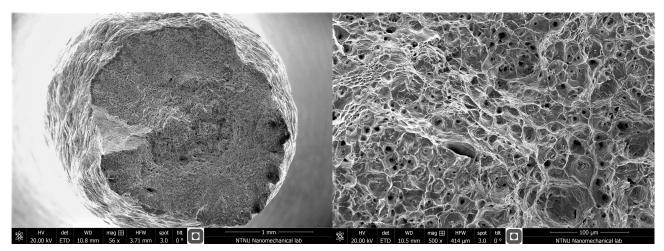
(b) Image showing the mostly ductile fracture surface.



(c) Overview image of polarised specimen 3.

(d) Brittle cleavage-type fracture characteristic.

Figure 4.14: Images showing the fracture surface of polarised specimens 2 and 3 for material A.

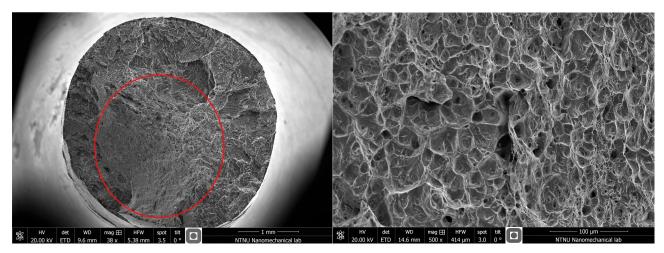


(a) Overview image of the reference specimen at low(b) Visible dimples in fracture surface at higher magnimagnification. fication.

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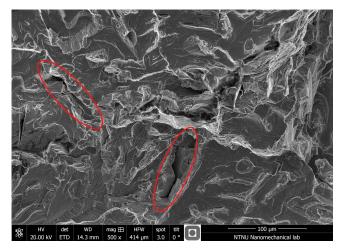
Figure 4.15: Images showing the fracture surface of the reference specimen for material B.

The fracture surface characteristics of the polarised specimens are provided in Figure 4.16. The image in Figure 4.16a gives an overview of the fracture surface at lower magnification. In the image, the area showing ductile fracture characteristics is circled in red. The circle is an approximation of the ductile area. Along the edge of the surface, brittle cleavage-type fracture is present, as shown at higher magnification in Figure 4.16c. In the image, cleavages are circled in red.



(a) Overview image of the polarised specimen.

(b) Image showing the dimples in ductile area of the specimen.



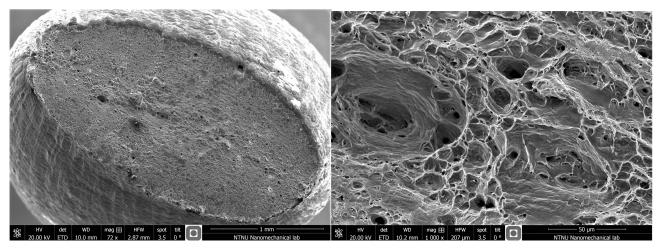
(c) Image taken at the edge of the specimen.

Figure 4.16: Images showing the fracture surface of polarised specimen 1 for material B.

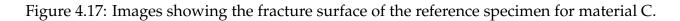
### Material C

Figure 4.17 depicts SEM images taken at different magnifications of the reference specimen for material C. Again, the reference specimen shows ductile fracture characteristics with

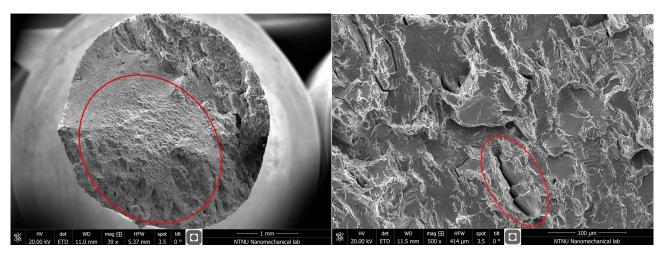
deformation close to the fracture surface and clearly visible dimples.



(a) Overview image of the reference specimen. (b) Ductile characteristics visible in the fracture surface.

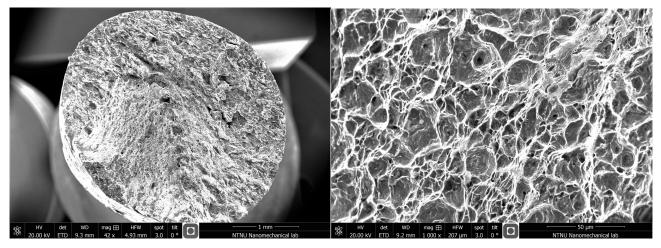


SEM images of the two polarised specimens from test material C is given in Figure 4.18. Figures 4.18a and 4.18b shows the fracture surface of polarised specimen 1 at different magnifications. A rough estimate of the area showing ductile fracture characteristics is circled in red in the former, while a cleavage is circled in the latter. Figures 4.18c and 4.18d are images of polarised specimen 2 from this material. In the former, the same mixed fracture surface characteristics are visble, and Figure 4.18d shows the dimples in the ductile area at higher magnification.



(a) Overview image of polarised specimen 1.

(b) Image showing brittle cleavage-type characteristics in specimen 2.



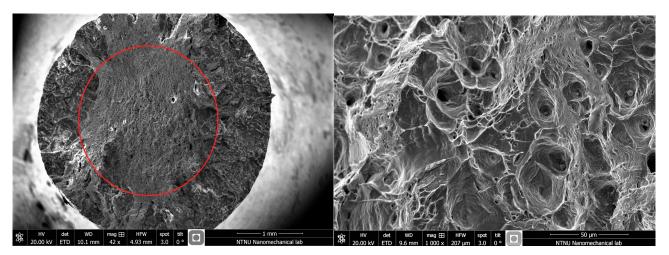
(c) Overview image of polarised specimen 2.

(d) Ductile cup-and-cone characteristics of polarised specimen 2.

Figure 4.18: Images showing the fracture surface of the polarised specimens for material C.

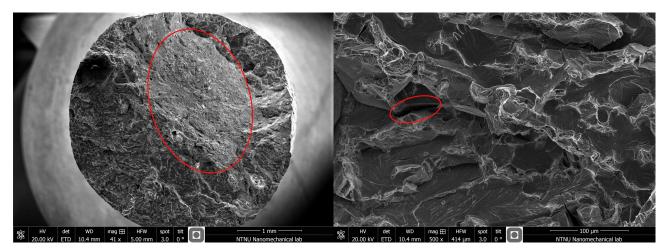
### **Material D**

As the reference specimen for test material D did not fracture in the Cortest proof ring, no fracture surface examination was performed on that specimen. Below, representative SEM images of the polarised specimens for this material are provided. Figures 4.19a and 4.19c are overviews of polarised specimen 1 and 3, respectively. The areas showing ductile fracture characteristics are circled in red. Figure 4.19b shows the brittle area of specimen 1 at higher magnification, while Figure 4.19d shows the brittle area of specimen 3 at higher magnification.



(a) Overview image of polarised specimen 1.

(b) Image showing ductile characteristics in specimen1.



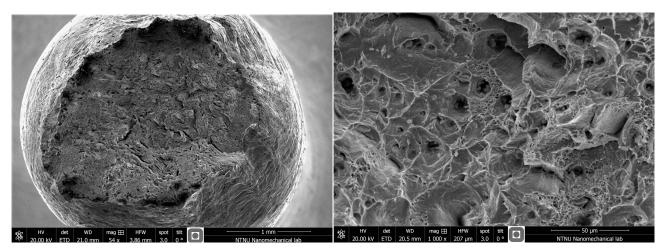
(c) Overview image of polarised specimen 3.

(d) Brittle characteristics of polarised specimen 3.

Figure 4.19: Images showing the fracture surface of the polarised specimens for material D.

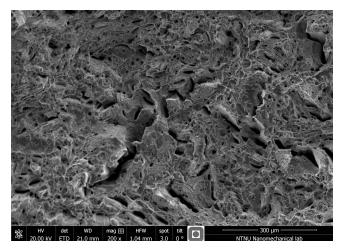
#### **Material E**

SEM images captured of the reference specimen fracture surface for material E is given in Figure 4.20. As for the other reference specimens, deformation of the specimen is visible as striations outside the fracture surface. Ductile dimple fracture characteristics are shown at higher magnification in Figure 4.20a. In Figure 4.20c, fracture characteristics similar to cleavages are visible.



(a) Overview image of the reference specimen.

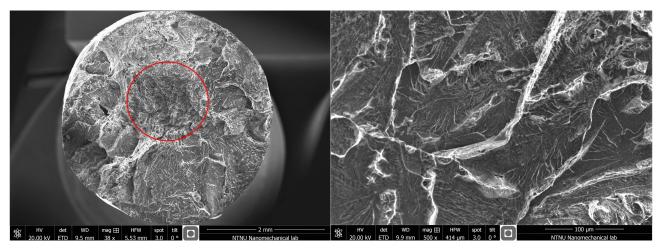
(b) Ductile characteristics visible in the fracture surface.



(c) Cleavage-like characteristics in the fracture surface.

Figure 4.20: Images showing the fracture surface of the reference specimen for material E.

The images in Figures 4.21 and 4.22 are of the polarised specimens for material E. In Figure 4.21*a*, and overview of the fracture surface for polarised specimen 1 is provided with the ductile area circled in red. Brittle fracture characteristics are shown in Figure 4.21b.

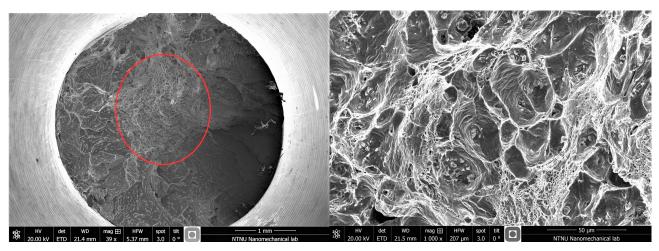


(a) Overview image of polarised specimen 1.

(b) Image showing brittle cleavage-type characteristics in specimen 1.

Figure 4.21: Images showing the fracture surface of the polarised specimen 1 for material E.

Images from polarised specimens 2 and 3 are given in Figure 4.22. In the overview image to the right in the figure the ductile area is circled in red. The dark area to the right in Figure 4.22a is due to the fracture surface not being plane, but rather having a slight angle. Figure 4.22b depicts ductile fracture characteristics of polarised specimen 3 at higher magnification.



(a) Overview image of polarised specimen 3.

(b) Ductile cup-and-cone characteristics of polarised specimen 3.

Figure 4.22: Images showing the fracture surface of polarised specimens 2 and 3 for material E.

### 4.5.2. Brittle area measurements

All measurements for the radii of the polarised specimens are provided in Appendix E. As an example of how the measurements were obtained, a SEM image of one of the polarised specimens from test material B with the measurements is provided in Figure 4.24 below.

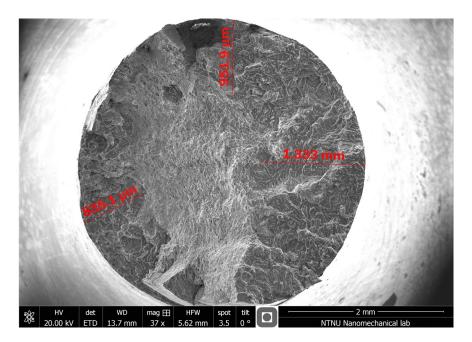


Figure 4.23: SEM image with measurements for the length of brittle area.

In Table 4.7 the average and standard deviation values for the ductile and brittle areas are provided along with the same values for the brittle/ductile ratio. From the table, it is clear that test materials B and E have the highest ratios with 77,47% and 77,58%, respectively. The lowest ratio is that of material A. In Figure 4.24 the minimum, maximum and average values for all test materials are presented, sorted from the highest average value to the lowest.

	Ductile area		Brittle area		%DB	
Material	[ <i>mm</i> <sup>2</sup> ]		$[mm^2]$		[%]	
	Ave.	3,00	Ave.	6,57	Ave.	54,38
Material A	SD	0,66	SD	0,68	SD	10,18
	Ave.	1,84	Ave.	8,16	Ave.	77,47
Material B	SD	0,66	SD	0,68	SD	10,18
	Ave.e	2,26	Ave.	7,00	Ave.	67,65
Material C	SD	1,11	SD	1,22	SD	13,98
	Ave.	2,52	Ave.	7,45	Ave.	66,21
Material D	SD	0,29	SD	0,41	SD	5,40
	Ave.	1,95	Ave.	8,70	Ave.	77,58
Material E	SD	0,29	SD	0,26	SD	3,76

Table 4.7: Brittle/ductile ratio results

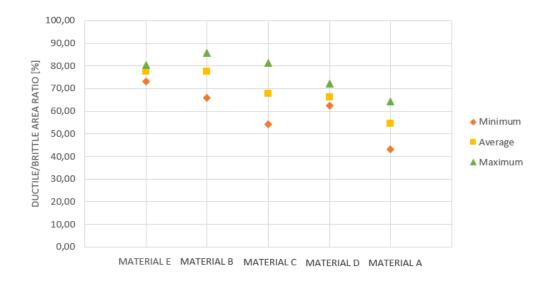


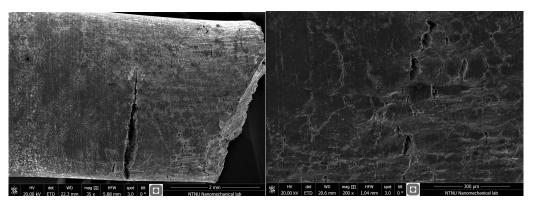
Figure 4.24: Graph showing the results for the ductile/brittle ratio estimation.

### 4.5.3. Secondary cracking

In the figures below, SEM images of secondary cracks for the different test materials are presented.

### Material A

Figure 4.25 shows secondary cracks in the polarised test specimens from material A.



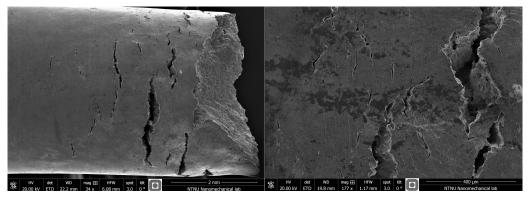
(a) Secondary cracking in material A.

(b) Secondary cracks in material A at higher magnification.

Figure 4.25: Images showing the secondary cracks in test material A.

### Material **B**

Figure 4.26 shows secondary cracks in the polarised test specimens from material B.



(a) Secondary cracking in material B.

(b) Secondary cracks in material B at higher magnification.

Figure 4.26: Images showing the secondary cracks in test material B at different magnifications.

### Material C

Figure 4.27 Shows secondary cracking in polarised test specimens from material B.

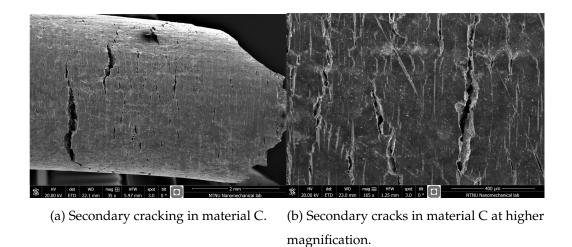
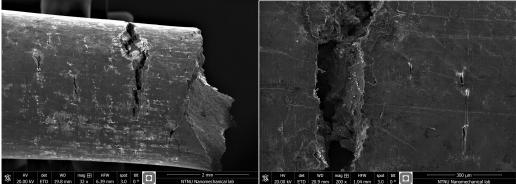


Figure 4.27: Images showing the secondary cracks in test material C.

### Material D

Figure 4.28 Shows secondary cracking in polarised test specimens from material D.



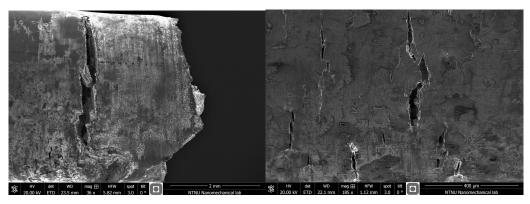
(a) Secondary cracking in material D.

(b) Secondary cracks in material D at higher magnification.

Figure 4.28: Images showing the secondary cracks in test material D.

### Material E

Figure 4.29 Shows secondary cracking at different magnifications in polarised test specimens from material E.



(a) Secondary cracking in material E.

(b) Secondary cracks in material E at higher magnification.

Figure 4.29: Images showing the secondary cracks in test material E.

# 5. Discussion

### 5.1. Tensile Testing

The results of the tensile tests performed in this thesis were quite consistent. Test material A was found to have the highest average YS at 663,8MPa, while material B had the lowest at 574,0 MPa. The largest difference in YS between parallels was found for test material E at approximately 31 MPa. The smallest UTS/YS ratio average was found for test material D at 128.6%, while the largest average ratio was 142.9% for test material B. It should be mentioned that test material E had a similar value to material D at 128.7%.

### 5.2. Metallographic Examination

#### 5.2.1. Microstructure

The microstructure is highly dependent on production method. Materials A and C are both produced through hot extrusion, resulting in a lamellar structure with elongated austenite islands in the ferrite matrix in the direction parallel to the pipe length. This is the direction of extrusion when producing a bar or a pipe, and the microstructure is therefore as expected. However, the austenite islands of material C appear more rounded and the distance between them is greater in some areas. This difference in the microstructures of the materials is probably due to the cold work performed on test material A, and not performed for material C. For the direction normal to the pipe length, the microstructure of both materials consists of circular austenite islands.

Test materials B and E are from centrifugal cast pipes. The microstructure of material B is bimodal with small austenite grains between larger, needle shaped islands. As can be seen from Figure 4.6a, the etching appears different for material E compared to the other test materials. During etching of this specimen, the material reacted differently with the 20%NaOH etchant, and the image is therefore more coloured. The reason for this is unknown. The oxalic acid etching step was not performed in order to investigate whether the combination of the two etching steps caused the colouring of the material as it was first observed after both etching steps had been performed. However, this did not give a positive result and it seems it was the NaOH etchant the material reacted differently to. As the duplex structure is clearly visible in the image, it was decided to include it in the thesis. The microstructure for material E includes needle shaped austenite islands as do material B, but they are smaller than the ones in material B. For both directions compared to the pipe length for these materials, the ferrite grains between the austenite islands appear larger in material E versus material B.

The OM images from test material D in the direction parallel to the pipe length reveals round austenite islands which are slightly elongated with some bimodal austenite grains dispersed throughout the ferrite matrix. The austenite islands also appear quite large. For the direction normal to the pipe length, the microstructure consists of more rounded austenite islands. Also for this direction there are some bimodal austenite grains between the larger islands. The material was produced from a forged bar, and the microstructure shown in Figure 4.5bis in accordance with this production method.

The literature states that higher ferrite content promotes HISC in SDSS [15, 16]. However, as the ferrite content was only provided by the supplier for materials B, C and D, a full comparison of the effects of this value on susceptibility towards HISC between all the test materials was not possible. However, the three materials for which the ferrite content was provided are from each of the three main production routes. A preliminary comparison was therefore conducted. As mentioned in the chapter describing the materials, the ferrite contents of materials B, C and D were 49,5%, 54% and 49%, respectively. These are all close to a 50/50 phase distribution between austenite and ferrite, which is recommended for obtaining optimal mechanical and corrosion properties in SDSS [11]. How these results might have influenced the resistance towards HISC is discussed in more detail in the section on HISC testing below.

When performing the metallographic examination, features appearing to be secondary phases became visible after the electrolytic etching of materials A, B, D and E. From Figure 4.2a, clusters of these secondary phases are visible in the larger ferrite grains of material A in the direction parallel to the pipe length. The same holds true for the direction normal to the pipe length in material B (Figure 4.3b. In the direction normal to pipe length of material D, what appears to be secondary phases are visible along austenite and ferrite/austenite grain boundaries. The latter is also visible for the same direction in material E. Whether there are any secondary phases in the direction parallel to the pipe length for material E is not known as no images with oxalic etch was procured due to the problems with the etching of this material. As the secondary phase in materials A and B is found in clusters in the ferrite grains, the most probable phase is CrN.

The possible secondary phases at the austenite and austenite/ferrite grain boundaries in materials D and E could be either sigma phase or  $Cr_2N$ . For test material E, the most likely possible phase is the latter as there are no secondary phases visible in the image when etching with only NaOH. Whether or not chromium nitrides have a detrimental effect on SDSS materials with respect to HISC susceptibility is debated in the industry [20]. In addition, the extent of the secondary phase visible in the OM images is small, and would therefore not affect the performance of the materials. However, it should be noted that the features observed as possible secondary phases in the test materials might be etching artifacts, and not secondary phases at all. To ascertain whether the features are secondary phases or not, and what type of possible secondary phases, a more comprehensive analysis using EDX should be performed. This was, however, outside the scope of this work.

#### 5.2.2. Austenite spacing

As seen from Figure 4.7, the material with the largest austenite spacing is material E with 27,13  $\mu$ m. The smallest austenite spacing was found for material C with 24,95  $\mu$ m. The austenite spacing of materials A and B are quite similar, with values of 27,13 $\mu$ m and 26,66 $\mu$ m, respectively. This corresponds well with the distance between the austenite islands visible in Figures 4.2 to 4.6. However, the standard deviation of the values were very high for all materials, with material C having the smallest deviation of 14,79 and material E having the largest deviation, which is 65,80. The high standard deviation results in high values for the percent relative accuracy. According to DNV-RP-F112 [28], results should only be accepted with %RA values at 10% or below. One reason for the high standard deviation and %RA is the fact that the measurements were performed by hand. Another is the bimodal microstructures; with a wide range of grain sizes in the same microstructure, deciding which grains to disregard with respect to the austenite spacing was difficult. From Table 4.2 it can be seen that the materials with a larger degree of bimodal austenite grains have larger standard deviations. As the %RA values are so high, the results of the austenite spacing measurements are not conclusive. However, they do give an indication of the real values.

### 5.3. Review of HISC Testing

Before reviewing and evaluating the HISC results, a few subjects should be discussed. On the whole, the testing proceeded without interruption, and the few incidents that took place were quickly corrected.

#### Low temperature creep

When operating the Cortest proof rings, one permanent challenge was the relaxation of the rings. The relaxation made distinguishing between measurement errors and low temperature creep difficult. An attempt to solve this was to correct for relaxation and/or creep during the second step of HISC testing. The correction involved checking the outer ring diameter every 24 hours during this step and adjusting it if necessary. However, relaxation of the rings were observed in that time interval as well. Due to no apparent permanent solution of the problem, upon fracture the threshold load was found using the last measured outer diameter the specimen held for 24h and using this when inserting the load cell.

### Pre-charging of specimens from material C

During pre-charging of the specimens from material C and D, some of the specimens fell out of the electrical circuit, causing them to corrode. For material C, this happened twice. As there were only one spare test specimens for this material it was decided to move forward with the experiments using the two polarised specimens which had been pre-charged properly. Thus, when looking at the results there is one less specimen for material C than the other materials.

#### **Reference specimen from material D**

It was previously mentioned that the reference specimen from test material D did not fracture due to lack of room on the test ring. Thus, the results for this material is not necessarily accurate. When calculating the TLRR, the load used was the load at which there was no more room in the ring rather than the last load the specimen held for 24h. Also, as no necking occurred in the specimen, the measured diameter after testing was much higher than it would be at fracture. This means that in reality the TLRR and RA ratio values would be higher than the results presented below indicates. This impacts the RA ratio results the most, as can be seen from 2.12 and Table 4.5. The %YS results are not affected by this, as the reference specimen is not used when calculating this value.

### 5.4. Review of HISC Results

#### 5.4.1. Threshold load reduction ratio

As stated in the previous chapter, test material C achieved the lowest average value for the threshold load reduction ratio. A low reduction rate indicates a high resistance towards HISC, as there is less difference between threshold load for the reference and polarised specimens. The standard deviation for this material is also the lowest. However, this might be due to the fact that there were only two polarised specimens for this material as pre-charging a third specimen was not possible, as mentioned above. Test material A and D also have quite low values for the TLRR. However, the standard deviation for material A is lower, and thus the variation in the results is lower for this material. This indicates less variation of the results for material A, and thus a more accurate result. The highest values for TLRR, indicating the lowest resistance towards HISC, are for materials B and E.

Materials A and C was produced through hot extrusion, and as the materials have similar TLRR values, this indicates that the microstructure obtained through this production method is less susceptible to HISC. During manufacturing, material A was cold worked. As stated by [25] and [26], cold work decreases a material's resistance towards HISC. This explains the slight difference between the TLRR values for the two materials, along with the difference in austenite spacing measurements. Both materials contain tungsten (W), It has been suggested by the industry that W increases a material's resistance towards HISC. Unfortunately, at the time of this thesis there is no documentation on this matter.

Test material D was manufactured from a forged bar. Forged components are usually considered to have lower resistance towards HISC than materials produced through other methods which achieve finer microstructures. However, this is not seen in the results from the testing conducted in this thesis as material D performs better than the centrifugally cast materials. One possible explanation is that the material contains W, which might have increased the resistance towards HISC, along with finer austenite spacing than the two cast materials. Test material B and E, which have the highest TLRR values, are the two centrifugally cast materials. As the TLRR results are so much higher for these materials than for the other production methods, this indicates a lower resistance towards HISC for materials manufactured this way. Of these two materials, only E contains W. However, as material E has the highest TLRR value this result contradicts the industry's experience with W increasing the resistance towards HISC. On the other hand, there might be some other detrimental effects which have counteracted the positive effect of W in the material, such as the high austenite spacing.

When it comes to the effect of ferrite content on the susceptibility towards HISC, the reported values contradicts the literature as it is material C which have the largest ferrite content at 54%. A higher ferrite content should indicate a lower resistance towards HISC, but it is not the case for these results. Both materials B and D have lower ferrite content values at approximately 49% and have higher TLRR values than material C. However, as for the possible positive effect on susceptibility towards HISC of W in the microstructure, the effects of the ferrite content might have been counteracted by other microstructural features. The finer austenite spacing of material C could be the explanation for why this material performs better than the other two despite having a higher ferrite content.

#### 5.4.2. Yield strength ratio

As seen from Table 4.4 and Figure 4.9, the highest average value for the %YS was found for test material C at 132,20%. As for the TLRR results, this indicates the highest resistance towards hydrogen embrittlement for this material. Material A also has a high %YS value at 122,57%. The fact that these materials have the highest values for this test parameter as well strengthens the indication that the microstructure for extruded pipes has a lower susceptibility towards HISC. As it is material C which again have the higher value of the two extruded pipes, it is further evidence of the cold work performed on material A reducing the resistance towards HISC. Materials B and D have quite similar average values at 116,44% and 115,91%, respectively. Again, material E has the lowest value at 94,40%. This time with quite a large margin. The difference between material E and the other materials is probably due to the larger austenite spacing for this material compared to the others. All of these results correspond reasonably well with the TLRR results, probably due to the same reasons as mentioned in the previous section.

When comparing the UTS/YS values to the %YS values, the extruded materials A and C and the forged material D have high to intermediate results for both test parameters while the centrifugally cast has the lowest results for both parameters. For both UTS/YS and %YS, material C performs slightly better than material A with UTS/YS values of 135,2% and 130,2% and %YS values of 132,2% and 122,57%, respectively. Once again, a possible explanation is the cold deformation performed on material A. Material D, however, performs best of all test materials for %UTS/YS, and has low %YS values. This variation between the two test parameters is most likely due to the large austenite spacing causing the %YS values to decrease more with respect to the UTS/YS value compared to materials A and C with finer austenite spacing. The centrifugally cast materials B and E have the lowest values for both UTS/YS and %YS. However, the large austenite spacing of material E causes a large difference in %YS values (116,44% for B and 94,40% for E) between the two materials despite the approximately equal UTS/YS values of 128,6% for B and 128,7% for E. Also for this test parameter, the large austenite spacing of material E seems to contradict the experience with W contributing positively to HISC resistance.

#### 5.4.3. Reduction in area ratio

From the results presented in Figure 2.12, material D has the lowest RA ratio value by a large margin. The value is 11,17%. However, this result is not valid as the smallest cross-section measured for the reference specimen was so high due to the specimen's not fracturing. Thus, the RA ratio result for this material is excluded from the discussion below.

When excluding material D, it is material C which has the lowest RA ratio at 74,30%. As a low RA ratio indicates a lower level of embrittlement, this result indicates that material C has a greater resistance towards HISC. However, the standard deviation for this material is very high (21,21). One explanation for this might be the fact that only two specimens were tested for this material. On the other hand, the standard deviation is so much higher than for the other materials that this cannot be the sole reason. For materials A, B and E, the RA ratios increase by approximately 6% for each material, with material A having the lowest of the three at 80,14%. Again, the general trend of the results is the same as for the previous test parameters with centrifugally cast materials B and E showing the poorest performance with respect to resistance towards HISC.

### 5.5. Hydrogen Content

The hydrogen measurements provided in Figure 4.11 and Table 4.6 show that test material C has the highest hydrogen content of 82,17ppm after pre-charging and HISC testing, while test material D has the lowest hydrogen content at 48,98ppm. The intermediate results are materials B, A and E with hydrogen contents of 67,58ppm, 60,06ppm and 50,40ppm, respectively. The hydrogen contents of materials D and E are very similar with only a 0,42ppm difference. Due to the fact that the testing for hydrogen content was only performed after HISC testing was finished, it is impossible to distinguish between hydrogen absorbed during pre-charging and during the HISC testing in the Cortest proof rings. However, as hydrogen diffuses more rapidly at higher temperatures per Equation 2.12, it may be assumed that the majority of the hydrogen diffused into the material during pre-charging as this was performed at an elevated temperature, whereas the HISC testing was performed at ambient temperatures. However, most of the test specimens spent more time in the Cortest proof rings than they did during pre-charging. The time difference varied for the materials and each polarised specimen, but an average estimate is 2,5 weeks in the rings compared to 10 days in the pre-charging cell. To ascertain which step causes the most hydrogen to diffuse into the materials, hydrogen testing should be performed directly after pre-charging as well as after the HISC testing.

The ferrite content provided for materials B, C and D compared to the measured hydrogen content is in accordance with the literature [15, 16] as the material with the largest ferrite content (C) also has the largest hydrogen content. The opposite holds true for material D; it has the smallest measured ferrite and hydrogen contents. Unfortunately, a general trend for all test materials cannot be determined due to the lack of ferrite content values for materials A and E. However, the literature also [17] suggests that materials with coarser microstructures should absorb more hydrogen due to less tortuous hydrogen paths caused by a larger austenite spacing. This causes more absorption points on the surface and more continuous hydrogen diffusion in the ferrite phase. The results of the hydrogen measurements in this thesis contradicts this, as the general trend is that the test materials with the largest austenite spacing (D, E) contains the least hydrogen, and those with the finest austenite spacing (C) contains the most. This might be due to the ferrite content counteracting the positive effect

of the austenite spacing. In addition, there are other factors that might cause this discrepancy between the results and literature. In general, the materials with the largest austenite spacing tended to fracture during or directly after loading from the threshold load to fracture load, while the materials with finer austenite spacing tended to fracture some time after loading. This resulted in the test specimens in the former category being moved from the Cortest proof rings to the freezer closer to the time of fracture than the latter as the specimens were not under constant observation during testing. Upon fracture, the electrical circuit was broken, and thus the hydrogen in the materials with finer microstructures had more time to diffuse out of these materials.

### 5.6. Fractography

### 5.6.1. Fracture surface examniation

As shown in the previous chapter, the reference specimens for all test materials exhibited ductile fracture characteristics. Deformation is visible close to the fracture surface, and all surfaces contained a dimpled structure over the entire cross-section. However, the reference specimen for material E also contained some fracture characteristics similar to cleavages in the center of the fracture surface as seen in Figure 4.20c. This might be due to this material having a coarser structure, and therefore a smaller degree of ductility than the other materials. The ductility of the materials prior to hydrogen exposure is also evident in the tensile testing, as the stress-strain curves drop after reaching UTS. This can be seen in Figures 5 to 9 in Appendix A. From these figures, it is evident that the drop is smaller for test material E, further confirming the poorer mechanical properties for this material. For the polarised specimens the fracture surfaces were quite different from the reference specimens. The most prominent difference was the change in fracture surface characteristics along the cross-section. With one exception, namely specimen 2 for test material C (Figure 4.18c), all polarised specimens exhibit both ductile and brittle fracture characteristics in different areas of the surface, with the brittle characteristics most often close to the edge of the fracture surface. The ductile areas can be found both close to the center of the fracture surface, as in Figure 4.19a, and close to the edge, as in Figure 4.22a. As material C has the lowest austenite spacing and the previous test parameters discussed indicates this material having a high resistance towards HISC, this might be the explanation for the mixed fracture characteristics over most of the fracture surface of the mentioned polarised specimen.

In the transition zone between the brittle and ductile areas, the surface characteristics was more mixed. For the previously mentioned specimen from material C, almost the entire fracture surface exhibits such mixed characteristics. One hypothesis is that for these areas, the austenite phase fractured through a more ductile mechanism and therefore a dimpled fracture surface [16]. Conversely, the ferrite would fracture through a more brittle mode, causing more brittle fracture characteristics. To investigate the validity of this hypothesis, a more comprehensive characterisation of the transition zones should be conducted than was within the scope of this thesis.

### 5.6.2. Brittle Area Estimation

It should be noted that the measurements for calculating the brittle area may not be accurate as they were obtained essentially by hand, and the exact point where the fracture surface transitioned from brittle to ductile was difficult to establish due to the mixed characteristics transition zone. However, the results of the measurements are presented as an estimate, and used as an estimated embrittlement index to investigate possible differences in embrittlement through the thickness of the test specimens.

Although the fracture surfaces for all the test materials exhibited similar fracture characteristics, there were small differences in the size of the embrittled areas, as presented in the "Results" chapter. The maximum estimated value for the brittle area was found for test material E, while the minimum value was found for material A. These values were 77,58% and 54,38%, respectively. When comparing these results with the results from the threshold load reduction ratio, they correspond somewhat. Material A has the lowest brittle/ductile area ratio, and also a low TLRR value. The same holds true for materials C and D; they both have low TLRR and %DB values. Likewise can it be observed that materials B and E have the highest values for both test parameters. This further supports the theory of hot extruded pipes having the highest resistance towards HISC and centrifugally cast pipes being more susceptible to this fracture mode.

### 5.6.3. Secondary cracking

The SEM images of the surface area on the side of the polarised specimens in Figures 4.25 to 4.29 show that secondary cracking has occurred for all test materials. The presence of secondary cracking along with the documented presence of hydrogen is indicative of HISC taking place in the material. Also, it means that HISC initiation has taken place on multiple points on the specimen, not only for the crack responsible for fracture of the test specimen.

### 5.7. Overall Test Results

The objective of this thesis was to investigate the difference in susceptibility towards HISC between the test materials provided by GE Oil & Gas. To be able to test a material's performance with respect to HISC, hydrogen must be present in the microstructure. This was achieved through the pre-charging and polarisation during HISC testing, as hydrogen was found in the material when employing the melt extraction technique. Together with the secondary cracking observed on the surfaces of the test specimens, this confirms that HISC has occurred in the materials investigated in this thesis. From the other test results obtained in this work, there is a clear trend in the resistance towards HISC between the different production methods of 25%Cr SDSS materials.

Test parameter	Test material Ranking
AYS	A - D - E - C - B
UTS/YS	D - C - A - E - B
Austenite spacing	C - B - A - D - E
TLRR	C - D - A - B - E
%YS	C - A - D - B - E
RA ratio	C - A - B - E
%DB	A - D - C - B - E
Н	C - B - A - E - D

Table 5.1: Ranking of test results from best to worst with respect to HISC.

A summary of the results is provided in Table 5.1. From the rankings in the table it is clear that the materials which performed best overall with respect to resistance towards HISC are

the hot extruded materials A and C, with C tending to have slightly better results. As previously mentioned, the most likely explanation for this difference is the cold work performed on material A.

When it comes to material D, which was manufactured from a forged bar, the results of the tests are very varied; however, the general trend is intermediate results with respect to the susceptibility towards HISC. Also evident from Table 5.1 is the poor performance of the centrifugally cast materials B and E. For most test parameters, these materials have the worst performance with respect to HISC. It is clear that the microstructure achieved through this production method is not optimal when exposed to CP in seawater. This is most likely closely related to the large austenite spacing found for these materials.

### 5.7.1. Further work

For more definitive conclusions for the investigation executed in this thesis, some further work should be conducted. For the tensile testing, the strain at fracture should be documented and discussed in relation to the HISC results. When it comes to the microstructures obtained through the different production methods, some additional testing should be done with respect to the presence and effect of secondary phases. One such test could be EDX analysis of the microstructures to confirm or refute the presence of secondary phases in the microstructures. Additional testing should also include measuring of the ferrite content as this was not reported for all test materials, and thus only a preliminary investigation could be conducted based on the values reported for materials B, C and D.

The possible positive effect of the alloying element W should also be investigated and reported on as there is no documentation on this subject at present. This could be achieved through HISC testing of materials with identical chemical composition apart from varying amounts of W. As for the austenite spacing, a method for measurement producing smaller standard deviations and thus %RA values should be employed. One possibility is to use software when conducting the measurements and determine specific limits for the size of small, bimodal austenite grains to be disregarded due to their not contributing to the trapping of hydrogen.

Pertaining to the HISC testing equipment, this was prone to relaxation, making it difficult to distinguish between relaxation of the rings and low temperature creep. To avoid this in

future investigations, constant load testing using Cortest proof rings could be replaced with SSRT. This would most likely remove the relaxation aspect of the testing. In addition, the equipment should not have an upper limit for allowable elongation as the Cortest proof rings have, which resulted in the reference specimen for material D not going to fracture during testing. In addition, the electrical set-up during HISC testing should be such that the electrical circuit is not broken upon fracture of the specimen as it was for this thesis. This would result in more accurate hydrogen measurements. When it comes to hydrogen measurements, this should be performed both after pre-charging and HISC testing to be able to distinguish the hydrogen absorption during the two steps.

Additional characterisation of the transition zone found on the fracture surfaces should also be conducted to better understand the HSIC fracture mechanism. This would also enable more accuracy when indexing the embrittlement through thickness of the specimens.

# 6. Conclusion

Stepwise increased load testing was performed to investigate the difference in susceptibility to HISC for five 25%Cr SDSS materials obtained through different production routes. This was followed by an analysis of the fracture surfaces and measurement of hydrogen content. The microstructures were also examined using optical microscopy to document the microstructures resulting from the different production methods.

Based on the testing conducted for the materials in this thesis, the production method for 25% Cr SDSS giving the highest resistance towards HISC is hot extrusion, i.e. the materials supplied to GE Oil & Gas from Nippon Steel & Sumitomo Metal Co. and Tubacex Tubos Inoxidables S.A. This is due to the superior performance for most of the test parameters, which most likely is the result of the fine microstructure with a low degree of bimodal austenite grains and low austenite spacing values. It was also found that subsequent cold working of an extruded pipe increases the susceptibility towards HISC slightly.

Intermediate test results were obtained for the pipe from IBF S.P.A. which was manufactured from a forged bar. The highest susceptibility towards HISC was found for the centrifugally cast materials from Fondinox S.P.S. and Kuhn Special Steel. This result is attributed to the large austenite spacing and high degree of bimodal austenite grains present in the structure as bimodal austenite reduces the amount of austenite contributing to hydrogen trapping, increasing the free diffusion paths for hydrogen through the material.

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# Appendix A

# **Test Specimen Locations**

Below, the test specimen locations for all materials are provided in Figures 1 to 4 with the exception of material A. The test specimens for material A were removed from the pipe material prior to work on this thesis began, and an image of the test specimens in the pipe material was therefore not acquired.



Figure 1: Image of the test specimen location for material B.



Figure 2: Image of the test specimen location for material C.



Figure 3: Image of the test specimen location for material D.



Figure 4: Image of the test specimen location for material E.

# Appendix **B**

# **Stress-strain Curves**

Figures 5 to 9 show the stress-strain curves obtained through tensile testing of materials A to E, respectively.

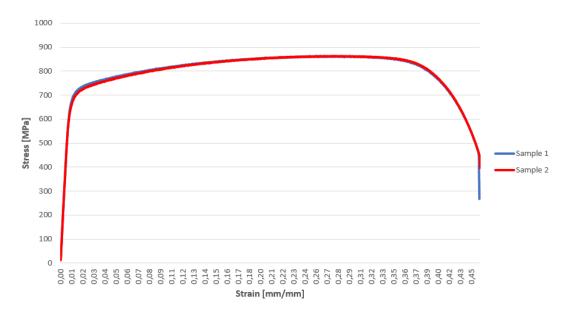


Figure 5: Stress-strain curve from tensile testing of material A.

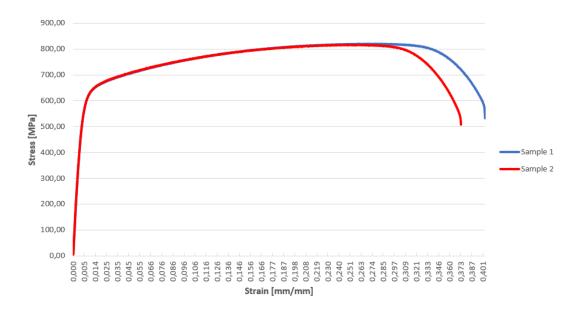


Figure 6: Stress-strain curve from tensile testing of material B.

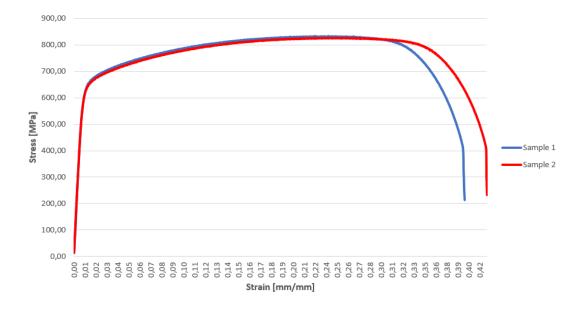


Figure 7: Stress-strain curve from tensile testing of material C.

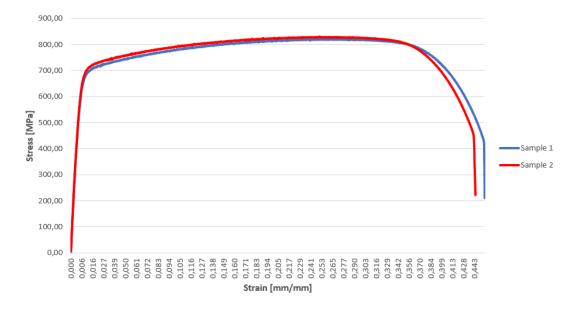


Figure 8: Stress-strain curve from tensile testing of material D.

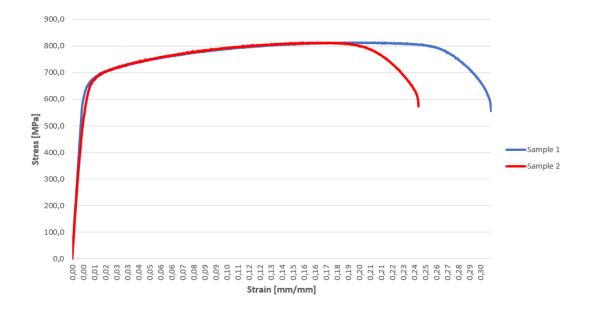


Figure 9: Stress-strain curve from tensile testing of material E.

# Appendix C

# Austenite Spacing Measurements

## Material A

Material A							
	Area 1	Area 2	Area 3	Area 4			
Mean	27,67	30,40	27,20	23,24			
Min	7,22	5,15	2,06	1,03			
Max	119,59	138,14	140,21	114,43			
Sum	3292,49	4893,70	5249,55	4322,42			
SD	21,02	22,19	20,59	19,05			
Mean		27	,13				
SD material		20	,71				
n	20,00						
t	2,09						
95%CI	9,69						
%RA		35,	,74				

Table 1: Austenite spacing measurements for test material A

## Material **B**

	Material B							
	Area 1	Area 2	Area 3	Area 4				
Mean	25,67	24,38	28,68	27,92				
Min	2,06	2,06	5,15	7,22				
Max	156,70	128,87	121,65	89,69				
Sum	3337,73	2462,29	3326,57	3797,77				
SD	22,45	18,62	25,72	18,76				
Mean		26	,66					
SD material		21,	,39					
n		20	,00					
t	2,09							
95%CI	10,01							
%RA		37	,54					

Table 2: Austenite spacing measurements for test material B.

# Material C

Material C						
	Area 1	Area 2	Area 3	Area 4		
Mean	26,852	23,096	25,171	24,695		
Min	7,216	7,505	8,247	7,216		
Max	160,825	160,825 72,165 84,561 82,4				
Sum	3222,199	2748,452	3423,242	3654,794		
SD	19,102	11,686	14,527	13,828		
Mean		24	,95			
SD material		14,	786			
n		20	,00			
t	2,09					
95%CI	6,92					
%RA		27	,73			

Table 3: Austenite spacing measurements for test material B.

# Material D

Material D							
	Area 1	Area 2	Area 3	Area 4			
Mean	51,21	46,95	49,38	42,42			
Min	7,22	6,19	7,22	6,19			
Max	245,37	207,23	249,48	161,87			
Sum	5991,76	5680,51	5530,13	4920,53			
SD	41,96	39,86	39,52	32,85			
Mean		47	,49				
SD material		38	,55				
n	20,00						
t	2,09						
95%CI	18,04						
%RA		37	,99				

Table 4: Austenite spacing measurements for test material D.

# Material E

Material E						
	Area 1	Area 2	Area 3	Area 4		
Mean	44,08	49,87	68,09	43,40		
Min	5,15	5,15	7,22	1,03		
Max	252,58	271,14	1575,26	158,78		
Sum	5818,80	5236,31	5514,97	3341,89		
SD	38,98	43,57	174,39	31,91		
Mean		51	,36			
SD material		72,	,21			
n	20,00					
t	2,09					
95%CI	33,80					
%RA		65	,80			

Table 5: Austenite spacing measurements for test material E.

# Appendix D HISC testing Calculations

# **Threshold Load Reduction Rate Calculation**

In this section, the calculations of the TLRR values are presented in Tables 6 to 10. As explained in the chapter on experimental methods the loads obtained by using the load cell,  $P_{th}$ , is inserted into Equation 3.3, and the  $\sigma_{th}$  and  $\sigma_{th,HISC}$  values are obtained, respectively. The TLRR values are then obtained by inserting the results from Equation 3.3 into Equation 3.4

### Material A

Table 6: Calculation of TLRR values for material A.

Sample condition	<i>d</i> <sub>0</sub> [mm]	$A_0 [\mathrm{mm}^2]$	P <sub>th</sub> [kg]	$\sigma_{th}$ [Mpa]	TLRR [%]
Reference	3,765	11,13	1043	920	
				$\sigma_{th,HISC}$ [Mpa]	
Polarised	3,765	11,13	897	791	14,0
Polarised	3,765	11,13	939	828	10,0
Polarised	3,765	11,13	933	823	10,5

### **Material B**

Table 7: Calculation of TLRR values for material B.

Sample condition	<i>d</i> <sub>0</sub> [mm]	$A_0 [\mathrm{mm}^2]$	P <sub>th</sub> [kg]	$\sigma_{th}$ [Mpa]	TLRR [%]
Reference	3,75	11,01	975	869	
				$\sigma_{th,HISC}$ [Mpa]	
Polarised	3,75	11,01	742	661	23,90
Polarised	3,75	11,01	727	648	25,44
Polarised	3,75	11,01	770	686	21,03

### Material C

Sample condition	<i>d</i> <sub>0</sub> [mm]	$A_0 [\mathrm{mm}^2]$	P <sub>th</sub> [kg]	$\sigma_{th}$ [Mpa]	TLRR [%]
Reference	3,745	11,01	990	882,1	
				$\sigma_{th,HISC}$ [Mpa]	
Polarised	3,745	11,01	920	819,8	7,07
Polarised	3,745	11,01	902	803,7	8,89

Table 8: Calculation of TLRR values for material C.

## Material D

## Table 9: Calculation of TLRR values for material D.

Sample condition	<i>d</i> <sub>0</sub> [mm]	$A_0 [{ m mm^2}]$	P <sub>th</sub> [kg]	$\sigma_{th}$ [Mpa]	TLRR [%]
Reference	3,75	11,01	932	830	
				$\sigma_{th,HISC}$ [Mpa]	
Polarised	3,74	10,98	883	789	5,00
Polarised	3,75	11,01	802	715	13,95
Polarised	3,76	11,10	826	730	12,08

## Material E

Table 10: Calculation of TLRR values for material E.

Sample condition	<i>d</i> <sub>0</sub> [mm]	$A_0 [\mathrm{mm}^2]$	P <sub>th</sub> [kg]	$\sigma_{th}$ [Mpa]	TLRR [%]
Reference	3,76	11,10	915	809	
				$\sigma_{th,HISC}$ [Mpa]	
Polarised	3,77	11,16	651	572	29,2
Polarised	3,75	11,04	693	616	23,9
Polarised	3,76	11,10	684	605	25,2

### **Reduction of Area Calculations**

In this section, the results of the RA calculations are presented for all test specimens in the tables below. The diameters are measured values for each test specimen. The areas are obtained from the diameter measurements and used for further calculations of the RA value for each test specimen using Equation 3.6. The results from Equation 3.6 were then used in Equation 3.7 to find the RA ratios for each test material presented in the "Results" chapter. The average  $d_{min}$ ,  $A_{min}$  and RA values reported in this section is the average of polarised samples only, as these values are compared to the reference sample in further calculations. It should also be noted that the RA results is presented as percentages in this appendix, while the fraction is used in Equation 3.6.

### Material A

Table 11: Calculations of areas used for obtaining the RA for material A.

Sample	<i>d</i> <sub>0</sub> [mm]	$A_0 [\mathrm{mm}^2]$
Reference	3,77	11,157
Polarised 1	3,76	11,098
Polarised 2		0,000
Polarised 3		0,000
Average	3,765	11,128
Sample	d <sub>min</sub> [mm]	$A_{min}  [\mathrm{mm}^2]$
Reference	2,04	2 2 7
	2,04	3,267
Polarised 1	3,57	10,005
Polarised 1 Polarised 2	,	
	3,57	10,005

In Table 11, only two original diameters are reported as the measurements for the other two test specimens were done incorrectly. Therefore, the average value of the two diameters reported was used for further calculations.

Sample	RA [%]
Reference	70,642
Polarised 1	10,090
Polarised 2	12,591
Polarised 3	19,406
Average	14,029

Table 12: Calculated RA values for test specimens from material A.

# Material **B**

Table 13: Calculations of areas used for obtaining the RA for material B.

Sample	<i>d</i> <sub>0</sub> [mm]	$A_0 [\mathrm{mm}^2]$
Reference	3,74	10,98
Polarised 1	3,75	11,04
Polarised 2		
Polarised 3		
Average	3,745	11,01
Sample	d <sub>min</sub> [mm]	$A_{min}  [\mathrm{mm}^2]$
Reference	2,16	3,66
Polarised 1	3,57	10,00
Polarised 2	3,56	9,95
Polarised 3	3,58	10,06
Average	3,57	10,00

In Table 13, only two original diameters are reported as the measurements for the other two test specimens were done incorrectly. Therefore, the average value of the two diameters reported was used for further calculations.

Sample	RA [%]
Reference	66,73
Polarised 1	9,13
Polarised 2	9,64
Polarised 3	8,62
Average	9,13

Table 14: Calculated RA values for test specimens from material B.

# Material C

Table 15: Calculations of areas used for obtaining the RA for material C.

Sample	<i>d</i> <sub>0</sub> [mm]	$A_0 [\mathrm{mm}^2]$
Reference	3,74	10,980
Polarised 1	3,75	11,039
Polarised 2	3,75	11,039
Average	3,75	11,019
Sample	d <sub>min</sub> [mm]	$A_{min}  [\mathrm{mm}^2]$
Reference	2,31	4,189
Polarised 1	3,62	10,287
Polarised 2	3,24	8,241
Average	3,43	9,264

Table 16: Calculated RA values for test specimens from material C.

Sample	RA [%]
Reference	62,0
Polarised 1	6,6
Polarised 2	25,2
Average	15,9

# Material D

Sample	<i>d</i> <sub>0</sub> [mm]	$A_0 [{ m mm^2}]$
Reference	3,75	11,04
Polarised 1	3,74	10,98
Polarised 2	3,75	11,04
Polarised 3	3,76	11,10
Average	3,745	22,08
Sample	d <sub>min</sub> [mm]	$A_{min}  [\mathrm{mm}^2]$
Reference	3,28	8,45
Polarised 1	3,58	10,06
Polarised 2	3,59	10,12
Polarised 3	3,52	9,73
Average	3,56	9,97

Table 17: Calculations of areas used for obtaining the RA for material D.

Table 18: Calculated RA values for test specimens from material D.

Sample	RA [%]
Reference	61,75
Polarised 1	54,43
Polarised 2	54,18
Polarised 3	55 <i>,</i> 95
Average	55,0

# Material E

Sample	<i>d</i> <sub>0</sub> [mm]	<i>A</i> <sub>0</sub> [mm2̂]
Reference	3,76	11,098
Polarised 1	3,77	11,157
Polarised 2	3,75	11,039
Polarised 3	3,76	11,098
Average	3,765	11,128
Sample	d <sub>min</sub> [mm]	A <sub>min</sub> [mm2̂]
Reference	2,37	4,409
	<b></b> ,01	4,409
Polarised 1	3,7	10,747
Polarised 1 Polarised 2		
	3,7	10,747

Table 19: Calculations of areas used for obtaining the RA for material E.

Table 20: Calculated RA values for test specimens from material E.

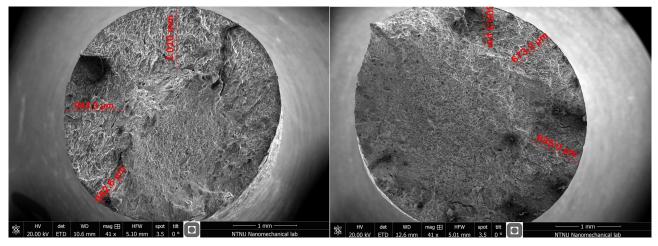
Sample	RA [%]
Reference	60,4
Polarised 1	3,4
Polarised 2	7,0
Polarised 3	2,4
Average	4,3

# Appendix E

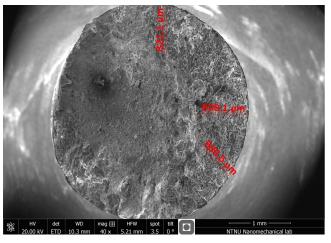
# **Brittle Area Measurements**

# Measured Radii of brittle areas

Figures 10 to 14 show the brittle area measurements obtained using SEM. Tables 21 to 25 provide the measured radii of the brittle areas of the fracture surface for test materials A to E, respectively.



(a) Brittle area measurement for polarised sample 1. (b) Brittle area measurement for polarised sample 2.

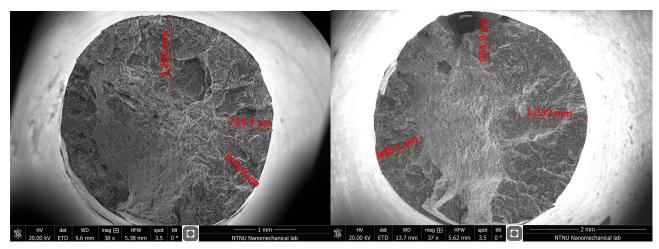


(c) Brittle area measurement for polarised sample 3.

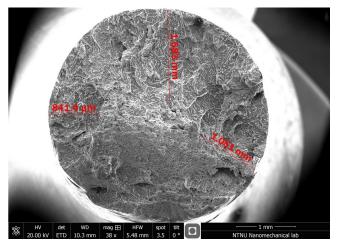
Figure 10: Brittle area measurements for material A.

Measurem. no.	Sample 1	Sample 2	Sample 3
1	652.6	600.3	821.1
2	943.3	673.2	828.1
3	1010	835.0	585.5
Ave.	868.6	702.8	744.9

Table 21: Length of the brittle areas of the fracture surfaces for test material A in  $\mu$ m.



(a) Brittle area measurement for polarised sample 1. (b) Brittle area measurement for polarised sample 2.

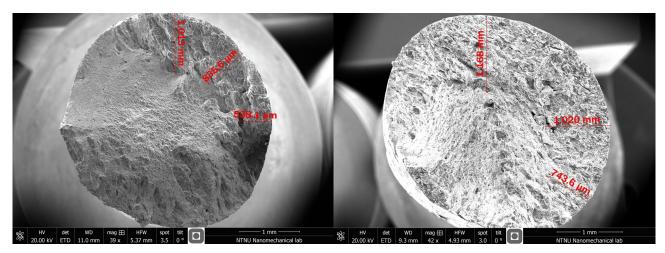


(c) Brittle area measurement for polarised sample 3.

Figure 11: Brittle area measurements for material B.

Measurem. no	Sample 1	Sample 2	Sample 3
1	1262	835.1	841.4
2	715.7	951.9	1583
3	674.9	1333	1051
Ave.	884.2	1040	1158.5

Table 22: Length of the brittle areas of the fracture surfaces for test material B in  $\mu$ m.

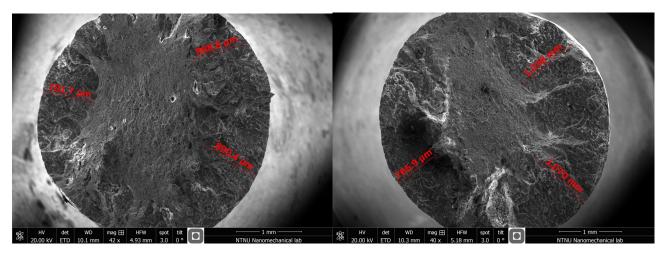


(a) Brittle area measurement for polarised sample 1. (b) Brittle area measurement for polarised sample 2.

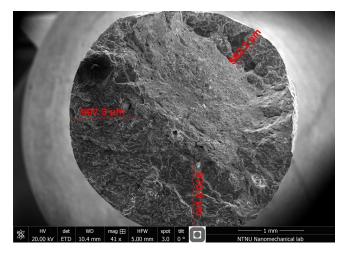
Figure 12: Brittle area measurements for material C.

Table 23: Length of the brittle areas of the fracture surfaces for test material C in  $\mu$ m.

Measurem. no.	Sample 1	Sample 2
1	1013	1168
2	835.6	1020
3	538.1	743.6
Ave.	795.6	977.2



(a) Brittle area measurement for polarised sample 1. (b) Brittle area measurement for polarised sample 2.

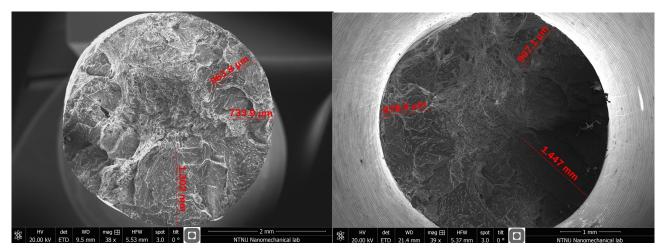


(c) Brittle area measurement for polarised sample 3.

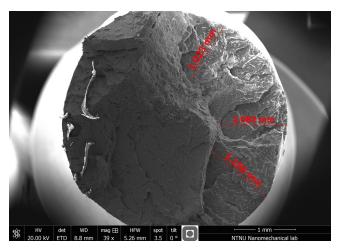
Figure 13: Brittle area measurements for material D.

Measurem. no.	Sample 1	Sample 2	Sample 3
1	781.7	765,9	997.3
2	888.8	1070	582.2
3	890.4	1038	970,9
Ave.	853.6	958.0	850.1

Table 24: Length of the brittle areas of the fracture surfaces for test material D in  $\mu$ m.



(a) Brittle area measurement for polarised sample 1. (b) Brittle area measurement for polarised sample 2.



(c) Brittle area measurement for polarised sample 3.

Figure 14: Brittle area measurements for material E.

Measurem. no.	Sample 1	Sample 2	Sample 3
1	963,8	878,9	1023
2	733,9	907,1	1082
3	1302	1447	1156
Ave.	999,9	1077,7	1087,0

Table 25: Length of the brittle areas of the fracture surfaces for test material E in  $\mu$ m.

# Ductile/brittle area ratio calculations

In this section the ductile/brittle area ratio results are provided in Tables 26 to 30. The equations used for calculating the %DB values are presented below:

$$r_{d} = r_{min} - r_{b}$$

$$A_{d} = \pi \cdot r_{d}^{2}$$

$$A_{b} = A_{min} - A_{d}$$

$$\% DB = 100\% \cdot \left(1 - \frac{A_{d}}{A_{b}}\right)$$

In the equations,  $r_{min}$  is the radius of the cross-section of the fracture surfaces, obtained from the measured minimum diameters, and b and d refers to values for the brittle and ductile areas of the fracture surfaces, respectively.

Table 26: Ductile/brittle area ratio calculations for material A.

Sample no.	Ad [ <i>mm</i> <sup>2</sup> ]	Ab [ <i>mm</i> <sup>2</sup> ]	%DB
1	2,63	7,38	64,36
2	3,53	6,20	43,08
3	2,83	6,13	53,80
Ave	3,00	6,57	54,38
SD	0,66	0,68	10,18

Table 27: Ductile/brittle area ratio calculations for material B.

Sample no.	Ad [ <i>mm</i> <sup>2</sup> ]	Ab [ <i>mm</i> <sup>2</sup> ]	%DB
1	2,55	7,46	65,83
2	1,72	80,23	79,11
3	1,25	8,81	85,78
Ave	1,84	8,16	77,47
SD	0,66	0,68	10,18

Sample no.	Ad [ <i>mm</i> <sup>2</sup> ]	Ab [ <i>mm</i> <sup>2</sup> ]	%DB
1	3,23	7,06	54,21
2	1,30	6,94	81,31
Ave	2,26	7,00	67,65
SD	1,11	1,22	13,98

Table 28: Ductile/brittle area ratio calculations for material C.

Table 29: Ductile/brittle area ratio calculations for material D.

Sample no.	Ad [ <i>mm</i> <sup>2</sup> ]	Ab [ <i>mm</i> <sup>2</sup> ]	%DB
1	2,75	7,31	62,32
2	2,20	7,92	72,22
3	2,60	7,13	63,52
Ave	2,52	7,45	66,21
SD	0,29	0,41	5,40

Table 30: Ductile/brittle area ratio calculations for material E.

Sample no.	Ad [ <i>mm</i> <sup>2</sup> ]	Ab [ <i>mm</i> <sup>2</sup> ]	%DB
1	2,27	8,48	73,23
2	1,71	8,64	80,24
3	1,88	8,99	79,12
Ave	1,95	8,70	77,58
SD	0,29	0,26	3,76

# PROPERTIES OF S39274 TEST PIECES

# <u>1. Scope</u>

NSSMC sent tensile test pieces of S39274 to Norwegian university. Followings are properties of these samples.

# 2. Description of samples

Table 1 Description of sam	ples
----------------------------	------

Size	Process	Material
OD 169.3mm × WT 25.85mm	Hot extrusion $\rightarrow$ Cold drawing $\rightarrow$ Heat treatment	S39274

# 3. Properties

# Table 2 Chemical compositions (mass %)

	С	Si	Mn	Р	S	Ni	Cr	Мо	N	Cu	W
Item 1 (Heat:F626012)	0.016	0.25	0.68	0.024	0.0002	6.2	25.1	3.2	0.29	0.53	2.10
UNS S39274	0.030	0.80	1.00	0.030	0.020	6.0	24.0	2.5	0.24	0.20	1.50
0110 009274	max.	max.	max.	max.	max.	/8.0	/26.0	/3.5	/0.32	/0.80	/2.50

# Table 3 Tensile properties

	YS	TS	EL
	(MPa)	(MPa)	(%)
Item 1 (Heat:F626012)	660	862	39
ASTM A789-S39274	min.	min.	min.
	550	800	15

	Technical information contained in this document describes only some representative properties or performance of products and does not
	necessarily mean assured values.
N	Further, as such information may be subject to change without notice, you are requested to ask the latest information when you order a
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88357 Cert. N° FOGLIO

BLATT - PAGE FEUILLE

# DI DE

SEC./ACC.TO/NACH/SELON

VON - OF

#### CERTIFICATO MATERIALI - MATERIAL CERTIFICATE - WERKSTOFF PRUEFZEUGNIS - CERTIFICAT MATIERE

CLIENTE		ORDINE N.	EN 10204/2.2	
CUSTOMER	GE OIL & GAS	ORDER N.	EN 10204/3.1	X
KUNDE		BESTELLUNG N.		
CLIENT		COMMANDE N.	EN 10204/3.2	

#### DESCRIZIONE SPEDIZIONE - DESCRIPTION OF DELIVERY - UMFANG DER LIEFERUNG - DETAILS DU LOT

COLATA N.	QUANTITÀ	DENOMINAZIONE - DESCRIZIONE	GEGENSTAND - ABMESSUNG				
HEAT NR.	QUANTITY						
SCHMELZE NR.	STUECKZAHL	DESCRIPTION - SIZE	DESIGNATION - DIMENSION				
NO. DE COULEÈ	QUANTITÈ						
L 7628		TEST SAMPLING					
ANALISI CHIMICA -	ANALISI CHIMICA - CHEMICAL ANALYSIS - HEMISCHE ZUSAMMENSETZUNG - COMPOSITION CHIMIQUE						

	NOT SHARE THE REAL PROPERTY OF					the second s					and the second se	W	
LEGA ALLOY		с	Cr	Ni	Мо	Mn	Si	Р	S	Ν			
LEGIERUNG	MIN	0,000	24,000	6,000	4,000	0,000	0,000	0,000	0,000	0,100			
ALLIAGE	MAX	0,030	26,000	8,000	5,000	1,500	1,000	0,040	0,040	0,300			
A995 GR 5A		0,023	25,124	7,507	4,149	0,755	0,564	0,023	0,005	0,242			

PROPRIETA' MECCANICHE - MECHANICAL PROPERTIES - MECHANISCHE EIGENSCHAFTEN - ESSAIS MECANIQUES

Rp 1% (MPa)	Rp 0.2% (MPa)	Rmn (MPa)	A (%)	Z (%)	НВ	Resilienza - Re Kerbschlagzaehigk			
						т= -46		-46°C	l6°C
min =	min = 515	min = 690	min = 18	min =		KV JOULE	KCU JOULE	DVM JOULE	LE mmq
	588	809	34		237	161			
						168			
				5		158			

Prove speciali	
Special tests	
Spezifische Pruefungen	
Essais Speciaux	
Trattamento termico	SOLUTION TREATMENT 1130°C/WATER
Heat Treatement	
Termische Behandlung	
Traitement Thermique	
Osservazioni	MELTING: ELECTRIC (INDUCTION)
Remarks	PRE=42,7
Bemerkungen	MATERIAL ACC. TO NORSOK MDS D56 REV.5
Observations	

Sergnano... 07/10/2016

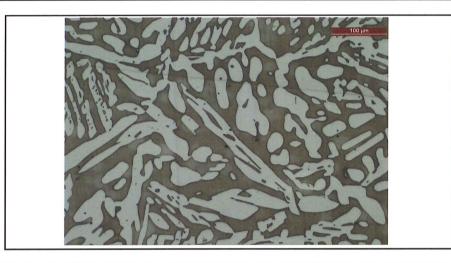
Resp. laboratorio

Resp. qualità



Ente collaudo

Via Marconi 40 26010 SERGN		QUALITY CONT	QUALITY CONTROL			
TEL. 0373 456 FAX 0373 455		FERRITE CONTENT CEF	PAGE 2 OF 2			
Accordance with		ASTM	E 562			
Customer		GE OIL & GAS				
Purchase Order						
Heat	L7628					
Material	A995 GR 5A					
Heat Treatment	SOLUTION ANNEALING 1130°C/WATER					
Instrument	OPTICAL METALLOGRAPHIC MICROSCOPE LEICA DM4000M LED					
Chosen of the fields		RANDOMLY				
Etching		ELECTROLITIC, OXALIC ACID + NaOH 40%				
Sample dimension		35X32X15mm				
Magnification		200X				
Grid points and shape	16	Square				
Fields	30	Position		1⁄2 Thk		

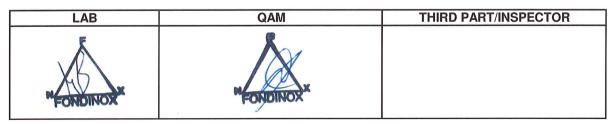


n.	field	n.	field	n.	field	n.	field
1	56,25	11	37,50	21	40,63	31	-
2	53,13	12	31,25	22	65,63	32	-
3	43,75	13	46,88	23	68,75	33	-
4	43,75	14	37,50	24	50,00	34	-
5	37,50	15	50,00	25	37,50	35	-
6	62,50	16	50,00	26	53,13	36	-
7	68,75	17	56,25	27	56,25	37	-
8	56,25	18	46,88	28	31,25	38	-
9	50,00	19	50,00	29	50,00	39	-
10	50,00	20	56,25	30	46,88	40	-

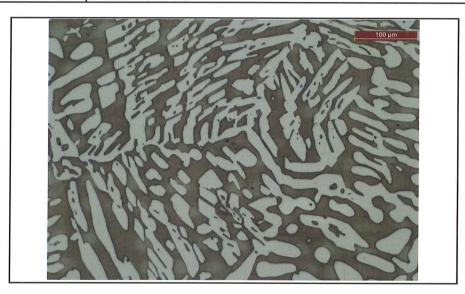
Volume fraction Vf [%]	49,479
standard deviation s [%]	9,885
95%CI	3,691
%RA	7,459
t	2,045

Vf	± 95% CI	]
49,48	3,69	]%

**Req.** 35-55 %



Via Marconi 4 26010 SERGN		QUALITY CONTROL	88357 SM			
TEL. 0373 456 FAX 0373 455		METALLOGRAPHIC CERTIFICATE	PAGE 1 OF 2			
Accordance with		MDS D56 REV.5				
Customer	GE OIL & GAS					
Purchase Order						
Heat	L7628					
Material	A995 GR 5A					
Heat Treatment	SOLUTION ANNEALING 1130 °C/WATER					
Instrument	OPTICAL METALLOGRAPHIC MICROSCOPE LEICA DM4000M LED					
Etching		ELECTROLITIC, OXALIC ACID + NaOH 40%				
Etching T		20 ℃				
Sample dimension		35X32X15mm				
Magnification		200x				
Position		T/2				



COMMENTS	MICROSTRUCTURE FREE FROM DETRIMENTAL INTERMETALLIC PHASES AND PRECIPITATIONS
RESULTS	SATISFACTORY

LAB	QAM	THIRD PART/INSPECTOR
M FONDINOX		

	Via Marconi, 42/48 - 26010 SERGNANO (CR) Tel. +39 0373 45651						CONTROLLO QUALITA' QUALITY CONTROL					HT 4803					
Fax +39 0373 455100						CERTIFICATO DI TRATTAMENTO TERMICO HEAT TREATMENT CERTIFICATE FOGLIO DI											
FONDINOR email: tondinox@tondinox.com						SEE CERT. 3.1 Nr. 88357 PAGE OF											
CLIENTE GE	ORDINE ORDER							-   .	COMM IOB No	ESSA D.	N						
COLATA L 762 HEAT	28			MATERIALE A995 GR 5A					- 1	<b>SP. MAX. mm.</b> 32 mm THCK MAX							
FORNO AS	BELOW INDIC	ATED		COMBU FUEL	COMBUSTIBILE         GAS         CICLO         TT02           FUEL         CYCLE         CYCLE         CYCLE						_						
TIPO TRATT. SO			0	DIAGF	RAMMA				O TE	RMI	0						
SPECIFICA	1200						IAGR										
	RAFFREDAMENTO IN RUNNING WATER									/							
CAMPO TEMP. TEMP. RANGE °C	GRAD. SA HEATING F °C/H MA	RATE	GRAD. DISCESA COOLING RATE °C/H MAX	1000 950 900				1									
20-600	580°C/	h		850				/									
600	HOLDING	60'		800													
600-1000	133°C/	h		700													
1000	HOLDING 60'			650 650 600 550													
1000-1130	87°C/h			10 550									_				
1130	HOLDING 24	500 450 400															
				350 300 250 200													
TEMP. DI REGIME HOLDING TEMP. °C	1130	1130 PERMANENZA 3 HOLDING TIME H															
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NOTE					F										-		
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	QCMgr DATA Date 07/10/2016						ENTE ISPETTIVO DATA Off. Inspector Date										

FONDINOX

Via Marconi, 42/48 - 26010 SERGNANO (CR)

Tel. +39 0373 45651 Fax +39 0373 455100

email: fondinox@fondinox.com

# CONTROLLO QUALITA' QUALITY CONTROL

CERTIFICATO PROVA DI CORROSIONE PITTING CORROSION TEST CERTIFICATE FOGLIO DI

PAGE

OF

CLIENTE: GE OIL & G	AS	ORDINE N.						
CUSTOMER		ORDER No.						
COLATA:	L 7628							
HEAT NUMBER	SEE CERT. 3.1 Nr. 88357							
LEGA: ALLOY	A995 GR 5A							
TRATTAMENTO: HEAT TREATED	SOLUTION TREATMENT 11	130°C/WATER						
RIFERIMENTI: references	S TEST DURATION: 2							
PROVINO: 50 SPECIMEN	X 25 X 10							
SOLUZIONE: AS PER ASTM G 48 SOLUTION								
RISULTATI:     NO WEIGHT LOSS       RESULTS     NO PITTING AT 20X MAGNIFICATION								
	TEST RESULTS ACCOMPL							
	TECHNICAL DOCUMENT							
QCMgr	DATA Date 07/10/2016	ENTE ISPETTIVO Off. Inspector	DATA Date					



#### INSPECTION CERTIFICATE EN 10204:2004 / 3.1

Number: 577628 Page: 1 / 4	Rev: 00
Created on: Date: 24.04.2013	Modified on: 25.04.2013

# TTI - TUBACEX TUBOS INOXIDABLES

Registro Mercantil de Alava, Tomo 587, Folio 189, Hoja VI 2885 - N.I.F. A-01140227

1 res cruces, 8 01400 Llodio (Alava) SPAIN TL: +34 946719300 FAX: +34 946725062 E-MAIL: qualitytti@tubacex.es

#### CUSTOMER DESCRIPTION

CLIENT SOLD TO SFF SCANDINAVIAN FITTINGS & FLANGES A/S JACOB ASKELANDSVEI 5 4391 SANDNES NORWAY CLIENT SHIP TO SFF SCANDINAVIAN FITTINGS & FLANGES A/S JACOB ASKELANDSVEI 5 4391 SANDNES NORWAY

#### CLIENT ORDER: 278485 SALES ORDER: 129610

MATERIAL:SEAML. STAINL. STEEL TUBES/PIPES HEAT-TREATED, PICKLED, PICKLED-PASSIVATED GRADE: S32760, STANDARD: ASTM A790/A790M-11 NORSOK M630 REV.5 MDS D51 REV.4 GP 29-01-02 VERSION 1.0.0 N041050-E244MA Rev.3 Piping Class Sheet PCS 1 #UD01 TOLERANCES: ASTM A999/A999M-12 RANDOM LENGTHS 4.000/7.000 MM PLAIN ENDS, DIMENSIONS: 168,28 X 14,27 MM - 6" SCH 120 HOT FINISHED



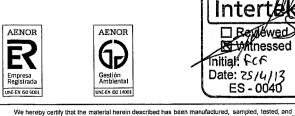
PROJECT: Kizomba Sattelite Phase II CLIENT: VETCOGRAY SCANDINAVIA CLIENT ART. CODE: N39005-P244 PRODUCT NO: 52183 Compliance with Client specification: Signed: JT SFF Q.C. - DEPT.

Sales Item	Client Item	Delivery No	Lot No.	Heat No	Pieces	Weight	Tot Lgth	Un Lgth
10	ART.CODE:N39005-P244 - ITEM NOº 1	ļ	200097973	46836	10	3.284 KG	59,05 M	4000-7000 MM
10	ART.CODE:N39005-P244 - ITEM NO° 1	ŀ	200098050	47013	10	3.220 KG	57,57 M	4000-7000 MM
10	ART.CODE:N39005-P244 - ITEM NO° 1	ŀ	200098052	47024	12	4.043 KG	72,77 M	4000-7000 MM
10	ART.CODE:N39005-P244 - ITEM NO° 1	ļ	200098066	47051	26	9.170 KG	164,26 M	4000-7000 MM
10	ART.CODE:N39005-P244 - ITEM NO° 1	Ļ	200098327	47045	11	3.593 KG	64,18 M	4000-7000 MM

#### RAW MATERIAL

KAW MATERIAL	
Heat Nr:	Supplier
46836	ACERALAVA (SPAIN)
47013	ACERALAVA (SPAIN)
47024	ACERALAVA (SPAIN)
47045	ACERALAVA (SPAIN)
47051	ACERALAVA (SPAIN)

•. •



We hereby certify that the material herein described has been manufactured, sampled, tested, and inspected in accordance with above standards and specifications and satisfies order#s requirements. This certificate is issued by a computerized system and it is valid without original signature. In case the owner of the certificate would release as a copy of it, he must attest its conformity to the issued, assuming the responsibility for any unlawful or TUBACEX, not allowed use. Any forgery or faisification of this certificate shall legally prosecuted.

#### Method

Electric furnace+AOD Electric furnace+AOD Electric furnace+AOD Electric furnace+AOD Electric furnace+AOD

L. Fdez de Nogran TUBACEX TUBOS **INOXIDABLES S.A.** 5.04.20 Date INGENIERIA DE CALIDÃO BYFECHOR 46

Iñigo Arriola Alcibar



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#### INSPECTION CERTIFICATE EN 10204:2004 / 3.1

Number: Page: 2 / 4	577628 1	Rev: 00
Created of Date: 24.		Modified on: 25.04.2013

1         0,01           1         0,01           1         0,01           1         0,01           1         0,01           1         0,25           1         0,25           1         0,25           1         0,24           1         0,24           1         0,24	C 14 14 12 14 16 13 $\mathbf{N}$ $\mathbf{N}$ 4 55 4 4 55 4 4 55 4 4 55 4 4 55 4 4 55 4 4 55 4 7 0 4 7 0 20 20 20 20 20 20 20 20 20 20 20 20 2	Mn 0,74 0,78 0,65 0,77 Pren 41,6590 41,6590 41,6090 41,4570 41,420 41,3150 Direct wa Rp0.2 <i>MPa</i> 610 624 609 595 615	L: Ladle C: Si 0,390 0,440 0,430 0,450 0,480 0,480 Rp1.0 <i>MPa</i> 693 701 688 684	P 0,024 0,023 0,025 0,025 0,027	0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0	S 0005 0006 0005 0004 A5 %	Ni 6,75 7,00 6,95 7,00 6,85 Type	Cr 25,70 25,60 25,55 25,65 25,45	Mo 3,59 3,61 3,63 3,60 3,61	Cu 0,66 0,63 0,66 0,64 0,66	<b>W</b> 0,590 0,610 0,610 0,600
1 0,01 1 0,01 1 0,01 1 0,01 1 0,01 1 0,01 1 0,25 1 0,25 1 0,24 1 0,24 1 0,24 1 0,24 1 0,24 1 0,24 <b>Sample</b> 2 2 4 5	14 12 14 16 13 N N 4 4 55 4 4 4 55 4 4 155 4 145 4 170 4 <sup>∞</sup> C , D. T <sup>∞</sup> C 20 20 20 20 20 20 20 20 20 20	0,74 0,78 0,65 0,67 0,72 <b>Pren</b> 41,6590 41,6590 41,6090 41,4570 41,4420 41,3150 Direct wa <b>Rp0.2</b> <i>MPa</i> 610 624 609 595 615	0,390 0,440 0,430 0,450 0,480 mPa 693 701 688	0,024 0,023 0,025 0,027 enched MPa 847	0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0	005 005 0006 0005 0004 A5 %	6,75 7,00 6,95 7,00 6,85	25,70 25,60 25,55 25,65	3,59 3,61 3,63 3,60	0,66 0,63 0,66 0,64	0,590 0,610 0,610 0,610
1       0,01         1       0,01         1       0,01         1       0,01         1       0,25         1       0,25         1       0,24 <td< td=""><td>12 14 16 13 N N 4 4 4 55 4 4 4 55 4 4 4 55 4 4 4 70 4 <sup>°</sup>C , D. T <sup>°</sup>C 20 20 20 20 20 20 20 20 20 20</td><td>0,78 0,65 0,67 0,72 <b>Pren</b> 41,6590 41,6590 41,6090 41,4570 41,4420 41,3150 Direct wa <b>Rp0.2</b> <i>MPa</i> 610 624 609 595 615</td><td>0,440 0,430 0,450 0,480 Rp1.0 <i>MPa</i> 693 701 688</td><td>0,023 0,025 0,025 0,027 enched MPa 847</td><td>0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0</td><td>005 006 005 004 A5 %</td><td>7,00 6,95 7,00 6,85</td><td>25,60 25,55 25,65</td><td>3,61 3,63 3,60</td><td>0,63 0,66 0,64</td><td>0,610 0,610 0,610</td></td<>	12 14 16 13 N N 4 4 4 55 4 4 4 55 4 4 4 55 4 4 4 70 4 <sup>°</sup> C , D. T <sup>°</sup> C 20 20 20 20 20 20 20 20 20 20	0,78 0,65 0,67 0,72 <b>Pren</b> 41,6590 41,6590 41,6090 41,4570 41,4420 41,3150 Direct wa <b>Rp0.2</b> <i>MPa</i> 610 624 609 595 615	0,440 0,430 0,450 0,480 Rp1.0 <i>MPa</i> 693 701 688	0,023 0,025 0,025 0,027 enched MPa 847	0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0	005 006 005 004 A5 %	7,00 6,95 7,00 6,85	25,60 25,55 25,65	3,61 3,63 3,60	0,63 0,66 0,64	0,610 0,610 0,610
1 0,01 1 0,01 1 0,01 1 0,25 1 0,25 1 0,24 1 0,24 1 0,24 1 0,24 1 0,24 1 0,24 Sample 2 2 4 5	14 16 13 N N 4 4 4 55 4 4 4 55 4 4 4 7 4 3 °C , D. T °C , D. T °C 20 20 20 20 20 20 20 20 20 20	0,65 0,67 0,72 <b>Pren</b> 41,6590 41,6090 41,4570 41,4420 41,3150 <b>Direct</b> wa <b>Rp0.2</b> <i>MPa</i> 610 624 609 595 615	0,430 0,450 0,480 Rp1.0 <i>MPa</i> 693 701 688	0,025 0,025 0,027 enched MPa 847	0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0	0006 0005 0004 A5 %	6,95 7,00 6,85	25,55 25,65	3,63 3,60	0,66 0,64	0,610 0,610
1 0,01 1 0,01 1 0,25 1 0,25 1 0,24 1 0,25 1 0,24 1 0,24 1 0,24 1 0,25 1 0,25 1 0,25 1 0,25 1 0,25 1 0,24 1 0,45 1 0,45	16 13 N 13 13 14 155 4 145 4 145 4 170 170 170 170 170 170 170 170	0,67 0,72 <b>Pren</b> 41,6590 41,6090 41,4570 41,4420 41,3150 Direct was <b>Rp0.2</b> <i>MPa</i> 610 624 609 595 615	0,450 0,480 Ater que <b>Rp1.0</b> <i>MPa</i> 693 701 688	0,025 0,027 enched MPa 847	0,0 0,0 0,0 7 8 42" % 44	0005 1004 A5 %	7,00 6,85	25,65	3,60	0,64	0,610
1 0,01 eq 1 1 0,25 1 0,25 1 0,24 1 0,24 1 0,24 1 0,24 1 0,24 T 1100 Sample 2 2 4 5	13 N 13 13 13 13 14 155 4 145 4 145 4 170 170 170 170 170 170 170 170	0,72 <b>Pren</b> 41,6590 41,6090 41,4570 41,4420 41,3150 Direct was <b>Rp0.2</b> <i>MPa</i> 610 624 609 595 615	0,480 ater que <b>Rp1.0</b> <i>MPa</i> 693 701 688	0,027 enched MPa 847	0,0	0004 	6,85			-	-
leq         I           1         0,25           1         0,25           1         0,24           1         0,24           1         0,24           1         0,24           1         0,24           1         0,24           1         0,24           1         0,24           1         0,24           5         3	N 4 660 4 155 4 145 4 145 4 170 4 <sup>∞</sup> C , D. <sup>∞</sup> C , D. <sup>∞</sup> C 20 20 20 20 20 20 20 20 20 20	Pren 41,6590 41,6090 41,4570 41,4420 41,3150 Direct wa Rp0.2 <i>MPa</i> 610 624 609 595 615	<b>Rp1.0</b> <i>MPa</i> 693 701 688	enched Rm MPa 847	A2" % 44	A5 %		25,45	3,61	0,66	0,600
1 0,25 1 0,25 1 0,24 1 0,24 1 0,24 T 1100 Sample 2 2 4 5	570 4 560 4 155 4 145 4 170 4 <sup>∞</sup> C , D. <sup>∞</sup> C , D. <sup>∞</sup> C 20 20 20 20 20 20 20 20 20 20	41,6590 41,6090 41,4570 41,4420 41,3150 Direct wa <b>Rp0.2</b> <i>MPa</i> 610 624 609 595 615	<b>Rp1.0</b> <i>MPa</i> 693 701 688	<b>Rm</b> <i>MPa</i> 847	<b>A2''</b> % 44	%	Туре				
1 0,25 1 0,25 1 0,24 1 0,24 1 0,24 T 1100 Sample 2 2 4 5	570 4 560 4 155 4 145 4 170 4 <sup>∞</sup> C , D. <sup>∞</sup> C , D. <sup>∞</sup> C 20 20 20 20 20 20 20 20 20 20	41,6590 41,6090 41,4570 41,4420 41,3150 Direct wa <b>Rp0.2</b> <i>MPa</i> 610 624 609 595 615	<b>Rp1.0</b> <i>MPa</i> 693 701 688	<b>Rm</b> <i>MPa</i> 847	<b>A2''</b> % 44	%	Туре				
1 0,25 1 0,24 1 0,24 1 0,24 <b>F</b> 1100 <b>Sample</b> 2 2 4 5	560 4 155 4 145 4 170 4 <sup>∞</sup> C , D <sup>∞</sup> C , D <sup>∞</sup> C 20 20 20 20 20 20 20 20 20 20	41,6090 41,4570 41,4420 41,3150 Direct wa <b>Rp0.2</b> <i>MPa</i> 610 624 609 595 615	<b>Rp1.0</b> <i>MPa</i> 693 701 688	<b>Rm</b> <i>MPa</i> 847	<b>A2''</b> % 44	%	Туре				
1 0,24 1 0,24 1 0,24 F 1100 Sample 2 2 4 5	*55 4 445 4 170 4 *70 4 *70 *70 4 *70 4 *70 *70 *70 *70 *70 *70 *70 *70 *70 *70	41,4570 41,4420 41,3150 Direct wa <b>Rp0.2</b> <i>MPa</i> 610 624 609 595 615	<b>Rp1.0</b> <i>MPa</i> 693 701 688	<b>Rm</b> <i>MPa</i> 847	<b>A2''</b> % 44	%	Туре				
1 0,24 1 0,24 F 1100 Sample 2 2 4 5	445 4 4770 4 1770 4	41,4420 41,3150 Direct wa <b>Rp0.2</b> <i>MPa</i> 610 624 609 595 615	<b>Rp1.0</b> <i>MPa</i> 693 701 688	<b>Rm</b> <i>MPa</i> 847	<b>A2''</b> % 44	%	Туре				
1 0,24 F 1100 Sample 2 2 4 5	*70 4 *C , D. T *C 20 20 20 20 20 20 20 20 20 20 20 20 20	41,3150 Direct wa <b>Rp0.2</b> <i>MPa</i> 610 624 609 595 615	<b>Rp1.0</b> <i>MPa</i> 693 701 688	<b>Rm</b> <i>MPa</i> 847	<b>A2''</b> % 44	%	Туре				
Sample 2 2 4 5	T ℃ 20 20 20 20 20 20 20 20	<b>Rp0.2</b> <i>MPa</i> 610 624 609 595 615	<b>Rp1.0</b> <i>MPa</i> 693 701 688	<b>Rm</b> <i>MPa</i> 847	<b>A2''</b> % 44	%	Туре				
Sample 2 2 4 5	T ℃ 20 20 20 20 20 20 20 20	<b>Rp0.2</b> <i>MPa</i> 610 624 609 595 615	<b>Rp1.0</b> <i>MPa</i> 693 701 688	<b>Rm</b> <i>MPa</i> 847	<b>A2''</b> % 44	%	Туре				
Sample 2 2 4 5	T ℃ 20 20 20 20 20 20 20 20	<b>Rp0.2</b> <i>MPa</i> 610 624 609 595 615	<b>Rp1.0</b> <i>MPa</i> 693 701 688	<b>Rm</b> <i>MPa</i> 847	<b>A2''</b> % 44	%	Туре			er on an an an a state an	
2 2 4 5	<i>℃</i> 20 20 20 20 20 20	<i>MPa</i> 610 624 609 595 615	<i>MPa</i> 693 701 688	<i>MPa</i> 847	<i>%</i> 44	%	Туре				 T
2 2 4 5	<i>℃</i> 20 20 20 20 20 20	<i>MPa</i> 610 624 609 595 615	<i>MPa</i> 693 701 688	<i>MPa</i> 847	<i>%</i> 44	%	Туре				
2 2 4 5	<i>℃</i> 20 20 20 20 20 20	<i>MPa</i> 610 624 609 595 615	<i>MPa</i> 693 701 688	<i>MPa</i> 847	<i>%</i> 44	%	ryhe				
2 4 5	20 20 20 20 20 20 20	610 624 609 595 615	693 701 688	847	44						
2 4 5	20 20 20 20 20	624 609 595 615	701 688				L				
4 5	20 20 20 20	609 595 615	688	052	38	43 37	L L				
5	20 20 20	595 615		836	38 42	41	L				
	20 20	615	<b>FX</b> /	835	42 36	35	L				
ر.	20		697	835 841	36	35	L				
4		618	691	842	38	35	L				
5	20	614	691	844	40	37	L				
2	20 20	613	694	839	36	35	L				
3	20	594	708	854	36	35	L				
Sample	HRC1	HRC2									
2	24,0	25,0									
2	22,0	23,0									
4	24,0	25,0									
5	24,0	25,0									
3	24,0	25,0									
4	24,0	25,0									
5	24,0	25,0									
2	24,0	25,0									
3	24,0	25,0									
•											
Sample	т	Wspec	Ecv 1	Ecv 2	Ecv 3	Ecv AVC	5 Туре				
-	°C	mm	J	J	J	J					
2	-46	10,00	220	247	248	238	L				
2	-46	10,00	293	293	280	289	L				
4	-46 ·	10,00	293	231	293	272 <sup>.</sup>	L				
5	-46	10,00	280	261	232	258	L				
	·	Re Re Re Re Re Re Re Re Re Re	wiewed thessed CF 5/4/13 - 0040 mpled, tested, a r#s requirements	nd s. This wover		Æ				BLES S.A. A DE CALIDAI	}
		5 -46	5 -46 10,00 Integrited Baseribed has been manufactured, san described has been manufactured, san described has been manufactured, san described has been manufactured, san for and it is valid without original signatu fit, he must attest its conformity to the is not allowed use. Any forger or faisifice	5 -46 10,00 280 Intertet Reviewed Hitial. FCF Date: 25/4/13 ES - 0040	5 -46 10,00 280 261	L. For the specifications and satisfies order#s requirements. This mand it is value without or this certificate	L. Folez de Date: 25/4/13 ES - 0040 Date:	5 -46 10,00 280 261 232 258 L Intertext Reviewed Revi	L. Folez de Nograro The specifications and salisfies order#s requirements. This mand it is valiable sonformity to the issued, asymptotic tested, and the additional signature. In case the owner the law of the sonformity to the issued, asymptotic tested and the sonformity to the issued, asymptotic tested and the additional signature. In case the owner the law of the solution of this certificate	5 -46 10,00 280 261 232 258 L Interted Reviewed Reviewed Reviewed Reviewed Intial, FCF Date: 25/4/13 ES-0040 Date: 25/4/13 BY TECHO E Date: 25/4/13 BY TECHO E Thigo 7	5 -46 10,00 280 261 232 258 L Interted Reviewed Revie

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### INSPECTION CERTIFICATE EN 10204:2004 / 3.1

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Created on: Date: 24.04.2013	Modified on: 25.04.2013

IMPACT TEST									
Lot No.	Sample	Т	Wspec	Ecv 1	Ecv 2	Ecv 3	Ecv AVG	Type	
2001100	~ <b>F</b>	ĉ	mm	J	J	J	J	-71	
200098066	3	-46	10,00	261	293	259	271	L	
200098066	4	-46	10,00	249	274	250	258	Ľ	
200098000	4 5		-		235	220	238	L	
20000000		-46	10,00	293					
200098327	2	-46	10,00	276	261	270	269	L	
	3	-46	10,00	286	261	260	269	L	
2077 201 201 4 0007		0000	~ .						
CORROSION ACCOR									
Lot No.	Sample	Т	Pits-20x	W.loss	time				
		°C		g/m2	Horas				
200097973	2	50	N	0,3600	24,0				
200098050	2	50	N	0,1600	24,0				
200098052	4	50	N	0,1000	24,0				
	5	50	N	0,1300	24,0				
200098066	3	50	Ν	0,3000	24,0				
	4	50	N	0,0900	24,0				
	5	50	N	0,2500	24,0				
200098327	2	50	N	0,2300	24,0 24,0				
200030321	2	50	N	0,2700	24,0 24,0				
	3	50	IN	0,1000	24,0				
TERRITE ACCORDIN		1 12 5 (2)							
FERRITE ACCORDIN									
Lot No.	Sample		Dev.Ferr						
		%	%						
200097973	2	54,02	1,91						
200098050	2	53,20	2,07						
200098052	4	54,56	2,43						
	5	54,74	1,79						
200098066	3	54,92	2,36						
	4	54,55	2,20						
	5	54,02	2,44						
200098327	2	54,96	1,78						
200090527	3	54,39	2,16						
	5	54,57	2,10						
METALURGICAL TE	STS								
METALLOGRAPHIC F			יעדייער	ი ლი <b>ა</b>		2			
METALLOGRAPHIC F	ERRITE CO.	NTENT C	THECK AC	C. 10 A	SIM E56	2			
- Ferrite content				-			-	DSS	
section, including	ng locati	ons nea	ar inner	surfac	e and m	id thi	ckness		
- Point count co	nducted a	t 500X	mag.						
- Sample Electro	liticallv	Etched	l using :	NaOH					
1	1		5						
		<b>N</b> T							
METALLOGRAPHIC E	XAMINATIO	IN							
- Sample etched	using NaO	H ASTM	E407 Et	chant N	o.98 ·				• •
- Metallographic	examinat	ion is	conduct	ed over	the co	mplete	section	•	
- Examination con	nducted a	t 500X	mag.						
		Æ							
			nter	Fdely 1					
AENOR	ENOR	Ľ	incer		2				
			Revie	fed			Λ		TUBACEX TUBOS
FL (			<b>Statile</b>	sed	L.	Fdez	.∫de No	graro	INOXIDABLES S.A.
Empresa G	iestión	15	tal FCF			2.5	1	3.2.0	INGENIERIA DE CALIDAD
Registrada A	mbiental		te: 25/4	112		~	-		TAG: A
UNE-EN ISO 5001	-EN ISO 14001		ES - 00			1	2 or	מותף ל	Altorat
We hereby certify that the mate	rial herein describe	d has been m	anumanuneu, ser	mpled, tested,		ate\	E 25.0 B	1.2013	15- Contraction of the second se
inspected in accordance with above certificate is issued by a computeri	e standards and sp zed system and it is	s valid without	nd satisfies orde original signatu	re, In case the	owner		R	TECHI	Ifigo Arriola Alcibar
of the certificate would release as responsibility for any unlawful or T	a copy of it, he mu	ist attest its co	nformity to the is	sued, assumin	gthe				
	shall legally p	prosecuted.					1		

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#### INSPECTION CERTIFICATE EN 10204:2004 / 3.1

Number: 577628 Page: 4 / 4	Rev: 00
Created on: Date: 24.04.2013	Modified on: 25.04.2013

ETCH STRUCTURE ACC. ASTM A923 MET.A: UNAFFECTED STRUCTURE. MATERIAL FREE FROM INTERMETALLIC PHASES AND PRECIPITATES. UNIFORM STRUCTURE ACROSS FULL WALL THICKNESS NON-DESTRUCTIVE TESTS FERRITE CONTENT DETERMINED BY FISCHER FERRITOSCOPE TO 10% OF PRODUCTS TO BE BETWEEN 35% - 55% FERRITE CONTENT POSITIVE MATERIAL IDENTIFICATION TEST ON EACH TUBE/PIPE BY "X-RAY-FLUORESCENCE-ANALYZER": SATISFACTORY HYDROSTATIC PRESSURE TESTED AT 190 bar, 2750 PSI DURING 5 SEC ON EACH TUBE/PIPE: SATISFACTORY DIMENSIONAL CHECKING ON EACH TUBE: SATISFACTORY VISUAL INSPECTION ON EACH TUBE: SATISFACTORY TECHNOLOGICAL TESTS FLATTENING TEST: SATISFACTORY MARKING TX3 TUBACEX 168,28 X 14,27 MM - 6" SCH 120 ASTM A790 S32760 HF SMLS HEAT/ PMI-AV LOT NO/ SPAIN PROJECT: KIZOMBA PH-II CALL OFF NO.4500114582 ITEM NO.1 -ART.CODE: N39005-P244

Colour coding as follows: - 2 stripes solid green ( RAL 6010)

#### REMARKS

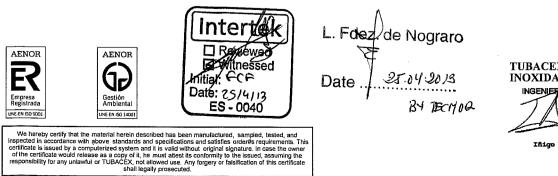
NO MERCURY, MERCURY COMPOUNDS OR MERCURY BEARING INSTRUMENTS AND/OR EQUIPMENT HAVE BEEN USED ALONG MANUFACTURING AND INSPECTION PROCESS.

NO WELDING OR WELD REPAIRS WERE MADE

MATERIAL MANUFACTURER APPROVED BY TÜV SÜD Industrie Service GmbH (NOTIFIED BODY 036)TO ISSUE CERTIFICATES OF SPECIFIC PRODUCT CONTROL IN ACCORDING TO PRESSURE EQUIPMENT DIRECTIVE 97/23/EC ANNEX 1 POINT 4.3.

MATERIAL CHARACTERISTICS COMPLY WITH POINT 7.5 OF ANNEX I TO PED BY HAVING AN ELONGATION AFTER RUPTURE AT TENSILE TEST NO LESS THAN 14% AND A BENDING RUPTURE ENERGY AT IMPACT TEST NO LESS THAN 27J AT 20°C.

MATERIAL IS FREE OF RADIATION CONTAMINATION



**TUBACEX TUBOS INOXIDABLES S.A.** INGENIERIA DE CALIDAD 10101

Iñigo Arriola Alcibar



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INSPECTION CERTIFICATE EN 10204 3.1 Annex 1 Microphotographs

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Date :	25/04/2013

## TTI - TUBACEX TUBOS INOXIDABLES, S.A.

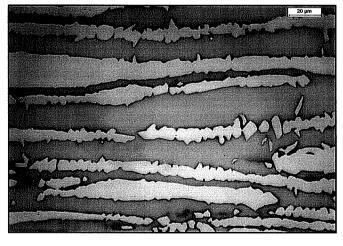
Registro Mercantil de Alava, Tomo 587, Folio 189, Hoja Vl2885 - N.I.F. A-01140227 Tres Cruces, 8 01400 Llodio (Álava)

Sales Order	:	129610
Sales Item	:	10
Standard	:	ASTM A790

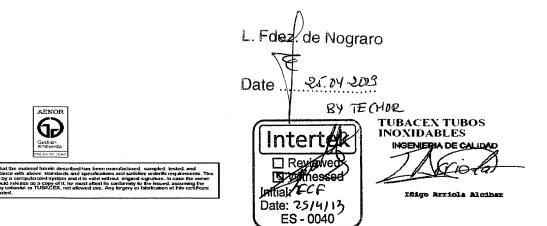
	-	
Grade	:	UNS S32760
Dimensions	:	6"SCH 120

# Microstructure: MATERIAL FREE FROM INTERMETALLIC PHASES AND PRECIPITATES. UNIFORM STRUCTURE ACROSS FULL WALL THICKNESS.

Etchant ASTM E407 no.98



p1303465-2 Heat 46836 ferrocianuro x500.jpg





INSPECTION CERTIFICATE EN 10204 3.1 Annex 1 Microphotographs

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Date	:	25/04/2013
Date	:	25/04/2013

# TTI - TUBACEX TUBOS INOXIDABLES, S.A.

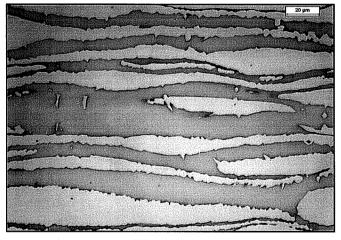
Registro Mercantil de Alava, Tomo 587, Folio 189, Hoja VI2885 - N.I.F. A-01140227 Tres Cruces, 8 01400 Llodio (Álava)

Sales Order	:	129610
Sales Item	:	10
Standard	:	ASTM A790
Grade	:	UNS S32760

Dimensions : 6"SCH 120

#### Microstructure: MATERIAL FREE FROM INTERMETALLIC PHASES AND PRECIPITATES. UNIFORM STRUCTURE ACROSS FULL WALL THICKNESS.

Etchant ASTM E407 no.98



p1303459-2 Heat 47013 ferrocianuro x500.jpg

L. Fored de Nograro 25.04.2013 Date BYFECHOR



We berefory certify that the material herein described has been manufactured, sampled, lested, and morecoid in accountse with above standards and specifications and subfies ordering the regularments. This certificate is issued by a computerized system and it is value which or organis signaluse, in case the owner the certificate is issued by a computerized system and it is value which or organis signaluse. In case the owner the certificate work release as a carry of it, here must abort its contraring to the issued, assuming the expensibility for any uthanks' or TUBACEX, not allowed use. Any largery or labulation of his certificate has legality processed.



TUBACEX TUBOS INOXIDABLES INGENIERIA DE CALIDAD Cion

Ifigo Arriola Alcibar



INSPECTION CERTIFICATE EN 10204 3.1 Annex 1 Microphotographs

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Date :	25/04/2013

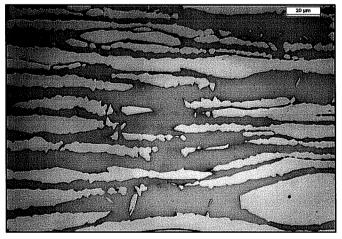
# TTI - TUBACEX TUBOS INOXIDABLES, S.A.

Registro Mercantil de Alava, Tomo 587, Folio 189, Hoja VI2885 - N.I.F. A-01140227 Tres Cruces, 8 01400 Llodio (Álava)

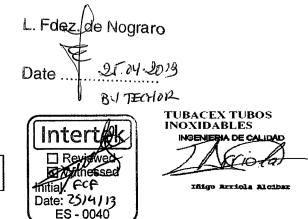
Sales Order	:	129610
Sales Item	:	10
Standard	:	ASTM A790
Grade	:	UNS S32760
Dimensions	:	6"SCH 120

Microstructure: MATERIAL FREE FROM INTERMETALLIC PHASES AND PRECIPITATES. UNIFORM STRUCTURE ACROSS FULL WALL THICKNESS.

Etchant ASTM E407 no.98



p1303464-4 heat 47024 ferrocianuro x500.jpg





We brothy carbly list the material interin described has been manufactured, sampled, tasked, and mapped in accordingt with allower standards in productions and subfield order togethermore. The cardinate is insured by a computerated system and it is valid velocit original signature, in case the owner of the contribute work interact and a copy of it. Its must start its contributing to the standard assuming the responsibility for any uninvest or TUBACEX, not allowed use. Any largety or blastication of bits ort if case the leading rescalad.



INSPECTION CERTIFICATE EN 10204 3.1 Annex 1 Microphotographs

Number :	577628
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Date :	25/04/2013

#### TTI - TUBACEX TUBOS INOXIDABLES, S.A.

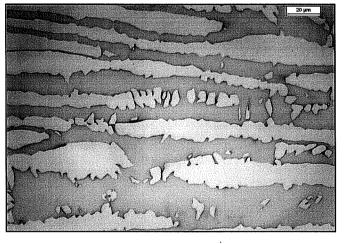
Registro Mercantil de Alava, Tomo 587, Folio 189, Hoja VI2885 - N.I.F. A-01140227 Tres Cruces, 8 01400 Llodio (Álava)

Sales Order : 129610 Sales Item : 10 Standard : ASTM A790

Grade	:	UNS S32760
Dimensions	:	6"SCH 120

Microstructure: MATERIAL FREE FROM INTERMETALLIC PHASES AND PRECIPITATES. UNIFORM STRUCTURE ACROSS FULL WALL THICKNESS.

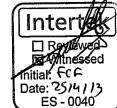
Etchant ASTM E407 no.98



p1303464-5 heat 47024 ferrocianuro x500.jpg

L. Fdez. de Nograro 25.14 2013 Date ..

BY TECHOR



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Ifigo Arriola Alcibar





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## TTI - TUBACEX TUBOS INOXIDABLES, S.A.

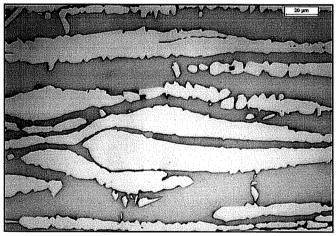
Registro Mercantil de Alava, Tomo 587, Folio 189, Hoja Vl2885 - N.I.F. A-01140227 Tres Cruces, 8 01400 Llodio (Álava)

Sales Order Sales Item	:	129610 10
Standard	:	ASTM A790
Grade	:	UNS S32760

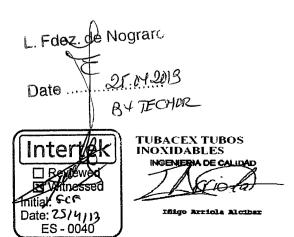
Oludo	•	0110 00210
Dimensions	:	6"SCH 120

Microstructure: MATERIAL FREE FROM INTERMETALLIC PHASES AND PRECIPITATES. UNIFORM STRUCTURE ACROSS FULL WALL THICKNESS.

Etchant ASTM E407 no.98



p1303463-3 Heat 47051 ferrocianuro x500.jpg





We hereby cettily that the material herein describenthas been manufactured, sampled, tested, and mapcical in accordance with above standards and specifications and satisfies orderfly requirements. This conflictule is according a complexitered system and it is with without ordinal signalus. In case the owner requestibility for any universe straining and the state without ordinal signalus, in case the owner requestibility for any universe and USACEX, not allowed use. Any largency or balactation of the certification and four sections.



INSPECTION CERTIFICATE EN 10204 3.1 Annex 1 Microphotographs

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Page :		6/9
Date :		25/04/2013

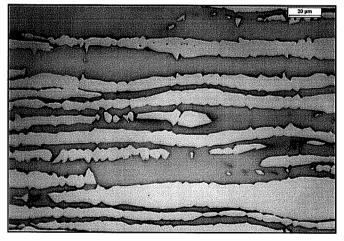
# TTI - TUBACEX TUBOS INOXIDABLES, S.A.

Registro Mercantil de Alava, Tomo 587, Folio 189, Hoja VI2885 - N.I.F. A-01140227 Tres Cruces, 8 01400 Llodio (Álava) SPAIN

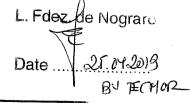
Sales Order Sales item	:	129610 10
Standard	:	ASTM A790
Grade	:	UNS S32760
Dimensions	:	6"SCH 120

Microstructure: MATERIAL FREE FROM INTERMETALLIC PHASES AND PRECIPITATES. UNIFORM STRUCTURE ACROSS FULL WALL THICKNESS.

Etchant ASTM E407 no.98



p1303463-4 Heat 47051 ferrocianuro x500.jpg





TUBACEX TUBOS INOXIDABLES INGENIERIA DE CALIDAD Ľφ



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We hereby cruitly that the material later th described has been manufactured, sampled, tested, and impected to accordinate with above standards on all specifications and usfoles codering requirements. This cruitfactu is insured by a competenzed system and it is valid writed, original separature, in case the waves of the cruitfacture work indexes as easy of it, he must aben its continenty to the insured, assuming the responsibility for any unfancture or TUSPACEK, not allowed use. Any stepsy or fashication of this cellificate work in energies.



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Page :	7/9
Date :	25/04/2013

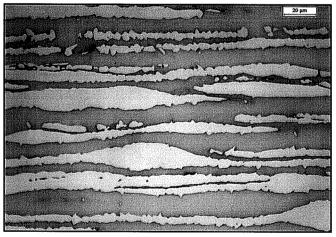
#### **TTI - TUBACEX TUBOS INOXIDABLES, S.A.** Registro Mercantil de Alava, Tomo 587, Folio 189, Hoja VI2885 - N.I.F. A-01140227 Tres Cruces, 8 01400 Llodio (Álava) SPAIN

Sales Order : 129610 Sales Item : 10 Standard : ASTM A790

Grade	:	UNS S32760
Dimensions	:	6"SCH 120

Microstructure: MATERIAL FREE FROM INTERMETALLIC PHASES AND PRECIPITATES. UNIFORM STRUCTURE ACROSS FULL WALL THICKNESS.

Etchant ASTM E407 no.98



p1303463-5 Heat 47051 ferrocianuro x500.jpg



Ve hereby certify that the material herein described has be repected in accordance with above standards and specifi d by a computerized system and it is valid without, organic asymptotic tookd release as a copy of it, he must altest its conformity to the ist my calawild on TUBACEX, not allowed use. Any longery or faisilities of the ning the

L. Forez de Nograro 25.04-2013 Date . BY TECHOR TUBACEX TUBOS INOXIDABLES INGENIERIA DE CALIDAD thessed KLIOT K Initial. FCF Date: 25/4113 ES - 0040 Ifigo Arriola Alcibar



INSPECTION CERTIFICATE EN 10204 3.1 Annex 1 Microphotographs

Number :	577628
Page :	8/9
Date :	25/04/2013

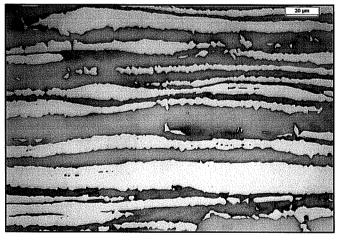
TTI - TUBACEX TUBOS INOXIDABLES, S.A.

Registro Mercantil de Alava, Tomo 587, Folio 189, Hoja VI2885 - N.I.F. A-01140227 Tres Cruces, 8 01400 Llodio (Álava) SPAIN

Sales Order	:	129610
Sales Item	:	10
Standard	:	ASTM A790
Grade	:	UNS S32760
Dimensions	:	6"SCH 120

Microstructure: MATERIAL FREE FROM INTERMETALLIC PHASES AND PRECIPITATES. UNIFORM STRUCTURE ACROSS FULL WALL THICKNESS.

Etchant ASTM E407 no.98

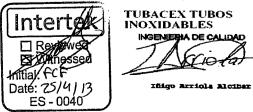


p1303460-2 Heat 47045 ferrocianuro x500.jpg

L. Fdez/de Nograru 2T.04.2013 Date BY TEMPR



We herefy certify list the moterial herein described has been manufactured: sampled. Estud, and important in accordance with above standards and specifications and statistics colorism. This more than the state of the of the certificate work interact as a copy of the next attent is containing the more state of the st





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Date :	25/04/2013

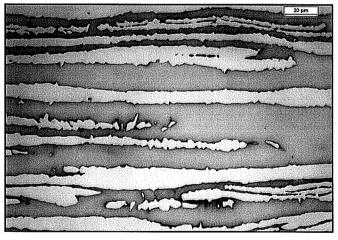
# TTI - TUBACEX TUBOS INOXIDABLES, S.A.

Registro Mercantil de Alava, Tomo 587, Folio 189, Hoja VI2885 - N.I.F. A-01140227 Tres Cruces, 8 01400 Llodio (Álava) SPAIN

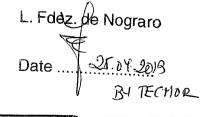
Sales Order	:	129610
Sales Item	:	10
Standard	:	ASTM A790
Grade	:	UNS S32760
Dimensions	:	6"SCH 120

Microstructure: MATERIAL FREE FROM INTERMETALLIC PHASES AND PRECIPITATES. UNIFORM STRUCTURE ACROSS FULL WALL THICKNESS.

Etchant ASTM E407 no.98



p1303460-3 Heat 47045 ferrocianuro x500.jpg



nter dewed R **Witnessed** AND FOF Date: 25/4/13 ES - 0040

TUBACEX TUBOS INOXIDABLES INGENIERIA DE CALIDAD Liota



We beretry certify that the material herein described has been manufactured, samplest, tested, and mospectri in accordance with above instruktion and specifications and studies coloride registerment. This certificate is insured by a compaterized system and it is valid without, original signature, in case the owner of the controlled work frequence as a carp of it, he most after the centre may be be based, assuming the responsibility for any subsets or TUBACEX, not allowed use. Any property of tablactement on the certificate statistication encourted.

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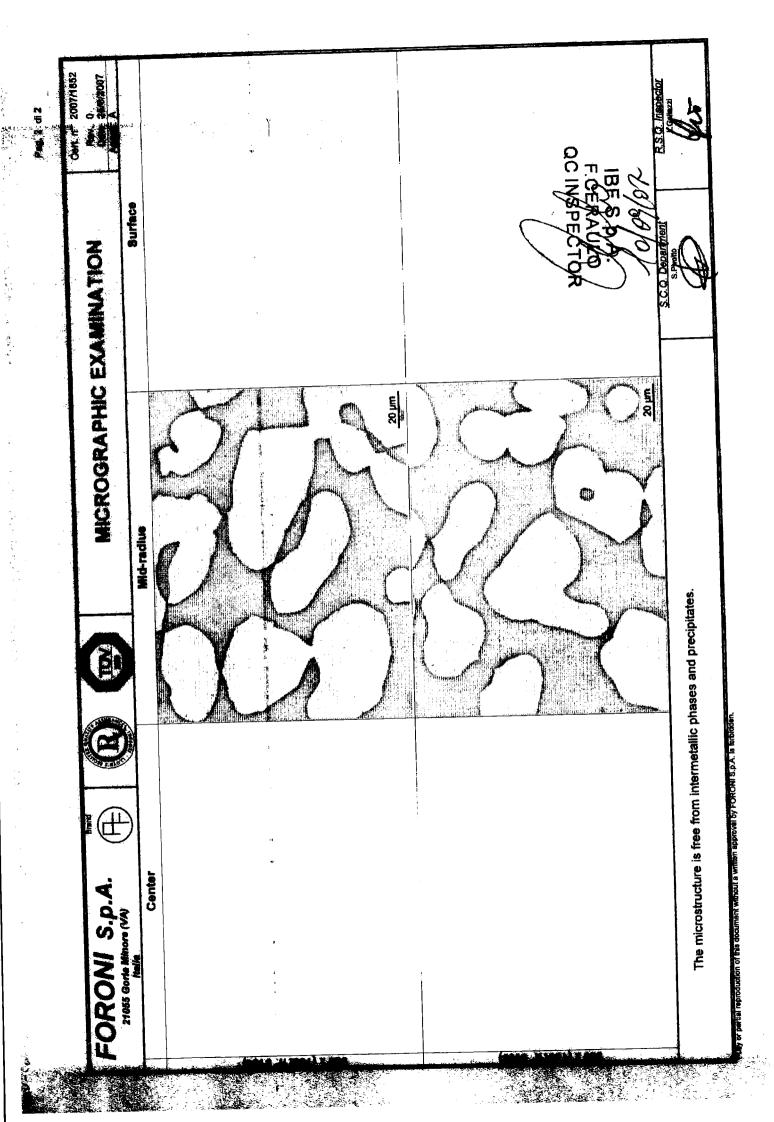
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Ifigo Arriola Alcibar

Utron.         Im.         Data         Before         Specification         Immunol of the control of	Arr.         Date         IBF Order         Specification         Material           005899         06/11/2007         2007000066         ASTM A790         532760         532760           005899         06/11/2007         2007000066         ASTM A790         532760         532760         532760         532760           005899         06/11/2007         2007000066         ASTM A790         532760         532760         532760         532760         532760         532760         532760         532760         532760         532876         5387         532876         5458         532876         5458         53286         5388         536.10         3487         8,355         53286         5387         53286         5388         53286         5388         53286         5388         53286         5388         53286         5388         53286         5388         53286         5388         53286         5388         53286         5388         53286         5388         53286         5388         53286         5388         53286         5388         53286         5388         53286         5388         53286         5388         53286         5388         53286         5388         53286         5388         53286	FinishingCustomerSmlsSFFSCANDINAVIANFITTINGS&g.No00521851DMGMDOR00521851DMGNDOR00521851PMGNDOR00521851 </th <th></th>	
05595         05/11/2007         207000056         ATM AP30         32150         Ball         SPE SCANDISAVIAN FITTINGS & FL         L00000 ENV 2.0           001011         001011         00101         00101         00101         00101         00101         00101           001011         001011         0010	005899         06/11/2007         2007000066         ASTM A790         S32760         S32760           cminimum         cminim         cminii         cminiii	Smls         SFF         SCANDINAVIAN         FITTINGS         &           g.No.         G.I.Reg.Item         DWG         0.011         DWG         0.011         DWG           g.No.         0.52185         1         DWG         0.52185         1           NDOR NO         0.52185         1         DWG         0.52185         1           NDOR NO         0.52185         1         1         1         1         1           NDOR NO         0.52185         1         1         1         1         1         1           NDOR NO         0.52185         1 <td< th=""><th><b>D80 REV.02 of</b> HT.Lot H10000244 H10000243 H10000243 H100000243 H100000243 H100000243 H100000243 H100000246 H100000246 H100000246 H100000246 H100000246 H100000246 H100000246 H100000246 H100000250 H100000250 H100000250</th></td<>	<b>D80 REV.02 of</b> HT.Lot H10000244 H10000243 H10000243 H100000243 H100000243 H100000243 H100000243 H100000246 H100000246 H100000246 H100000246 H100000246 H100000246 H100000246 H100000246 H100000250 H100000250 H100000250
g.Mo         C.I.Req.Lem         DMG         Heat         HT.Lot           MOR NO: 552185         1         04337         H10000244           XDOR NO: 552185         1         04335         1         10000244           XDOR NO: 552185         1         04335         1         10000244           XDOR NO: 552185         1         04335         11         04335         1100000243           XDOR NO: 552185         1         04347         H10000243         04335         1100002243           XDOR NO: 552185         1         04347         H10000243         04335         1100000243           XDOR NO: 552185         1         1         04347         H100000243         04347         H100000243           XDOR NO: 552185         1         1         04347         H100000243         04347         H100000243           XDOR NO: 552185         1         1         04347         H100000243         04347         H100000243           XDOR NO: 552185         1         1         1         04347         H100000243         04347         H100000243           XDOR NO: 552185         1         1         1         1         04347         H100000243           XDOR NO: 5521	derification interfail activity interfaile activity interfail activity interfaile activity actout activity activity activity activity activity act	G.No.       C.I.Reg.Item         NDOR NO       052185       1	HT.Lot         M.Test           H100000244         551           H10000244         551           H10000243         5513           H10000243         5513           H10000243         5513           H10000243         5513           H10000243         5513           H10000243         5513           H10000245         5567           H10000245         5567           H10000245         5568           H10000245         5567           H10000245         5568           H10000245         5567           H10000245         5567           H10000254         5568           H100000245         5567           H100000246         5568           H100000240         5568           H100000240         5568           H100000250         5578           H100000250         5578
g.No.         C. I. Reg. item         2NG         Heat.         HT.Lot.           X0000 NO<0022185         1         04335         H100000243           X0000 NO<0022185         1         04347         H100000243           X0000 NO<0022185	Tem Description         PCS MU Quantity Tag           005 PIPE SMLS 10° SCH-120         ASTM A790 S32760 ANST B36.10         34 MT         8,105 VUS           005 PIPE SMLS 10° SCH-120         ASTM A790 S32760 ANST B36.10         34 MT         8,195 VUS           005 PIPE SMLS 10° SCH-120         ASTM A790 S32760 ANST B36.10         34 MT         8,195 VUS           005 PIPE SMLS 10° SCH-120         ASTM A790 S32760 ANST B36.10         45 MT         8,195 VUS           005 PIPE SMLS 10° SCH-120         ASTM A790 S32760 ANST B36.10         46 MT         6,425 VUS           005 PIPE SMLS 10° SCH-120         ASTM A790 S32760 ANST B36.10         49 MT         6,425 VUS           005 PIPE SMLS 10° SCH-120         ASTM A790 S32760 ANST B36.10         49 MT         6,425 VUS           005 PIPE SMLS 10° SCH-120         ASTM A790 S32760 ANST B36.10         49 MT         6,425 VUS           005 PIPE SMLS 10° SCH-120         ASTM A790 S32760 ANST B36.10         59 MT         8,136 VUS           005 PIPE SMLS 10° SCH-120         ASTM A790 S32760 ANST B36.10         59 MT         8,135 VUS           005 PIPE SMLS 10° SCH-120         ASTM A790 S32760 ANST B36.10         59 MT         8,135 VUS           005 PIPE SMLS 10° SCH-120         SCH-120         ASTM A790 S32760 ANST B36.10         59 MT         8,135 VUS           005 PIPE SMLS	g.No.     C.I.Reg.Item       NDOR     NO     052185     1       NDOR     052185     1	HT.Lot         M.Test           7         H100000244         551           6         H100000244         5512           5         H100000243         5513           5         H100000243         5513           6         H100000243         5513           7         H100000243         5513           7         H100000245         5567           7         H100000245         5567           7         H100000245         5568           4         H100000246         5568           4         H100000250         5578           4         H100000250         5578           4         H100000250         5578
AETM         ACTM         ACTM <th< td=""><td>ASTW         A790         S32760         ANSI         B36.10         34         WT         B,105           ASTW         A790         S32760         ANSI         B36.10         34         MT         B,285           ASTW         A790         S32760         ANSI         B36.10         45         MT         B,285           ASTW         A790         S32760         ANSI         B36.10         45         MT         B,252           ASTW         A790         S32760         ANSI         B36.10         46         MT         6,425           ASTW         A790         S32760         ANSI         B36.10         50         MT         B,215           ASTW         A790         S32760         ANSI         B36.10         50         MT         B,219           ASTW         A790         S32760         ANSI         B36.10         50         MT         B,190           ASTW         A790         S32760         ANSI         B36.10         54         MT         B,215           ASTW         A790         S32760         ANSI         B36.10         57         MT         B,225           ASTW         A790         S32760</td><td>: 052185 : 052185</td><td>H10000244 H10000242 H10000243 H100000243 H100000243 H100000245 H100000245 H100000245 H100000245 H100000248 H100000248 H100000248 H100000250 H100000250 H100000250</td></th<>	ASTW         A790         S32760         ANSI         B36.10         34         WT         B,105           ASTW         A790         S32760         ANSI         B36.10         34         MT         B,285           ASTW         A790         S32760         ANSI         B36.10         45         MT         B,285           ASTW         A790         S32760         ANSI         B36.10         45         MT         B,252           ASTW         A790         S32760         ANSI         B36.10         46         MT         6,425           ASTW         A790         S32760         ANSI         B36.10         50         MT         B,215           ASTW         A790         S32760         ANSI         B36.10         50         MT         B,219           ASTW         A790         S32760         ANSI         B36.10         50         MT         B,190           ASTW         A790         S32760         ANSI         B36.10         54         MT         B,215           ASTW         A790         S32760         ANSI         B36.10         57         MT         B,225           ASTW         A790         S32760	: 052185 : 052185	H10000244 H10000242 H10000243 H100000243 H100000243 H100000245 H100000245 H100000245 H100000245 H100000248 H100000248 H100000248 H100000250 H100000250 H100000250
Arms Argo Sarrow Awar Sard 1         Fr         5.35         WHONG AW         0.3215         11         0.4315         110000004           Arms Argo Sarrow Awar Sard 1         6.6         5.35         WHONG AW         0.3215         11         0.4315         110000004           Arms Argo Sarrow Awar Sard 10         6.6         5.31         WHONG AW         0.3215         11         0.4315         110000004           Arms Argo Sarrow Awar Sard 10         6.6         5.31         WHONG AW         0.3215         11         0.4315         110000004           Arms Argo Sarrow Awar Sard 10         9.7         5.13         WHONG AW         0.3215         11         0.4315         110000004           Arms Argo Sarrow Awar Sard 10         9.7         5.13         WHONG AW         0.3215         11         0.4315         110000004           Arms Argo Sarrow Awar Sard 10         9.7         5.14         WHONG AWA         0.3215         11         110000004         1144         110000044         110000044         110000044         110000044         110000044         110000044         110000044         111000044         111000044         111000044         111000044         111000044         111000044         1111000044         1111000044         1111000044         1	ASTW A790 S32760 ANST B36.10 36 MT 8,350 ASTW A790 S32760 ANST B36.10 42 MT 8,195 ASTW A790 S32760 ANST B36.10 45 MT 6,850 ASTW A790 S32760 ANST B36.10 45 MT 6,425 ASTW A790 S32760 ANST B36.10 50 MT 8,215 ASTW A790 S32760 ANST B36.10 51 MT 7,885 ASTW A790 S32760 ANST B36.10 52 MT 8,190 ASTW A790 S32760 ANST B36.10 52 MT 8,120 ASTW A790 S32760 ANST B36.10 54 MT 8,120 ASTW A790 S32760 ANST B36.10 55 MT 8,125 ASTW A790 S32760 ANST B36.10 57 MT 8,145 ASTW A790 S32760 ANST B36.10 57 MT 8,185 ASTW A790 S32760 ANST B36.10 57 MT 8,145 ASTW A790 S32760 ANST B36.10 57 MT 8,145 ASTW A790 S32760 ANST B36.10 57 MT 8,145 ASTW A790 S32760 ANST B36.10 57 MT 8,270 ASTW A790 S32760 ANST B36.10 57 MT 8,280 ASTW A790 S32760 ANST B36.10 50 MT 8,260 ASTM A790 S32760 0,0002 0,4900 7,0000 25,590 3,6500 0,2530 0 5100 0,0250 0,0003 0,5000 7,0200 25,410 3,6500 0,2550 0 5100 0,0260 0,0003 0,5000 7,0200 25,410 3,6500 0,2550 0 5100 0,0260 0,0003 0,5000 7,0200 25,400 3,6500 0,2550 0 5100 0,0260 0,0003 0,5000 7,0200 25,400 3,6500 0,2550 0 5100 1,0260 0,0003 0,5000 7,0200 24,400 3,6500 0,2550 0 5100 1,0260 0,0003 0,5000 7,0200 24,400 3,6500 0,2550 0 5100 1,0250 0,0000 0,2500 6,9500 25,4100 3,6500 0,2550 0 5100 1,0250 0,	: 052185 : 052185	H10000244 H10000243 H100000243 H100000243 H100000243 H100000245 H100000245 H100000245 H100000248 H100000248 H100000248 H100000248 H100000250 H100000250
ASTM AND STATE ON REF 134.10         4.8 % 154.0         4.5 % 154.00         4.5 % 154.0         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00         4.5 % 154.00 <td>PIPE       SNL       10°       SCH-120       ASTM       A790       S32760       ANST       B36.10       42       MT       8,195         PIPE       SNLS       10°       SCH-120       ASTM       A790       S32760       ANST       B36.10       45       MT       8,195         PIPE       SNLS       10°       SCH-120       ASTM       A790       S32760       ANST       B36.10       45       MT       8,195         PIPE       SNLS       10°       SCH-120       ASTM       A790       S32760       ANST       B36.10       48       MT       5,230         PIPE       SNLS       10°       SCH-120       ASTM       A790       S32760       ANST       B36.10       59       MT       6,8215         PIPE       SNLS       10°       SCH-120       ASTM       A790       S32760       ANST       B36.10       54       MT       6,825         PIPE       SNLS       10°       SCH-120       ASTM       A790       S32760       ANST       B36.10       54       MT       6,920         PIPE       SNLS       10°       SCH-120       ASTM       A790       S32760       ANST       B36.10</td> <td>NO: 052185 NO: 052185</td> <td>H100000242 H100000243 H100000243 H100000245 H100000245 H100000245 H100000245 H100000248 H100000248 H100000248 H100000248 H100000250 H100000250</td>	PIPE       SNL       10°       SCH-120       ASTM       A790       S32760       ANST       B36.10       42       MT       8,195         PIPE       SNLS       10°       SCH-120       ASTM       A790       S32760       ANST       B36.10       45       MT       8,195         PIPE       SNLS       10°       SCH-120       ASTM       A790       S32760       ANST       B36.10       45       MT       8,195         PIPE       SNLS       10°       SCH-120       ASTM       A790       S32760       ANST       B36.10       48       MT       5,230         PIPE       SNLS       10°       SCH-120       ASTM       A790       S32760       ANST       B36.10       59       MT       6,8215         PIPE       SNLS       10°       SCH-120       ASTM       A790       S32760       ANST       B36.10       54       MT       6,825         PIPE       SNLS       10°       SCH-120       ASTM       A790       S32760       ANST       B36.10       54       MT       6,920         PIPE       SNLS       10°       SCH-120       ASTM       A790       S32760       ANST       B36.10	NO: 052185 NO: 052185	H100000242 H100000243 H100000243 H100000245 H100000245 H100000245 H100000245 H100000248 H100000248 H100000248 H100000248 H100000250 H100000250
FSN: 793 03776 ANKE 186.10       6 FT       5.15       VARDOR NO       6.3135       1       6.433       H100000243         SSN: 793 03776 ANKE 186.10       6 FT       5.23       VARDOR NO       6.315       1       6.433       H100000243         SSN: 793 03776 ANKE 186.10       6 FT       5.23       VARDOR NO       6.52155       1       6.433       H100000243         SSN: 793 03776 ANKE 186.10       6 FT       5.23       VARDOR NO       6.52155       1       6.434       H100000243         SSN: 793 03776 ANKE 186.10       6 FT       5.24       VARDOR NO       6.52155       1       6.434       H100000243         SSN: 793 03776 ANKE 186.10       5 FT       7.82       VARDOR NO       6.52155       1       6.434       H100000243         SSN: 793 03776 ANKE 186.10       5 FT       7.82       VARDOR NO       6.52155       1       6.0000444       H100000243         SSN: 793 03776 ANKE 186.10       5 FT       8.134       FUL       8.14       H100000243       H100000243       H100000243       H100000243       H100000243       H100000244       H100000244<	PIPE SNLS 10" SCH-120       ASTM A790 S32760 ANST B36.10       45 MT       6,850         PIPE SNLS 10" SCH-120       ASTM A790 S32760 ANST B36.10       46 MT       6,850         PIPE SNLS 10" SCH-120       ASTM A790 S32760 ANST B36.10       46 MT       6,850         PIPE SNLS 10" SCH-120       ASTM A790 S32760 ANST B36.10       49 MT       6,425         PIPE SNLS 10" SCH-120       ASTM A790 S32760 ANST B36.10       49 MT       6,425         PIPE SNLS 10" SCH-120       ASTM A790 S32760 ANST B36.10       59 MT       8,215         PIPE SNLS 10" SCH-120       ASTM A790 S32760 ANST B36.10       54 MT       6,820         PIPE SNLS 10" SCH-120       ASTM A790 S32760 ANST B36.10       54 MT       6,435         PIPE SNLS 10" SCH-120       ASTM A790 S32760 ANST B36.10       54 MT       8,130         PIPE SNLS 10" SCH-120       ASTM A790 S32760 ANST B36.10       57 MT       8,135         PIPE SNLS 10" SCH-120       ASTM A790 S32760 ANST B36.10       57 MT       8,135         PIPE SNLS 10" SCH-120       ASTM A790 S32760 ANST B36.10       57 MT       8,135         PIPE SNLS 10" SCH-120       ASTM A790 S32760 ANST B36.10       57 MT       8,135         PIPE SNLS 10" SCH-120       ASTM A790 S32760 ANST B36.10       57 MT       8,136         PIPE SNLS 10" SCH-120	NO : 052185 NO : 052185	H100000243 H100000243 H100000245 H100000245 H100000245 H100000245 H100000248 H100000248 H100000248 H100000250 H100000250 H100000250
ATM AND STATO MARE INST: 0       W. W. L. S. W. WOOK NO 102118       1       0333       H1000021         STM AND STATO MARE INST: 0       W. W. WOOK NO 102118       1       0333       H1000021         STM AND STATO MARE INST: 0       W. W. WOOK NO 102118       1       0333       H1000021         STM AND STATO MARE INST: 0       W. W. WOOK NO 102118       1       0333       H1000021         STM AND STATO MARE INST: 0       W. W. WOOK NO 102118       1       0334       H1000021         STM AND STATO MARE INST: 0       W. W. WOOK NO 102118       1       0334       H1000021         STM AND STATO MARE INST: 0       W. W. WOOK NO 102118       1       0334       H1000021         STM AND STATO MARE INST: 0       W. W. WOOK NO 102118       1       0334       H1000021         STM AND STATO MARE INST: 0       W. W. WOOK NO 102118       1       0334       H1000021         STM AND STATO MARE INST: 0       W. W. WOOK NO 102118       1       0334       H1000021         STM AND STATO MARE INST: 0       W. WOOK NO 102118       1       1       0334       H1000021         STM AND STATO MARE INST: 0       W. WOOK NO 102118       1       1       0334       H1000021         STM AND STATO MARE INFOLUNCINSTANDING STATO MARE INFOLUNCING STATO	PITE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1046 MT6,850PITE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1048 MT5,230PITE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1048 MT5,230PITE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1050 MT8,215PITE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1051 MT7,885PITE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1051 MT7,885PITE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1053 MT8,920PITE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1054 MT8,135PITE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1057 MT8,135PITE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1057 MT8,135PITE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1057 MT8,135PITE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1059 MT8,270PITE SMLS 10" SCH-120ASTM A790 S32760 ANST B	NO : 052185 NO : 052185	H100000243 H100000243 H100000245 H100000245 H100000245 H100000248 H100000248 H100000248 H100000250 H100000250 H100000250
Ref         State         S	PIPE SMLS       IO°       SCH-120       ASTM       ATYO       SST (0)       SCH-120       SCH       SCH <td>NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185</td> <td>H100000245 H100000245 H100000245 H100000248 H100000248 H100000248 H100000248 H100000250 H100000250 H100000250</td>	NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185	H100000245 H100000245 H100000245 H100000248 H100000248 H100000248 H100000248 H100000250 H100000250 H100000250
Rev         Norward         Screen         Scren         Scren         Scren	PITESMLSIOOCHIO <thi< td=""><td>NO : 052185 NO : 052185</td><td>H100000245 H100000245 H100000248 H100000248 H100000248 H100000250 H100000250 H100000250</td></thi<>	NO : 052185 NO : 052185	H100000245 H100000245 H100000248 H100000248 H100000248 H100000250 H100000250 H100000250
<pre>ser // reside and list in the control of the c</pre>	PIPE SMLS 10° SCH-120       ASTM A790 S32760 ANST B36.10       51 MT       7,885         PIPE SMLS 10° SCH-120       ASTM A790 S32760 ANST B36.10       53 MT       8,020         PIPE SMLS 10° SCH-120       ASTM A790 S32760 ANST B36.10       53 MT       8,020         PIPE SMLS 10° SCH-120       ASTM A790 S32760 ANST B36.10       54 MT       8,020         PIPE SMLS 10° SCH-120       ASTM A790 S32760 ANST B36.10       54 MT       8,435         PIPE SMLS 10° SCH-120       ASTM A790 S32760 ANST B36.10       57 MT       8,435         PIPE SMLS 10° SCH-120       ASTM A790 S32760 ANST B36.10       57 MT       8,435         PIPE SMLS 10° SCH-120       ASTM A790 S32760 ANST B36.10       59 MT       8,270         PIPE SMLS 10° SCH-120       ASTM A790 S32760 ANST B36.10       59 MT       8,270         PIPE SMLS 10° SCH-120       ASTM A790 S32760 ANST B36.10       59 MT       8,270         PIPE SMLS 10° SCH-120       ASTM A790 S32760 ANST B36.10       59 MT       8,270         PIPE SMLS 10° SCH-120       ASTM A790 S32760 ANST B36.10       59 MT       8,270         PIPE SMLS 10° SCH-120       ASTM A790 S32760 ANST B36.10       59 MT       8,270         PIPE SMLS 10° SCH-120       ASTM A790 S32760 ANST B36.10       59 MT       8,270         PIPE SMLS 10° SCH-100	NO : 052185 NO : 052185	H10000245 H10000248 H10000248 H100000248 H100000248 H100000250 H100000250
SEM A70 55206 NRT B6:10         2 MT         6,100         04347         H100000245           SEM A70 55206 NRT B6:10         5 MT         6,100         04347         H100000245           SEM A70 55206 NRT B6:10         5 MT         6,100         04347         H100000245           SEM A70 55206 NRT B6:10         5 MT         6,100         052185         1         04347         H100000245           SEM A70 55206 NRT B6:10         5 MT         6,130         WE         6,130         WE         6,130         04347         H100000245           SEM A70 55206 NRT B6:10         5 MT         8,130         WE         6,130         WE         6,130         04347         H100000245           SEM A70 52206 ART B6:10         5 MT         8,170         WE         8,170         WE         04347         H10000245           SEM A70 52206 ART B6:10         5 MT         8,170         WE         8,170         WE         441         4	FIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1052 MT8,020PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1053 MT8,190PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1054 MT8,135PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1055 MT8,185PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1055 MT8,435PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1057 MT8,435PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1057 MT8,435PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1059 MT8,270PIPE SMLS 10.00,01600,58000,00020,49007,00002,4400PICE SCH0,01600,02600,00020,47007,03002,44000,2490PICE SCH	NO : 052185 NO : 052185 NO : 052185 NO : 052185 NO : 052185 NO : 052185 NO : 052185	H100000245 H100000248 H100000248 H100000250 H100000250 H100000250
ABSW AP00 S22760 ANST B34.10         54 PM         5.325         VERDOR NO         052165         1         0434         F10000248           ABSW AP00 S22760 ANST B34.10         54 PM         5.325         VERDOR NO         052165         1         0434         F10000248           ASW AP00 S22760 ANST B34.10         56 PM         8.325         VERDOR NO         052165         1         0434         F10000248           ASW AP00 S22760 ANST B34.10         56 PM         8.327         VERDOR NO         052185         1         0434         F10000248           ASW AP00 S22760 ANST B34.10         56 PM         8.270         VERDOR NO         052185         1         0434         F10000248           ASW AP00 S22760 ANST B34.10         56 PM         8.270         VERDOR NO         052185         1         0434         F10000248           ASW AP00 S22760 ANST B34.10         56 PM         8.270         VERDOR AP00024         F10000226         F10000226 </td <td>PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1053 MT8,190PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1054 MT8,325PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1055 MT8,435PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1057 MT8,435PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1057 MT8,435PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1057 MT8,270PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1059 MT8,270PIPE SMLS 10" SCH-120SSH 78,2705,25005,500PIPE SMLS 10.0,01500,01600,02600,00020,47007,0000PIPE SML0,01400,51000,02000,47007,03002,4400PIPE SMLS0,01400,5100<!--</td--><td>NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185</td><td>H10000248 H10000248 H10000248 H10000250 H10000250 H10000250</td></td>	PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1053 MT8,190PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1054 MT8,325PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1055 MT8,435PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1057 MT8,435PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1057 MT8,435PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1057 MT8,270PIPE SMLS 10" SCH-120ASTM A790 S32760 ANST B36.1059 MT8,270PIPE SMLS 10" SCH-120SSH 78,2705,25005,500PIPE SMLS 10.0,01500,01600,02600,00020,47007,0000PIPE SML0,01400,51000,02000,47007,03002,4400PIPE SMLS0,01400,5100 </td <td>NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185</td> <td>H10000248 H10000248 H10000248 H10000250 H10000250 H10000250</td>	NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185 NO: 052185	H10000248 H10000248 H10000248 H10000250 H10000250 H10000250
ASTM 7790 532766 ANST 36:10         5 MT         6.135         1         04334         HI0000243           ASTM 7790 537766 ANST 36:10         5 MT         6.135         VEXDOR NO: 052185         1         04334         H10000245           ASTM 7790 537266 ANST 36:10         5 MT         6.135         VEXDOR NO: 052185         1         04334         H10000245           ASTM 7790 537266 ANST 36:10         5 MT         6.135         VEXDOR NO: 052185         1         04334         H10000245           ASTM 7790 53726 ANST 36:10         5 MT         6.135         VEXDOR NO: 052185         1         04334         H10000245           ASTM 7790 53766 ANST 36:10         5 MT         6.135         05216         4.135         04334         H10000245           ASTM 0.0002 0.5400 7.5000 2.5400 3.6500 0.5500 0	PIPE SMLS 10" SCH-120       ASTM A790 S32760 ANSI B36.10       54 MT       8,435         PIPE SMLS 10" SCH-120       ASTM A790 S32760 ANSI B36.10       57 MT       8,435         PIPE SMLS 10" SCH-120       ASTM A790 S32760 ANSI B36.10       57 MT       8,185         PIPE SMLS 10" SCH-120       ASTM A790 S32760 ANSI B36.10       57 MT       8,185         PIPE SMLS 10" SCH-120       ASTM A790 S32760 ANSI B36.10       59 MT       8,270         PIPE SMLS 10" SCH-120       ASTM A790 S32760 ANSI B36.10       59 MT       8,270         PIPE SMLS 10" SCH-120       ASTM A790 S32760 ANSI B36.10       59 MT       8,270         MICAL COMPOSITION       ASTM A790 S32760 ANSI B36.10       59 MT       8,270         MICAL COMPOSITION       C % MN % F % S1 % Ni % C % MO % N %       8,270         MICAL COMPOSITION       0,0160 0,0250 0,0002 0,4300 7,0000 25,430 3,6400 0,2490       0,2490         0 0.0160 0,5800 0,0220 0,0002 0,5000 6,9600 25,410 3,6500 0,2440       0,2490       0,2490         0 0.0140 0,5100 0,0260 0,0002 0,5000 7,0200 25,410 3,6500 0,2540       0,2490       0,2550         0 0.0140 0,5100 0,0260 0,0002 0,5000 7,0200 24,400 3,6500 0,2610       0,0140 0,5100 0,0260 0,0003 0,5000 7,0200 25,470 3,6500 0,2610       0,2490         10 0,0140 0,5100 0,0260 0,0003 0,5000 7,0200 24,400 3,6500 0,2550       1400       1400       1400 <td>NO : 052185 NO : 052185 NO : 052185 NO : 052185 NO : 052185</td> <td>H10000248 H10000248 H10000250 H100000250 H100000250</td>	NO : 052185 NO : 052185 NO : 052185 NO : 052185 NO : 052185	H10000248 H10000248 H10000250 H100000250 H100000250
ASTM A790 532766 ANET B6.10         57 m         6,435 bit M10000243         A10000243         A10000244 bit M10000244           ASTM A790 532766 ANET B6.10         57 m         6,435 bit M10000245         1,435 bit M10000245         0,434 bit M10000245           ASTM A790 532766 ANET B6.10         57 m         6,270 VENDOR NO : 052165         1,135 bit M10000245         0,434 bit M10000245           ASTM A790 532766 ANET B6.10         59 m         6,270 VENDOR NO : 05216         1,135 bit M10000245         0,434 bit M10000245           ASTM A790 532766 ANET B6.10         59 m         8,270 VENDOR NO : 05216         1,435 bit M10000245         0,434 bit M10000245           0,0250 0,0002 0,5200 6,5400 0,5500 0,1550         M10000244           0,0260 0,0003 0,5000 7,000 2,5000 0,5500 0,5500 0,5500 0,550 0,550 0,5500 0,550 0,550 0,5500 0,550 0,500 0,550 0,1500 0,550 0,550 0,500 0,550 0,50	PIPE SMLS 10" SCH-120ASTM A790 S32760 ANSI B36.1055 MT8,435PIPE SMLS 10" SCH-120ASTM A790 S32760 ANSI B36.1055 MT8,185PIPE SMLS 10" SCH-120ASTM A790 S32760 ANSI B36.1059 MT8,270PIPE SMLS 10" SCH-120ASTM PF *Si *Ni *8,270PIPE SMLS 10" SCH-120ASTM PF *Si *Si *8,270PIPE SMLS 10" SCH-120Origio 0,0250 0,0022 0,4700 7,0300 25,470 3,6400 0,25400,2490PIPE SMLS 10" SCH 0,5000 0,0250 0,0002 0,5000 7,0200 25,470 3,6500 0,256014600PIPE SMLS 10" SCH 0,5000 0,0260 0,0003 0,5000 7,0200 24,400 3,6500 0,25501460PIPE SMLS 10" SCH 0,5000 0,0260 0,0003 0,5000 7,0200 24,400 3,6500 0,25501467PIPE SML 10" SCH 0,5000 0,0260 0,0003 0,5000 7,0200 24,400 3,6500 0,2550<	NO : 052185 NO : 052185 NO : 052185 NO : 052185	H10000248 H10000250 H10000250 H10000250
Active Note 53:2766         Mail         R.185         Mail          Mail         Mail<	preprintmultipleasyme A790 signed ANST B36.1057 MT8,185PreprintNUSSCH-120ASTM A790 signed ANST B36.1059 MT8,270PreprintNUSSCH-120ASTM A790 signed ANST B36.1059 MT8,270PreprintNUSSCH-120ASTM A790 signed ANST B36.1059 MT8,270MICALCOMPOSITIONASTM A790 signed ANST B36.1059 MT8,270MICALO,01600,55000,00220,49007,000025,5003,670000,011600,50000,02500,00020,44007,030025,5003,650000,011400,51000,02600,00030,50007,020024,4003,65000,251000,011400,51000,02600,00030,50007,020024,4003,65000,251010,011400,51000,02600,00030,50007,020024,4003,65000,251010,011400,51000,02600,00030,50007,020024,4003,65000,251010,01400,51000,02600,00030,50007,020024,4003,65000,250	NO : 052185 NO : 052185 NO : 052185	H100000250 H100000250
p1       s1       N14       Cr h       No1       No	PIPE SMLS 10" SCH-120       ASTM A790 532760 ANSI B36.10       59 MT       6,270         PIPE SMLS 10" SCH-120       ASTM A790 532760 ANSI B36.10       59 MT       6,270         MICAL COMPOSITION       ASTM A790 532760 ANSI B36.10       59 MT       8,270         MICAL COMPOSITION       ASTM A790 532760 ANSI B36.10       59 MT       8,270         MICAL COMPOSITION       ASTM A790 532760 ANSI B36.10       59 MT       8,270         0,0160 0,5500 0,0250 0,0002 0,4900 7,0000 25,500 3,6700 0,2450       0,2450       0,2450         0 0,0150 0,0000 0,0260 0,0002 0,4900 7,0300 25,470 3,6500 0,2540       0,2490       0,2540         0 0,0140 0,5100 0,0260 0,0002 0,4700 7,0300 25,470 3,6500 0,2540       0,2490       0,2610         0 0,0140 0,5100 0,0260 0,0003 0,5000 7,0200 24,400 3,6500 0,2560       0,2610       0,2610         1 0,0140 0,5100 0,0260 0,0003 0,5000 7,0200 24,400 3,6500 0,2550       0,2610       0,2610         1 0,0140 0,5100 0,0260 0,0003 0,5000 7,0200 24,400 3,6500 0,2550       0,2610       0,2610         1 0,0140 0,5100 0,0260 0,0003 0,5000 7,0200 24,400 3,6500 0,2550       0,2610       0,2610         1 0,0140 0,5100 0,0260 0,0003 0,5000 7,0200 24,400 3,6500 0,2250       0,2610       0,2610         2 0,0140 0,5100 0,0260 0,0003 0,5000 7,0200 24,400 3,6500 0,2250       0,2610       0,2610         2 0,071403       0,0003	NO : 052185 NO : 052185	H100000250
F & S & Si & Mi & Cr & Mo & N & Cu & M & Pre &           0.02250         0.0002         0.5200         0.5500         0.500         0.500         <	ON n % P % Si % Ni % Cr % Mo % N % 5500 0,0250 0,0002 0,4900 7,0000 25,500 3,6700 0,2450 5800 0,0250 0,0002 0,4900 7,0000 25,470 3,6400 0,2490 5000 0,0260 0,0002 0,4700 7,0300 25,470 3,6400 0,2490 5000 0,0240 0,0003 0,5000 7,0300 25,500 3,6500 0,2550 5100 0,0260 0,0003 0,5000 7,0200 24,400 3,6500 0,2550 fils : Solution annealing at 1100°C. Holding Time:2 mi tils : Solution annealing at 1100°C. Holding Time:2 mi tils : Solution annealing at 1100°C. Holding Time:2 mi see to water less than 60 seconds. Toron Steel Making Process: El. Furnace + AOD, see att 2007/1891, 2007/2264, 2007/2265.	2	
P #         S #         Ni #         Cr #         N #         Pre # </td <td><pre>MICAL COMPOSITION</pre></td> <td></td> <td></td>	<pre>MICAL COMPOSITION</pre>		
P         R         S         N	C %         Mn %         F %         S %         Si %         Ni %         Cr %         Mo %         Ni %           0,0160         0,5500         0,0250         0,0002         0,5900         3,6400         3,5400         0,2530           0,0160         0,5800         0,0250         0,0002         0,5200         5,500         3,6400         0,2530           0,0150         0,6000         0,0260         0,0002         0,4700         7,430         3,6400         0,2490           0,0140         0,5000         0,0260         0,0002         0,4700         7,0300         25,500         3,6500         0,2550           0,0140         0,5100         0,0260         0,0003         0,5000         7,0300         25,500         3,6500         0,2550           ARKS              0,2610         0,2550           ARKS                0,2550           ARKS		
0.0220 0.0002 0.9200 5.900 0.5500 0.5500 0.5500 0.5500 0.5500 0.5500 0.5500 0.5500 0.5200 0.2200 0.2200 0.2200 0.5500 0.5200 0.5200 0.5200 0.5200 0.5200 0.5200 0.5200 0.5500	0,0166 0,5500 0,0250 0,0002 0,4900 7,900 25,470 3,6400 0,2530 0,0160 0,5800 0,0230 0,0002 0,5900 0,25470 3,6400 0,2530 0,0150 0,6000 0,0240 0,0002 0,5000 6,9500 25,470 3,6900 0,2490 0,0140 0,5100 0,0240 0,0003 0,5000 7,0300 25,500 3,6500 0,2490 0,0140 0,5100 0,0260 0,0003 0,5000 7,0300 25,500 3,6500 0,2550 0,2610 0,0140 0,5100 0,0260 0,0003 0,5000 7,0200 24,400 3,6500 0,2550 eat Treatment details : Solution annealing at 1100°C. Holding Time:2 mi aw Material: by Foroni Steel Making Process: El. Furnace + AOD, see att 7/1852, 2007/1853, 2007/1891, 2007/2264, 2007/2265.		
0.0256         0.0002         0.5000         6.500         5.500         0.5000         0.5000         1.500           0.0266         0.0003         0.5000         7.000         2.500         0.5000         41.500           0.0266         0.0003         0.5000         7.000         0.5500         0.5500         0.5500         41.500           0.0003         0.5000         7.000         2.500         0.5500         0.5500         0.5500         41.500           0.0003         0.5000         7.000         2.500         0.5500         0.5500         41.530           0.0003         0.5000         7.000         2.550         0.5500         0.5500         41.530           0.0003         0.5000         7.000         2.550         0.5400         0.5500         41.530           0.0003         0.5000         7.000         5500         0.7400         0.7530         0.7400           1591         2007/2264         074457         074441         074442         074230           10.072306         0742307         0742364         0742304         0742304         074230           0712307         0742308         0742310         0742309         0742312         0742307	ARKS 0,0150 0,6000 0,0260 0,0002 0,5000 6,5600 25,430 3,6900 0,2490 0,0140 0,5000 0,0240 0,0003 0,5000 7,0300 25,500 3,6300 0,2610 0,0140 0,5100 0,0240 0,0003 0,5000 7,0200 24,400 3,6500 0,2550 arKS ext Treatment details : Solution annealing at 1100°C. Holding Time:2 mi ext Trime from furnace to water less than 60 seconds. 7/1852, 2007/1853, 2007/1891, 2007/2264, 2007/2265. 7/1852, 2007/1853, 2007/1891, 2007/2264, 2007/2265. 0,0794845.	0.6400	
0,0240 0,0002 0,4700 7,0300 25,500 3,6300 0,2510 0,5300 0,6400 41,660 0,0260 0,0003 0,4700 7,0300 25,500 3,6500 0,2550 0,5400 0,6500 41,530 s Solution annealing at 1100°C. Holding Time:2 min/mm Quenching in s solution annealing at 1100°C. Holding Time:2 min/mm Quenching in c water less than 60 seconds. Steel Making Process: El. Purmace + AOD, see attached Certificate n° 0,031, 2007/2264, 2007/2265. T.O.S.I." reports n° 07P4679, 07P4680, 07P4841, 07P4842, in metallographic determination according procedure ASTM E562 see 0712307, 07H2309, 07H2311, 07H2368 to 07H2370, 07H2309, 07H2377, 07H2309, 07H2311, 07H2368 to 07H2372 . St according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, 07H2377, 07H2399, 07H2390, 07H2390, 07H2377, 07H2399, 07H2390, 07H2377, 07H2399, 07H2390, 07H2377, 07H2399, 07H2390, 07H2377, 07H2399, 07H2390, 07H2377, 07H2399, 07H2391, 07H2377, 07H2399, 07H2391, 07H2377, 07H2399, 07H2391, 07H2377, 07H2399, 07H2390, 07H2377, 07H2399, 07H2390, 07H2377, 07H2396, 07H2390, 07H2377, 07H2377, 07H2390, 07H2377, 07H2396, 07H2390, 07H2377, 07H2377, 07H2390, 07H2377, 07H2396, 07H2390, 07H2377, 07H2396, 07H2390, 07H2377, 07H2396, 07H2390, 07H2377, 07H2396, 07H2390, 07H2377, 07H2377, 07H2377, 07H2377, 07H2377, 07H2377, 07H2377, 07H2377, 07H2377, 07H2377, 07H2377, 07H2377, 07H2377, 07H2377, 07H2377, 07H2377, 07H2377, 07H2377, 07H247,	ARKS 0,0140 0,5000 0,0240 0,0002 0,4700 7,0300 25,500 3,6300 0,2610 0,0140 0,5100 0,0240 0,0003 0,5000 7,0200 24,400 3,6500 0,2550 arks eat Treatment details : Solution annealing at 1100°C. Holding Time:2 mi er. Time from furnace to water less than 60 seconds. 7/1852, 2007/1853, 2007/1891, 2007/2264, 2007/2265. 7/84576, 07P4676, 07P4679, 07P4680, 4843, 07P4845.	0,6500	~
<pre>0,0256 0,0003 0,5000 7,0200 24,400 3,6500 0,2550 0,5400 0,6500 41,530 1 Solution annealing at 1100°C. Holding Time:2 min/mm Quenching in 0 water these than 60 seconds. 1 See attached Certificate n° 1 and these that 0 seconds. 1 and the process: El. Furnace + ADD, see attached Certificate n° 1 and the process: El. Furnace + ADD, see attached Certificate n° 1 and the process: El. Furnace + ADD, see attached Certificate n° 1 and the process: El. Furnace + ADD, see attached Certificate n° 1 and the process: El. Furnace + ADD, see attached Certificate n° 1 and the process: El. Furnace + ADD, see attached Certificate n° 1 and the process: El. Furnace + ADD, see attached Certificate n° 1 and the process: El. Furnace + ADD, see attached Certificate n° 1 and the process: El. Furnace + ADD, see attached Certificate n° 1 and dimensional inspections in compliance with IBF Purchaser's authorized inspection representative Purchaser's authorized inspection represe</pre>	ARKS 0,0140 0,5100 0,0260 0,0003 0,5000 7,0200 24,400 3,6500 0,2550 eat Treatment details : Solution annealing at 1100°C. Holding Time:2 mi er. Time from furnace to water less than 60 seconds. aw Material: by Foroni Steel Making Process: El. Furnace + AOD, see att 7/1852, 2007/1853, 2007/1891, 2007/2264, 2007/2265. or Mechanical test see "T.O.S.I." reports n° 0774676, 0774679, 0774680, 4843, 0774845.	0.6400	<i>c i i i i i i i i i i</i>
<pre>: Solution annealing at 1100°C. Holding Time:2 min/mm Quenching in o water less than 60 seconds. Steel Making Process: El. Furnace + AOD, see attached Certificate n° (1891, 2007/2264, 2007/2265. "T.O.S.I." reports n° 0794676, 07P4679, 07P4841, 07P4842, "T.O.S.I." reports n° 0794676, 07P4679, 07P4841, 07P4842, ortalographic determination according procedure ASTM E562 see st according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, 07H2377, 07H2379, 07H2380. st according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, 07H2377, 07H2379, 07H2380. st according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, of a according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, of a according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, of a according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, of a according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, of a according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, of a according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, of a according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, of a according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, of a according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, of a according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, of a according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, of a according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, of a according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, tescope Fischer: satisfactory ed visual and dimensional inspections in compliance with IBF profile regulations</pre>	0°C. Holding Time:2 mi urnace + AOD, see att 76, 07P4679, 07P4680,	0,6500	BRS/0/A
<pre>: Solution annealing at 1100°C. Holding Time:2 min/mm Quenching in o water less than 60 seconds. Steel Making Process: B1. Furnace + AOD, see attached Certificate n° /1891. 2007/2264. 2007/2265. /1801. 2007/2265. 2007/2265. /1801. 2007/2265. 07P4676, 07P4680, 07P4841, 07P4842, in metallographic determination according procedure ASTM E562 see 07H2377, 07H2308, 07H2361, 07H2368 to 07H3372. st according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, 07H2377, 07H2399, 07H2380. STM E213 (V NOTCH DIMENSIONS 5% WTh Max. 1.5mm ): satisfactory. tescope Fischer: satisfactory ed visual and dimensional inspections in compliance with IBF Purchaser's authorized inspection representative</pre>	0°C. Holding Time:2 mi urnace + AOD, see att 76, 07P4679, 07P4680,		R ANA WARE COUNTY
<pre>: Solution annealing at 1100°C. Holding Time:2 min/mm Quenching in o water less than 60 seconds. Steel Making Process: El. Furnace + AOD, see attached Certificate n° Steel Making Process: El. Furnace + AOD, see attached Certificate n° '1891, 2007/2264, 2007/2265. "T.O.S.I." reports n° 07P4676, 07P4679, 07P4680, 07P4841, 07P4842, "T.O.S.I." reports n° 07P4676, 07P4679, 07P4680, 07P4841, 07P4842, ion metallographic determination according procedure ASTM E562 see 07H2307, 07H2308, 07H2311, 07H2368 to 07H2372. st according ASTM dae Met.A, see "T.O.S.I." test report n° 07H2309, 07H2377, 07H2379, 07H2380. St according ASTM damet.A, see "T.O.S.I." test report n° 07H2309, cofficient of the DIMENSIONS 5% WTh Max. 1.5mm ): satisfactory. tescope Fischer: satisfactory ed visual and dimensional inspections in compliance with IBF Purchaser's authorized inspection representative [Inspector designated by the official regulations]</pre>	0°C. Holding Time:2 mi urnace + AOD, see att 76, 07P4679, 07P4680,		O INSPECTOD
<pre>o water less than 60 seconds. Steel Making Process: El. Furnace + AOD, see attached Certificate n° /1891, 2007/2264, 2007/2265, 07P4679, 07P4680, 07P4841, 07P4842, "T.O.S.I." reports n° 07P4676, 07P4679, 07P4680, 07P4841, 07P4842, ion metallographic determination according procedure ASTM E562 see 07H2307, 07H2308, 07H2311, 07H2368 to 07H2372 . st according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, 07H2377, 07H2379, 07H2380. STM E213 ( V NOTCH DIMENSIONS 5% WTh Max. 1.5mm ): satisfactory. tescope Fischer: satisfactory ed visual and dimensional inspections in compliance with IBF</pre>	urnace + AOD, see att 76, 07P4679, 07P4680,	Quenching	
Steel Making Process: ELL Furnace + AUD, see attached Certificate No. 11891, 2007/2264, 2007/2265. "T.O.S.I." reports n° 0774676, 0774679, 0774680, 0774841, 0774842, ion metallographic determination according procedure ASTM E562 see 0772307, 0772308, 07742311, 0772368 to 0772372 . st according ASTM G48 Met.A, see "T.O.S.I." test report n° 0772309, 0772377, 0772379, 0772380. STM E213 ( V NOTCH DIMENSIONS 5% WTh Max. 1.5mm ): satisfactory. tescope Fischer: satisfactory ed visual and dimensional inspections in compliance with IBF Purchaser's authorized inspection representative	urnace + AOD, see au 76, 07P4679, 07P4680,	, , , , , , , , , , , , , , , , , , ,	+ orthon
<pre>"T.0.5.1." reports n° 0774676, 0774679, 0774680, 0774841, 0774842, "T.0.5.1." reports n° 0774676, 0774679, 0774680, 0774841, 0774842, ion metallographic determination according procedure ASTM E562 see 0742307, 0742308, 0742341, 0742368 to 0742372 . 0742377, 0742379, 0742380. STM E213 ( V NOTCH DIMENSIONS 5% WTh Max. 1.5mm ): satisfactory. tescope Fischer: satisfactory ed visual and dimensional inspections in compliance with IBF Purchaser's authorized inspection representative</pre>	76, 07P4679, 07P4680,	rertiticate	
<pre>ion metallographic determination according procedure ASTM E562 see 07H2307, 07H2308, 07H2311, 07H2368 to 07H2372 . st according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, 07H2377, 07H2379, 07H2380. STM E213 ( V NOTCH DIMENSIONS 5% WTh Max. 1.5mm ): satisfactory. tescope Fischer: satisfactory ed visual and dimensional inspections in compliance with IBF Purchaser's authorized inspection representative</pre>			
<pre>ion metallographic determination according procedure ASTM E562 see 07H2307, 07H2308, 07H2311, 07H2368 to 07H2372 . st according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, 07H2377, 07H2379, 07H2380. STM E213 ( V NOTCH DIMENSIONS 5% WTh Max. 1.5mm ): satisfactory. tescope Fischer: satisfactory ed visual and dimensional inspections in compliance with IBF Purchaser's authorized inspection representative</pre>			
07H2307, 07H2308, 07H2311, 07H2368 to 07H2372 . st according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, 07H2377, 07H2379, 07H2380. STM E213 ( V NOTCH DIMENSIONS 5% WTh Max. 1.5mm ): satisfactory. tescope Fischer: satisfactory ed visual and dimensional inspections in compliance with IBF ed visual and dimensional inspections in compliance with IBF	4) For Ferrite volume fraction metallographic determination according procedure	E562	
st according ASTM G48 Met.A, see "T.O.S.I." test report n° 07H2309, 07H2377, 07H2379, 07H2380. STM E213 ( V NOTCH DIMENSIONS 5% WTh Max. 1.5mm ): satisfactory. tescope Fischer: satisfactory ed visual and dimensional inspections in compliance with IBF Purchaser's authorized inspection representative	5.		
07H2377, 07H2379, 07H2380. STM E213 ( V NOTCH DIMENSIONS 5% WTh Max. 1.5mm ): satisfactory. tescope Fischer: satisfactory ed visual and dimensional inspections in compliance with IBF Purchaser's authorized inspection representative	test	oort n° 07H2309,	
tescope Fischer: satisfactory ed visual and dimensional inspections in compliance with IBF Purchaser's authorized inspection representative	7H23I0、07H23I4、07H2376、07H2377、07H2379、07H2349。 THT ついいせんかいたいついていた たいれたTHT P213 ( VI NOTCH DIMENSIONS 5% WTh Max 1、5mm ):	satisfactory.	
ed visual and dimensional inspections in compliance with IBF Purchaser's authorized inspection representative	Ferrite cheched by Ferritescope Fischer: satisfactory		
Purchaser's authorized inspection representative	All pipes have been passed visual and dimensional inspections in compliance	ЦВ	
Purchaser's authorized inspection representative	Procedure IO-05.01		
			w the official requilations

BER 9A.	9) The pipes are in white pickled and passivated condition. 10) No weid repairs have been performed. 11) Futtening test: Passed 11) Aztrening test: Passed 13) AzTM A790-055 UNS 532760	05899       06/11/2007       2007000066       ASTM A790       532760       Smls       SFF       SCANDINAVIAN FITTINGS       & FL       140080       REV.02       Of         ohe immerial school and inspected and are in complance with the purchase order and relevant specification.       e pipes are in white pickled and passivated condition.       140080       REV.02       Of         ow weld repairs have been performed.       ow weld repairs have been performed.       0       weld repairs have been performed.	Purchase Order	Total a liabular line     Total a liabular line     Total a liabular line     Total a liabular line       Total a liabular line     Total a liabular line     Total a liabular line     Total a liabular line       Total a liabular line     Total a liabular line     Total a liabular line     Total a liabular line       Total a liabular
IBF's authorized inspection representative Inspection representative	t 20 t 20 t 20 t 20 t 20 t 20 t 20 t 20	THAT HUR TABLESS	Dispet         06/11/2001 200700066 MSTR 0790         033700         0.11         0579         0.11/2001 200700066         110000 000 000 000 000 000           minimum section manual mean mean mean mean mean mean mean mean	(17/0 t

IND MATERIAL TEST REPORT Inspection certificate EN 10204-3.1 March 20070014 March 2007014 March 4 March 20070014 March 2007014 March 4 March 200700242 + Draw conference 20070014 March 4 March 20070014 March 20070014 March 20070014 March 4 March 20070014 March 20070014 March 20070014 March 4 March 20070014 March 20070014 March 4 March 20070014 March 2007014 March 20070014 March 20070014 March 20070014	Ì			Ber identification:	Other properties Results:				ACTU CAR Method A (50°C x 24h) Parsed (Test n° 5104)	Passed			5104 & 510	Microstructure test to ASTM E407 etchant #98: free from intermetallic pliases and programmer and			Barrand	012		Passed		and the second	ですがというまででもった	RANTO	IBF Spp.A.	la halan	July 10F	the state of the second conceptions apply in the latest edition.	Unless otherwise stated, issue of the S.C.O. Department R.S.O. Inspector		H. Gallina 400	
CERTIFIED MA	Denvery condition:		Description:			Specification	Grain size	Ferrite content to ASTM E662		Corrosion test to				<sup>1</sup> Microstructure test to ASTM E4	Inclusional content			IT to ASTM A745		Visual check	Dimensional check	Fatigue testing						י : :			uality	
			и <sup>а</sup> :			5105 -	566 1	<u>с</u>	8	TRV	483		Ş			1	S.	   -+												No welds, no mercury and radioactive contamination.	f according to the Quality	
			сп			5105	–		S. 30 mm B.S	TRV	604 604				262	7		LNG.	- -2 -7 -7 -7 -7 -7 -7 -7 -7 -7 -7 -7 -7 -7	136	152									and redioac	ei produced	
			Lot n*:				See		5. 30 mm B.S.		121 496			69.0		-+	Ś	 	-+-									_		o mercury	ons. Materi	Sell-N-d-A
E.			Lot			5104 -	-	remarks	30 mm B.S.	TRV	20	-	+ †	40 35,3 67,3	$\left  \right $	2	8	LNG	9 <b>4</b>	132	126					· ·	a		2	o weldis, n	specificati	e FORDNI
		only).		L		There of					0 0 0			88	÷	L-	DAH Da		ပ္ ပ		<b>)</b> 		E	+	* 	S. S.	Ē		Ĕ		ntioned -	ibed in th
· ·		a (chemistry	Hoat Treatment:					Type	Daption	Direction	ě	- - 	U.T.S.	Elongation	in in included	Laroness	as delivered Position	Direction	Temperature			t of and	expansion	W)	Shear	Temperature	Deog D	Loed Increm		-	e with the m	System described in the FORONI 2.p.A. mod menuer.
ORONI S.p./ 21068 Gode Minore (VA) Marke	<b>customer 19</b> F 8PA <b>Meterial:</b> F55, UNS 532760.	Specifications: ASTM A479-06a (chemistry only).	0.1235	000	Bteel making process: E.F./A.O.D.	Chemical analys	% w Heat Product	MN 0,58 0	0,52 V		3,64 V	0,0002 V	0.55 V	0,253	W 0,64																The material is in compliance with the mentioned specifications. Material produced	System described in the FORONI 2. p.A. n



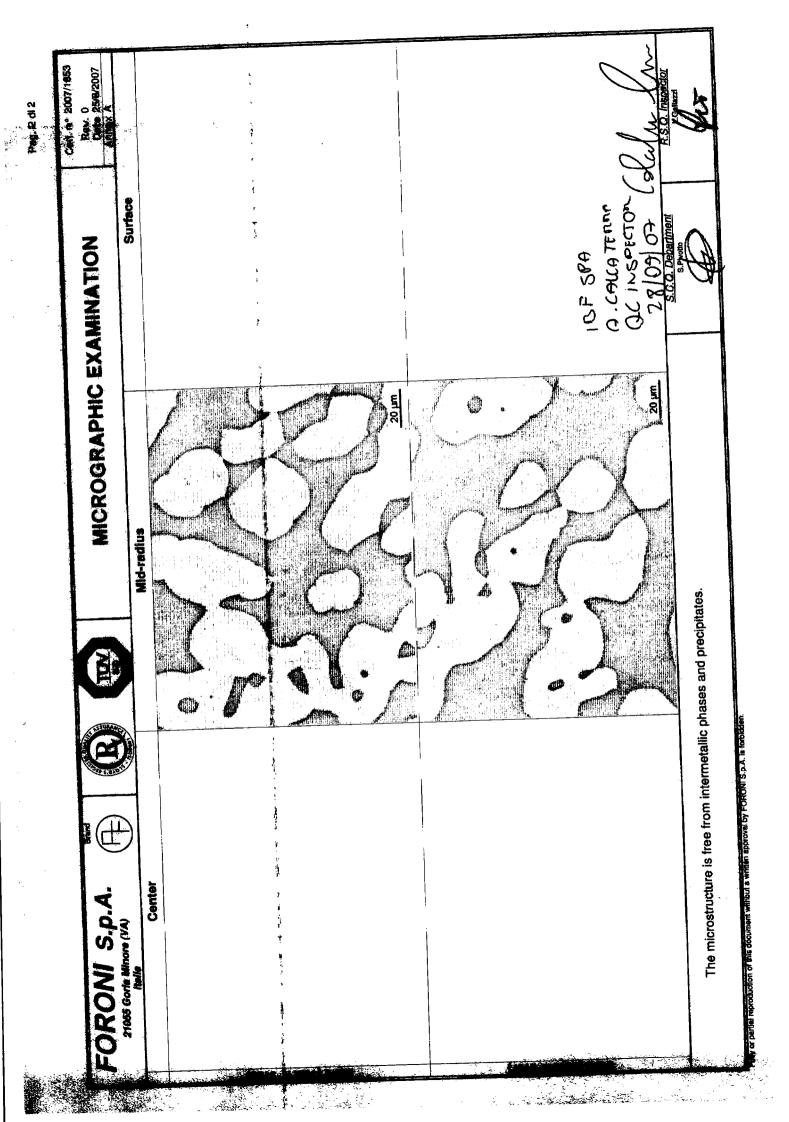
Common S.O.A.         Common S.O.A.         Inspection continuent of the section continuent of the sectin continuent of the section contintent of the section c	RONI S.p.A.       Instant       Instant </th <th></th> <th>CTT n*:     E407       97     - 6407       96     1 see       18.5     30 mm B.S.       121     121       10     121       10     121       10     121       10     121       10     121       10     121       10     121       10     121</th> <th>Inspection escription: bund bar N° of pleces Weight 2 2 2 Ferrite content to AST Corrosion test to AST</th> <th>M Certificate EN 10204-3.1 2007000242 + Order continu condition: Forgad, mill annealed and p annealed and p 273 Size 273 Size 274 Size 274</th> <th>2007/07/0114 Emoth minn Passe Passe</th>		CTT n*:     E407       97     - 6407       96     1 see       18.5     30 mm B.S.       121     121       10     121       10     121       10     121       10     121       10     121       10     121       10     121       10     121	Inspection escription: bund bar N° of pleces Weight 2 2 2 Ferrite content to AST Corrosion test to AST	M Certificate EN 10204-3.1 2007000242 + Order continu condition: Forgad, mill annealed and p annealed and p 273 Size 273 Size 274	2007/07/0114 Emoth minn Passe Passe
Pile         File           F55, UNG S32760.         F55, UNG S32760.           F56, UNG S32760.         ATTH A479-06a (chemistry only).           F56, UNG S32760.         ATTH A479-06a (chemistry only).           F56, UNG S32760.         ATTH A479-06a (chemistry only).           F66, UNG S32760.         ATTH A479-06a (chemistry only).           F66, UNG S32760.         ATTH A479-06a (chemistry only).           F67         Type         Load n1:           F77         F60, 13         Machtantation on the state on the	rijons: ASTM A479-06a (chemistry only). Pn° 04336 Meat Treatment: Rn° 0,0002 Meat Meat Treatment: Rn° 0,0002 Meat Meat Treatment: Rn° 0,0002 Meat Meat Treatment: Rn° 0,0002 Meat Treatment: Rn° 0,0002 Meat Meat Treatment: Rn° 0,0002 Meat Meat Treatment: Rn° 0,0002 Meat Treatment: Rn°		9: 6407 1 see 1 see 1 RV 1 121 121 121 121 121 121 121 1	Deliver Deliver Tiess to n test to	2	Pass
Print         Cutstantical programment:         Lot n*:         C11 n*:         R00           Ring         Processes:         E.F./A.O.D.         Macchanical programmes         6407         A           Ring         Processes:         Type         * see         * see<	ations: ASTM A479-06a (chemistry ordy). Pro- ding process: E.F.JA.O.D. emical analysis yes Position 0,015 0,0002 0,000		9. 1 see 1 see	n: 76655 t 76655 t 76655 t n lest to n lest to	Size atind A	Pass
335         Heart Treatment:         Lot n°:         Lot n°:         Data           1         Product:         Type         * set         * set         * set         * set           1         Flooduct:         Type         * set         * set <t< th=""><th>336 Heat Treatment: Broduct Treatment: Type Tooltion Position Temperature Contron</th><th></th><th>9.: 124 12407 124 121 121 121 121 121 121 121 121 121</th><th>n: 7665 + 7665 + 7665 + 7665 + 7665 + 7665 +</th><th>Size Time Sthod A</th><th>Pass Pass</th></t<>	336 Heat Treatment: Broduct Treatment: Type Tooltion Position Temperature Contron		9.: 124 12407 124 121 121 121 121 121 121 121 121 121	n: 7665 + 7665 + 7665 + 7665 + 7665 + 7665 +	Size Time Sthod A	Pass Pass
Receiver         Macchanical properties         Acchanical propertis         Acchanical properis         Acchanical	Product Teeth		* #407 - * \$407 - * see 1 * see 1 * * * * * * * * * * * * * * * * * * *	n test to	other Other	Pass
Bis         Machanical properties         5406         - 5407         <	Product Product Type Type Position Femperature C Position Temperature C MP		- 6407 - 6 1 see 1 see 30 mm B.S. 121 121 121 121 124 239,5	I test to	sthod A	Pass
Chemical analysis         Factor 1         Factor 1         Stole         - Stole	Chemical analysis         Tope         Teatn           6.w	k to to	. <b>6</b> 107 . <b>1</b> see remarks 7 30 mm B.S. 724 . <b>1</b> 21 . <b>1</b> 22 . <b>1</b> 2	I lest to	sthod A	49 % (Test n° 51 48 % (Test n° 51 Passed (Test n° 51 Passed (Test n° 51
6.4%         Type         Type         * see         *	6 w 2 y 1001 - Product - Product - Product - Type 0,0150 - 0,050 - 0,500 - 0,5	<sup>1</sup> see remarks 30 mm B.S. 121 121 491 491	<sup>1</sup> see remarks 1 30 mm B.S. TRV 121 121 475 724 40 39,5	Intent to Intest to	Method A	49 % (Test n° 510 48 % (Test n° 510 Passed: (Test n° 510 Passed (Test n° 510
Type         remarks         r	0,600         Type           0,50         0,50           0,50         Position           25,43         Position           6,96         Precision           3,69         Position           0,0002         Positive	remarks 30 mm B.S. 7RV 121 491 722	remarks 1 30 mm B.S. 121 121 475 724 40 39,5		Method A	Passed (Test n° 51 Passed (Test n° 51 Passed (Test n° 51
0.50         Positifor         30 mm B.S.         41 S         724         W         172         B         66,4         605         461         722         B         172         B         173         172         B         173         173         173         173         173         173         173         173         173         173	0,50 25,43 6,96 3,69 0,0002 0,0002 0,0002 0,0002 0,0002 0,0002 0,0002 0,0002 0,0002 0,0002 0,0002 0,0002 0,0000 0,000	30 mm B.S. TRV 121 491 491 722	30 mm B.S. TRV 121 475 724 40 39,5			i
25,43         Control         TRV         T	25,43 Position 6,96 Direction 3,69 Repetites 0,0002 Pry. 0,2% MPa	121 121 491 722 38.6	TRV 121 475 724 724			į
6,96         Emperature Temperature         °C         20         121         20         121           0,0020         0,0020         0,002         0,002         0,002         0,002         475         491         610         475           0,0200         0,0510         0,571         0,2%         MPa         803         722         818         724         W           0,0200         0,0200         0,249         MPa         803         722         818         724         W           17         Elongation         %         40         33,6         40         39,5         41         39,5         11,1 <td>6,96 66 166 166 166 166 166 166 166 166 16</td> <td>20 121 05 491 09 722 00 38.6</td> <td>121 475 724 40 39,5</td> <td></td> <td></td> <td></td>	6,96 66 166 166 166 166 166 166 166 166 16	20 121 05 491 09 722 00 38.6	121 475 724 40 39,5			
0.0000         0.00000         0.00000         0.000	0,0002 0,2%	005 491 309 722 22 40 38 6	724 724 40 39,5			
U         0,0260         72         818         724         W           U         0,051         17.5         MPa         809         722         818         724         W           0         0,050         72.6         MPa         809         722         818         724         W           0         0,059         Fencients         W         61,55         61,3         61,3         1           Re         0,65         Hardness         HRC         21         282         61,3         1           Re         0,65         HRC         21         106         106         1         1         1           Re         0,65         HRC         21         106         1         26         1         26         1         26         1		09 722 09 722	724 40 39,5	Victor avamination		
U         0.57         MPa         809         722         910         725         40         35,6         40         35,5         40         35,5         40         35,5         40         35,5         40         35,5         40         35,5         40         35,5         40         35,5         40         35,5         40         35,5         40         35,5         40         35,5         40         35,5         41,59         41         55         56         41         55         56         41         55         56         41         55         56         41         56         17         31 <td>0.0260 E Y.S. 1%</td> <td>309 /22 02 6 40 38 6</td> <td>40 39,5</td> <td>Macro examination</td> <td></td> <td></td>	0.0260 E Y.S. 1%	309 /22 02 6 40 38 6	40 39,5	Macro examination		
0.240         Ferr         Elongation         %         40         33,6         40         33,6         40         33,6         40         33,6         40         30,0         40	0.1.5.	A HE OV BOO	2			have and precipitates (Test n° 5106 & 51
No.         Control         Control <thcontrol< th=""> <thcontrol< th=""> <thcontr< td=""><td>0.37 540 540 % Elongation %</td><td></td><td>_</td><td>Microstructure test to ASTM</td><td>E407 etchant #98: free from intermetallic</td><td>phases and precipitors of the second</td></thcontr<></thcontrol<></thcontrol<>	0.37 540 540 % Elongation %		_	Microstructure test to ASTM	E407 etchant #98: free from intermetallic	phases and precipitors of the second
41.59     Hardness     HB     250     21     Inclusionial content       as convered     HC     21     anm B.S.     anm B.S.     anm B.S.     anm B.S.       Predition     100     NMB     anm B.S.     anm B.S.     anm B.S.     anm B.S.       Predition     100     NMB     anm B.S.     anm B.S.     anm B.S.     anm B.S.       Predition     100     NMB     anm B.S.     anm B.S.     anm B.S.     anm B.S.       Predition     173     188     NML check     and A.STM A745     QL2       ASTM ATAB     173     188     Dimension     and And A.STM A745     QL2       ASTM ATAB     173     188     Dimension     and And A.STM A745     QL2       ASTM ATAB     173     188     Dimension     and A	Contraction of Area	65,4	╞			
Reduced         HRC         21         30 mm B.S.         31 mm S.S.         <	41 59		202	Inclusional content		
ASTM A745 QL2 ASTM A745 QL2 Asterial not intended for use in aerospecelaircraft applications (rest on specimen solution annealed at 1100°C - W. G. removed from bar prolony i OF SPP Q.C 1/VSP FCT ON Q.C 1/VSP FCT ON Quality System Marual Misca Ed. 2003 Rev. 0 M. Sattived	Hardress					
ASTM A745 ASTM A745 Astron A745 Addental not intended for use in aerospace/alrcraft applications (rest on specimen solution annealed at 1100°C - W.G. removed from bar protony i C F S C O C I V S F C T O C I V S F C T O Unless otherwise stated, listed applications apply in the latest e Mications apply in the latest e Mications apply in the latest e Mications apply in the latest e	HRC		mm B.S.			
ASTM A145 ASTM A145 ASTM A145 Addental not intended for use in aerospace/alrcraft applications i CF SP COLOTE NTA COLOTE TE NTA COLOTE NTA COL			ING	i I I I	!	Passed
check Material not intended for use in aerospace/alrcraft applications i test on specimen solution annealed at 1100°C - W.G. removed from bar protony i CF SPP O.C 11 SPP O.C 11 SPP O.C 11 SPP Unless otherwise stated, listed specifications apply in the latest e M.C 20 Department M.C 4.Lived			46			
check Maserial not intended for use in aerospecel/sircraft applications i OF SPO O.C. N.C. nemoved from bar prolony i OF SPO O.C. 11 SP FCTON O.C. 11 SP FCTON O.C. 11 SP FCTON Mice a athenvise stated, listed spokthications apply in the latest e Mice attending applications apply in the latest e Mice attending applications apply in the latest e	Temperature	66	192			Passed
ng Material not intended for use in aerospace/alrcraft applications (rest on specimen solution annealed at 1100°C - W.G. removed from bar prolony i CF SP G.C.OLCATE N.N.A. C.C.I.VSP ECTON O.C. IVSP ECTON O.C. IVSP ECTON Missee otherwise stated, listed specifications apply in the latest e Miss Ed. 2003 Rev. 0 M. C.LING		<u> </u>	186	Visual cneck		Lassen
Prime     Prime     Prime     Prime     Prime     Prime     Prime       Prime     Prime     Pre     Prime     Prime     Prime	Charpy A	173	182	Dimensional check		Passed
Lateral     mm     Fatious leasing     Material not intended for use in aerospecializments       asparation     mm     Remarks:     Neering in the intended for use in aerospecializment applications.       shear     %     Remarks:     Neering in the intended for use in aerospecializment applications.       shear     %     Remarks:     Neering in the intended for use in aerospecializment applications.       shear     %     -1 Capability test on speciment solution annealed at 1100°C - W. O. removed from bar prolongation.       intended in term     %     -1 Capability test on speciment solution annealed at 1100°C - W. O. removed from bar prolongation.       intende in term     %     -1 Capability test on speciment solution annealed at 1100°C - W. O. removed from bar prolongation.       intende in tert     Material made in tert     %     -1 Capability test on speciment solution.       intende in tert     Material made in tert     S. C. O. Dagatiment According to the Quality.     M. M						
Remarka     Remarka <thremarka< th=""> <thremarka< th=""> <thremarka< th=""></thremarka<></thremarka<></thremarka<>	Lateral			IFatigue testing	in the standard for use in serospect	waircraft applications.
E     - Capability test on specimen source in the control of the contr	expansion			Remarks:	AGATAN NOT INTERNALL JOI LOW TO THE TAXAGE AND TAXAG	noved from bar prolongation.
Shear % Shear % C.				1 - 1 Capability test on specim		C
Sheat     A     COUCH TEAL MA       Importative     C     V       Importative     C     V       Importative     C     V       Importation     Material     A       Importation     Material     A       Imade in lariy     No weids, no mercury and radioactive contamination.     Miso Ed. 2003 Rev. 0       Imade in lary     No weids, no mercury and radioactive contamination.     Miso Ed. 2003 Rev. 0						
Unless otherwise stated, listed specific Manual Misio Ed. 2003 Rev. 0					G.COUATEAN	
Unless otherwise stated, listed specific Manual Misio Ed. 2003 Rev. 0	Temperature					or I didle XI
Unices otherwise stated, listed specific Quality System Manual MSQ Ed. 2003 Rev. 0	Load		!			していていていてい
Unless otherwise stated, listed specific Quality System Manual MSQ Ed. 2003 Rev. 0	Load Increm.				197	J
Quality System Manual MSG Ed. 2003 Rev. 0	Duration			- Unles	<b>BDBCIT</b>	
MSQ Ed. 2003 Rev. 0	Elondation		_			<u>Oeparimenti</u>
K.		ids. no mercury and ra	<b>.</b>			
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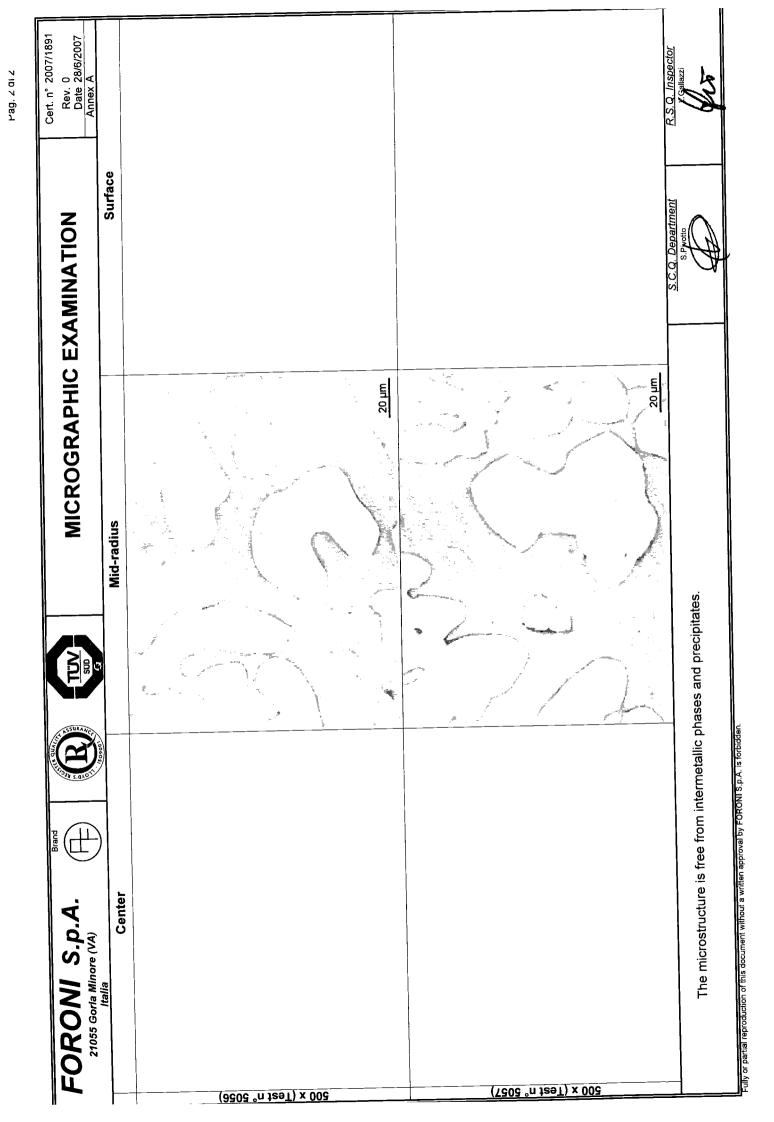


		Brand	ALL BURN				CERTIFIED N	CERTIFIED MATERIAL TEST REPORT	- REPORT	Cert. n° 2007/1891
FORONI S.p.A	.p.A.	(ft	R. M. S. M.	ASSURAW(			Inspect	Inspection certificate EN 10204-3.1	.3.1	Rev. 0 Date 28/6/2007
21055 Gorla Minore Italia	(VA)	5	100005/		G		Order n°:	20(	+ Order confirmation 2007/070114	
Customer IBF SPA Material: F55; UNS S32760	1760.						Delivery	ondition:	aled and peeled.	
ttions:	ASTM A479-06a (chemistry only)	only).								
	I Hant Transferent	ļ	Lot n°:		CTT n°:		Description:	Size		Length mm
<b>AOD / VIDP n°</b> 0432/ VAR / ESR n°		2				<u></u>	ar ieces Weigl		Bar identification:	Forging ratio: 5.5
Steel making process: E.F./A.O.D.							6   22765 Kg	Othe	erties	
Chemical analysis		N	Mechanical properves	5056	5057	5057	Sp	Specification: Descr	Description.	
M %	nct	I est II		0000	- -	1 see	Grain size			
C U,UT6 MN 0,55	Type		see remarks	remarks	remarks	remarks	Ferrite content to AS	ASTM E562		50 % (Test n° 5056) 51 % (Test n° 5057)
			30 mm B.S	30 mm B.S.	30 mm B.S.	30 mm B.S.			/e0°C v 34h)	Passed (Test n° 5056)
2	Position		TRV	TRV	TRV	TRV	Corrosion test to AS	ASTM G48 Method A (50 C	X 4411)	
-+	Temperature	ло С	20	121	20	121				
MO 3,6/	Y.S.		591	473	617	484				
	5.7		 				antion antion			
0,020 0,54	sile U.T.S.	+		1 ~ L	825	719	Macro examination			
	Elongation		4D 35,9	40 37,3	4D 32,0	4U 31,4	<sup>1</sup> Microstructure test to AST	Microstructure test to ASTM E407 etchant #98: free from intermetallic phases and precipitates (Test n° 5095 & 5097)	ermetallic phases and precipita	ttes (Test n° 5056 & 5057)
W 0,65		a a	60,4	64,2	00,3 262	04'0				
KE .	Hardness		16		22		Inclusional content			
		_								
		+-	30 mm B.S.		30 mm B.S.					
	Direction	+	LNG		LNG			012		Passed
	Temperature	o. C	-46		-46		UT to A			
	SƏ	-	134		106					Passed
	Charpy A	۔ -	101		134		Visual cireck			Passed
	do		102		116		D M I check			Passed
	J.d									
		mm					Remarks: A	Material not intended for use in aerospace/aircraft applications.	aerospace/aircraft applicatio	ns. scotion
	dwj						1- <sup>1</sup> Capability test on specir	- <sup>1</sup> Capability test on specimen solution annealed at 1100°C - W.Q. removed from bar provingation.	- W.Q. removed morn bar pron-	nganon.
	Shear	%								
	Temoerature	hure °C					<b>-</b>			
		+								
	S Load Increm	err. hours						<u> </u>	ifications apply in the latest	edition.
		+-						SS OUTEI WISE Stated, include	S C O Department	R.S.Q. Inspector
	5		welds no	No welds no mercury and radioactive contamination	d radioactiv	ve contami		Quality System Manual	M.Gallina	L. Contazzi
Material made in Italy	in Italy.				- possipere	ccordina t		MSQ Ed. 2003 Kev. U	M. Collina	N/N
The material is in compliance with the mentioned specifications. Material produced according to the process of	npliance with the mentioned specifications. material production of the FORONI S.p.A. MSQ Manual.	entioned s <sub>i</sub> rihed in the	pecificatior FORONI S	ns. material b.p.A. MSQ I	prouved e Manual.	- Ruppop			- land	5 Pow
				whiddan						

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Pag. 1 di 2



CTT n:: CTT n:: Roue S2 30 mm B S 1210 0 1210 0 121 0 486 0 1230 10 5210 0 1210 0 121 10 5210 0 1210 0 121 10 5210 0 1210 0 1200 0 1210 0 1200 0 1200		Brand				CERT	CERTIFIED MATERIAL TEST REPORT	. TEST REPORT	Cert n 2007/2264
Main         Condition:         Final         Condition:         Condit         Condition:         Condition:	FOKON S.P         21055 Gorla Minore (VA)	(H		Ì			Inspection certificate E	N 10204-3.1	Rev 0 Date 277/2007
Interention:     SLIA APS 0 to creating only       Interpretention:     <	Italia Customer IBF SPA Material: F55 UNS S32760			00 <b>0</b> 00			20 20 20	+ Order confirmation ill annealed and peeled	Item:
WUDP in Sector     Contraliant     C		06a (chemistry only	-						1
E         E         Direction         Direction         Direction         Result           New         Ver	proces	Heat Treatment:		Lot n°:	CTT n":	Description: Round bar N° of pieces	273 273 Ka		
Mode     Type     Tipe	E.F.A.O.D. Chemical analys	F	Mecha	inical properties		0	11		sults
051         The marks remarks remany remarks remarks remanks remarks remarks remarks r	w Hear 0.014								00 00 000 000 000 000 000 000 000 000
25-00     Poston     30mm 3-3 grund 5     Summ 3-3 grund 5 <td></td> <td>adki</td> <td>ren</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>48 % (Test n° 52 49 % (Test n° 52</td>		adki	ren						48 % (Test n° 52 49 % (Test n° 52
1/M         2/M         2/M <td></td> <td></td> <td>30 m T</td> <td></td> <td></td> <td></td> <td></td> <td>(50°C x 24h)</td> <td></td>			30 m T					(50°C x 24h)	
0.0003         0.0003<		Temper							
0.0250       0.1250       0.54       116       7.5       816       725       823       739       N         0.555       Freed of Area       %       60.7       36.1       41.53       41.54       41.5       41.55       41.55       45.2       45.2       45.2       45.2       45.2       45.2       45.2       45.4 <t< td=""><td></td><td>د ۲ د ۲</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>		د ۲ د ۲							
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×	Material made in Ital)		No weld	ls, no mercury an	d radioactive con	tamination.	MSO Ed 2003 Rev D	A Calina	Comarz
	The material is in complian	ce with the mentio. System described	ned specifi in the FOR	cations. Material ONI S.p.A. MSQ I	produced accord Manual.	ing to the Quality		H. Gallina	and

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Cert n. 2007.2264 Rev. 0 Date 277.2007 Annex A		P.A Violog	R S.O. Inspector
IINATION	Surface	IBFS. P.A OCHERNED	<u>S.C.O.Department</u>
MICROGRAPHIC EXAMINATION		tTų, 02	20.4m
MICROG	Mid-radius	•	ά
	5		The microstructure is free from intermetallic phases and precipitates
Bland			s free from intermetallic
FORONI S.p.A.	Italia Center		The microstructure
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Pag 2 di 2

	Brand		Ċ	(		CERTIFI	<b>ED MATERIAL</b>	<b>CERTIFIED MATERIAL TEST REPORT</b>		Cert n° 2007.2265
21055 Gorla Minore (VA)						=	Inspection certificate EN 10204-3.1	N 10204-3.1		
	//a 2A JNS S32760 2011 A 420 A63 (chamietry anly)					00	<b>Order n°:</b> 2007000242 <b>Delivery condition:</b> Forged. m	+ Order confirmation III annealed and peeled	2007/070114	с. ::
Specifications: ASIM A479	UDA (CREIIISUY OUN)	-					Cira.		Length	
AOD / VIDP n° 04347 VAR / ESR n° Steel mekinn process:	Heat Treatment:	7	Lot n":	CTT n°:	S O S	ion: tr eces	273 Iht	n Bar identification:	ε	Forging ratio: 4.6
E.F.A.O.D.		Machanic	Hochanical properties			10 01	1/300 VA	Other properties	Boculto	
Chemical analysis		Test n 5173	an properties	5174 5	5174		Specification	Description.	Results	
0.014	Type	' see remarks	e <sup>,</sup> see ks remarks	' see ' remarks ren	see or remarks 1 F	Ferrite content to	<b>A</b> STM E562		47 79	47 % (Test n° 5173) 52 % (Test n° 5174)
SI 0.47 ICR 25.50	Position	30 mm B S	30	S	30 mm B S	the tool tool tool tool	ASTM G48 Method A	(50°C × 24h)	Passed	(Test n° 5173)
NI 7.03	Direction	C 20	/ TRV 121			COROSION LEST IO			Passed	I (Test n <sup>c</sup> 51/4)
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N 0.261	Elongation	•,• 41) 35.2	5.2 40 38.2 3 67.0	07 17	38.0 63.7 <sup>1</sup> N	Microstructure test	t to ASTM E407 etchant #98_fr	Microstructure test to ASTM E407 etchant #98 free from intermetallic phases and precipitates (Test nº 5173 & 5174)	ind precipitates (Tes	it n° 5173 & 5174)
W 0.04 PRE 41.66	Hardness		10	255 21	<u> </u>	Inclusional content				
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	t Lateral expansion	ц Ш			<u>u lu</u>	Fatigue testing Remarks:	ligue testing Material not intended for use in the marks:	aer	ispace/aircraft applications. O. removed from bar prolongation	
	E Shear	c				Capability test o		-		
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	5 Elongation	0. 0			<u> </u>	ion i	Quality System Manual	S.C.O. Department	nt RS	O Inspector
Material made in Italy	ly.	No welds.	no mercury ar	or radioacuve cu		ton.	MSQ Fd 2003 Rev D			
The material is in compliance with the mentioned specifications. Material produced accurating to the work of the Sortem described in the FORONI S.p.A. MSQ Manual.	nce with the mentioned specifications. Material product System described in the FORONI S.p.A. MSQ Manual.	oned specifical d in the FORON	lions. Malerial VI S.p.A. MSQ	produced acco. Manual.	יי טי קיייט			r. gauna	*	
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Pag. 1 di 2



FORONI S.p.A.	MICROGRAPHIC EXAMINATION		Rev 0 Date 27 7 2007 Annex A
	Mid-radius	Surface	
	(mr) 05.		<u></u>
		IBFS.P.A OCHEMEWED Date: 20/1007	
The microstructure is free from intermetallic phases and precipitates.	u.r.0.7	S C 0. Department S Profile C 1 Inspector	spector a.:







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Sede regule e Ojjici. 20025 Legiano (MI) - Marisacane, 40 - 16. 0551.487210 - Fax 0551.522970
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Internet: www.laboratoriotosi.it - E-mail: labtosi@tiscalinet.it - Partita IVA e Codice Fiscale 12805730152

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	aPt	3m	lig-				N		ا بر	di di di		-i	Ň	11	$\Delta$	

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### Laboratorio T.O.S.I. s.r.l. Tecnici Organizzati al Servizio delle Imprese



Laboratorie di Prova Approvate Altestato N. 004 L US QUA 641 S

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					ne n° _571	1/07		******	10/07		• • •		di prova n	•	07P	4680	
				Order r	10.			of			l est re	eport no					
Cliente:	IB	F spa	1	Bolla	n° j	#		del	#		Data	1:	5/10/07				
Customer				Deliver	y note			of			date						
	0	4005			• • • •						E a al		1	4:		1	
Colata n°. Heat no.	U	4335		Materia Materia		SIMA	1 /90	UNS S327	bU		Fogl page	10	1	di of	,14,151 <b>9</b> ,441118,441	<b>I</b>	
rieat no.				Materie	21						puge			0.			
Materiale	ricevuto					-					Prov	e ese	guite				
in data:			#								in da	ita:	1	5/10/	07		
Material recive	d on								<u> </u>		Tests o	date					
Macchina	di prova		T1 Vickers					T4 Galdat		0.01/1			T7 Rockwe				
		X	T2 Brinell T3 Tinius						Federhaff 1				T8 Rockwe	ell Gal	lleo		
Test Machine		X	13 Timus	Oisen		scrizi			richieste e			 alo					
Q.tà pro					De	501121		-	l material descri		ateri	aic					
Tests q.	y .		<u>.</u>	Ň	.5 Pipes	O.D.	<u>`</u>		) lot H100		243 :	samp	le 5513		_		
									080 rev.1								
1	Lo	ngitud	linal tensi	le tes	t at room	ı temp	perat	ture acco	ording to A	STM	I E8	( 551	3-1)				
1									according								
3	Lo	ongitud	linal Cha	rpy V	Notch im	pact	test	at -46°C	accordin	g to A	ASTN	/ E2	3. ( 5513-	3).			
3	Br	inell ha	ardness t	<u>est H</u>	B, accord	ling to	AS	TM E10.									
									Valori richi	<u> </u>							
Contr	assegno	o n° pr	ovetta	Temp.	Snerv/Scost.	Rott		Allungament					npact test KV		Durezz		Piega
	Specimens r			Тетр. ° <b>С</b>	Y.stress/strength	Tensile s		Elongation	Red. of area		taria - S	ingle	Media - Average J		Hardnes HB	s	Bend
n°		ontrass	egno		RS Mpa	Rm	мра	<b>P44</b> 70	4. 70		<u> </u>						
		5513	3	20	>=550	>=7	50	>=25							<=27	0	
		0010		121	>=470							_		<u> </u>			
				-46						1	>=35	5	>=45		_		
Prov. n°.	For	ma	Sez.						Valori of	tenut	i - Obta	ained					
Specimens no.	Sha	вре	Section	°C	Rp 0,2%	Rn	n	A4	Z	Uni	taria - S	ingle	Media - Average				
	De mm >	Xmm Di	mm²		Мра	Мр	a	%	%		J	r	J		НВ		
									ļ					0.00			
5513-1	Ø1:	2,5	122,7	20	623,5	810	),8	37,6	ļ			ļ		263	261	263	<u> </u>
5540.0		0 5	400 7	404	<b>EAC 7</b>												
5513-2	Ø1:	2,5	122,7	121	546,7												
5513-3	10,0	x 10		-46				,		58	94	67	73,0			• •• •	
Osservazi	oni:												1	3F :	わ		
Remarks:														N.LA	NET		
				l risu			•	1)	no al soli can	• • •	testati				1		
Ente-Au	torizzat	to	/		Esecuto		es relat		specimens only		Res	pon	sa <u>bile La</u>	bora	torio		11
Authorized	KHV –	, M	WIT.		Examiner	i Ç	(			•	F 1		Responsib	_			/
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	alk	241	5							J					1/	$\bigtriangleup$	

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Laboratorio di Prova Approvato Attestato N. 004 L QUA 641 S

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				Ordine	en° 594/	07	del 12/10	)/07	Rappo	rto d	iprova n°	C	)7P4	841	
				Order no			of		Test report		-				
Cliente: Customer	IBF	spa		Bolla Delivery			<b>del#</b>		Data <sub>date</sub>	_22	/10/07				
Colata n°. Heat no.	043	54		<b>Mater</b> Material	iale AS	TM A 790	UNS S3276	0	Foglio page			di of		1	
Materiale ri	cevuto								Prove	eseg					
in data:			#						in data	1:	22	/10/0	7		
Material recived	on								Tests dat	_					
Macchina d	li prova		T1 Vickers				T4 Galdabir				T7 Rockwel			•••••	
			T2 Brinell V			X	T5 Mohr & F			_	T8 Rockwel	Gain			{
Test Machine		X	T3 Tinius C	lsen 3			T6 Mohr & F					_			
Q.tà prov	ve				De				del material	e					
Tests q.ty	·				Din eo O		puired tests and r			am	nle 5578			_	
				<u>N.2</u>	Pipes O	<u>.D. 10</u>	P.O. 1400		0000250	sam					
	<u> </u> .					tompor			STM E8 (	557	8-1)				
	Long	Ituai	nal tensil	e tes	t at room	eilo tost :	at 121°C		to ASTM	F21	(5578-2	)			
	Long	). בופ נותי הוי	evaled ler	nper	Notch im	nact test	at -46°C	according	g to ASTM	E23	3. ( 5578-3	ý).			
3	Long		nal Unal Irdnoog to	pyv ⊳ot⊔i	B, accord	ing to $\Delta$ S	STM E10	abberani	g .o / .o / .n.			- /			
3		en ne		<u>-st n</u>	D, accolu			alori richi	esti - Required						
				Temp.	Snerv./Scost.	Rottura	Allungamento	Strizione	Resilienza	_	pact test KV		Jurezza		Piega
	assegno o	-		Temp.	Y.stress/strength	Tensile strength		Red. of area	Unitaria - Sin	gle	Media - Average	1	Hardness		Bend
n°	Specimens no. o	rasse		°C	RS Mpa	Rm Mpa	A4 %	Z %	J		J		HB		α/D
		1033	<u></u>												
·· ·		5578		20	>=550	>=750	>=25					<	=270	<u>ן</u> כ	L
· · · ·				121	>=470		T								
· ·				-46					>=35		>=45				L
Prov. n°.	Forma		Sez.	<u>†                                    </u>				Valori o	ttenuti - Obtai	ned					
Specimens no.	Shape		Section	l °C	Rp 0,2%	Rm	A4	Z	Unnaria - Sin	gle	Media - Average	L			<u> </u>
opoolinione	De mm Xm	n Di	mm²		Mpa	Mpa	%	%	J			┣	НВ		
	<u> </u>								↓				0.0	040	
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5578-2	Ø12,	5	122,7	121	488,6				╂ _ ┠			<u> </u>			
										90	94,3				+ ·
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Osservazi	oni:														
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	torizzato RFV		WIT.			ne (	$\bigcirc$	A ORA		•	Responsit				1
Authorized	Inspector	2			Examiner					r 1	<b>`</b> 7	)		M	/
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C	appes	n fi	-				Y	```	$<  \star $		C	<u> </u>	17-	$\geq$	• 

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Laboratorio di Pro Approvato Attestato N. 004 L QUA 041 S

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Cliente:	IBF	ena		Ordin Order no Bolla			del <u>09/10</u> of del #		Rapporto d Test report no. Data 22	liprova n <u>°</u> /10/07		07P4	842	
•		spa				• • • • •	of		date					
Customer				Delivery	note		or		uale					
Colota nº	043	247		Mater	۵۵ مادز	STM & 790	UNS S3276	n	Foglio	1	di		1	
Colata nº.				Material					page		of			
Heat no.				Materia					F-8-					
Materiale ri	cevuto								Prove eseg	juite				
in data:			#						in data:	22	2/10/0	)7		
Material recived	lon								Tests date					
Macchina			T1 Vickers	Matsu	zawa		T4 Galdabir	ni 294J		T7 Rockwe	ll Digi	25R		
		х	T2 Brinell V			<b>x</b>	T5 Mohr & I	Federhaff 1	00KN	T8 Rockwe	ll Gali	eo		
Test Machine		x	T3 Tinius C			···· 🔽	T6 Mohr & I	Federhaff 6	00KN					
Q.tà pro						scrizione	delle prove	richieste e	del materiale					
Tests q.ty							uired tests and i							
Teste qui	<u> </u>			N.3	Pipes C	.D. 10"	sch. 120 ⊦	IT lot.H10	00000245 sam	ple 5567				
					•		P.O. 1400							
1	Lone	aitud	inal tensil	e tes	t at room	tempera	ature acco	rding to A	STM E8 ( 556	7-1)				
1	lion	a Ele	evated ter	nper	ature ten	sile test	at 121°C, a	according	to ASTM E21	(5567-2	)			
3	Lon	aitud	inal Char	V va	Notch im	pact test	at -46°C,	according	g to ASTM E23	3. ( 5567-	3).			
3			ardness te						-	·				
<u>├</u>				<b></b>				alori richi	esti - Required					
Contra	assegno o	n° pr	ovetta	Temp.	Snerv./Scost.	Rottura	Allungamento	Strizione	Resilienza KV -Im	pact test KV		Durezza		Piega
	Specimens no.			Temp.	Y.stress/strength	Tensile strength	Elongation	Red. of area	Unitaria - Single	Media - Average		Hardness		Bend
n° 1	<u> </u>		egno ·	°C	RS Mpa	Rm Mpa	A4 %	Ζ%	J	J		HB		α/D
			<u> </u>											
		5567	7	20	>=550	>=750	>=25					<=270	)	
		·	···· · • · -	121	>=470						<b>.</b>			
i				-46					>=35	>=45				
Prov. n°.	Form	a	Sez.					Valori o	ttenuti - Obtained		<b></b>			
Specimens no:	Shape	,	Section	°C	Rp 0,2%	Rm	44	Z	Unitaria - Single	Media - Average				
	De mn Xn		ពាករ <sup>2</sup>	ļ	Мра	Мра	%	%	J	J		HB	_	
														<b>-</b>
5567-1	Ø12,	5	122,7	20	571,4	781,8	38,2				243	250	246	I
·· ·	· — — · — ·			_ · _	1				<u>                                      </u>			╡ ╏		
5567-2	Ø12,	5	122,7	121	695,6				<u></u>					
				1										
5567-3	10,0 x	10		-46					150 200 135	161,7				L
Osservazi			<u> </u>	<u> </u>										
Remarks:														
							A							
<b> </b>				l risu	iltati del rapp	orto di prov	/a si riferi s.or	no ai soli car	noigni testati					
					Te:** re	port values re	late to the ested	specimens of		<u> </u>				11
EnterAu	tomzato		WIT.		Esecuto			BORA	Respon	sabile Le		atoric	)	//
	∐n <u>spe</u> ctor	Д			Examiner	<	> M	10		Responsit	ble			/
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### Laboratorio T.O.S.I. s.r.l. Tecnici Organizzati al Servizio delle Imprese



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del 09/10/07 Rapporto di prova nº 07P4843 Ordine n° 581/07 Test report no. Order no. del # Data 22/10/07 Bolla n° # IBF spa Cliente: date Delivery note Customer Foglio 1 di <u>1</u> Materiale ASTM A 790 UNS S32760 Colata nº. 04354 page Material Heat no **Prove eseguite** Materiale ricevuto 22/10/07 in data: #\_\_\_\_\_ in data: Tests date Material recived on T7 Rockwell Digi 25R T4 Galdabini 294J T1 Vickers Matsuzawa Macchina di prova X T5 Mohr & Federhaff 100KN T8 Rockwell Galileo T2 Brinell Wolpert Х X T6 Mohr & Federhaff 600KN T3 Tinius Olsen 358J х Test Machine Descrizione delle prove richieste e del materiale Q.tà prove Required tests and material description Tests q.ty N.3 Pipes O.D. 10" sch. 120 HT lot.H100000248 sample 5568 P.O. 140080 rev.1 Longitudinal tensile test at room temperature according to ASTM E8 ( 5568-1 ) 1 Long. Elevated temperature tensile test at 121°C, according to ASTM E21 ( 5568-2 ) 1 Longitudinal Charpy V Notch impact test at -46°C, according to ASTM E23. (5568-3). 3 Brinell hardness test HB, according to ASTM E10. 3 Valori richiesti - Required Piega Resilienza KV -Impact test KV Durezza Allungamente Strizione Temp. Snerv./Scost Rottura Contrassegno o nº provetta Unitaria - Single Media - Avera Hardness Bend Red. of area Tensile strength Elongation Specimens no. or marks remp. Y.stress/strength α/D HB Ζ% J J Rm Mpa A4 % Contrassegno °C Rs Mpa n° <=270 20 >=550 >=750 >=25 5568 >=470 121 >=35 >=45 -46 Valori ottenuti - Obtained Sez. Prov. nº. Forma Unitaria - Sinole Media - Average Rp 0,2% °C Rm **A**4 Ζ Section Specimens no Shape HΒ J J % mm<sup>2</sup> Мра % Mpa De mm X mm Di 242 246 246 602.4 803.9 39.2 122,7 20 Ø12,5 5568-1 122,7 121 497,1 Ø12,5 5568-2

10,0 x 10 5568-3 Osservazioni:

Remarks: I risultati del rapporto di prova si riferiscono ai soli campioni testati Test report values relate to the tested specimens only **Responsabile Laboratorio** Esecutore peratory Responsible

Y WIT. Examiner WILDES CALLINI

-46

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			•	<b>Ordir</b> Order n	<b>ne n° <u>587</u></b> no.	//07	del <u>10/1</u> of	0/07		<b>Rapp</b> Test rep		di prova n'	•	07P	4845	j.
Cliente:	IBF	spa	l .	Boila	an° ≠	¥	del ‡	#		Data	23	3/10/07				
Customer				Deliver			of			date .						
<b>Colata n°.</b> Heat no.	04	347		<b>Mate</b> r Materia		STM A 790	) UNS S3276	50		Fogli page	0	1	<b>di</b> of		1	
Materiale r in data:	icevuto		#							Prove in dat		•	3/10/0			
Material recived	d on			•						Tests d						
Macchina (		x	T1 Vickers T2 Brinell V			x	T4 Galdabi T5 Mohr &					T7 Rockwe T8 Rockwe				
Test Machine		X	T3 Tinius C	Disen	358J	X	T6 Mohr &	Federhaff 6	00KN							
Q.tà pro	ve				De	scrizione	delle prove	richieste e	del m	ateria	ale					
Tests q.t	<u>+</u>			<u> </u>			quired tests and									
				<u>N.</u>	1 Pipe O	<u>.D. 10" s</u>	sch. 120 H			250	<u>sam</u>	<u>ple <b>557</b>7</u>				
1		~itud	inal toneil	la tac	+ of room	tompore		080 rev.1			/ 557	7 4 \				
1		-				•	ature acco at 121°C, a	-			•		1			
3		-		•			at i∠i C, a ∶at -46°C,	-				•				
3	1	-	ardness te			-		according	, 10 /			5. ( 5577-	5 ).			
•				1	<u>, accord</u>	ing to ric		/alori richie	esti -	Require		<u> </u>				
Contra	assegno o	n° pr	ovetta	Temp.	Snerv./Scost.	Rottura	Allungamento					npact test KV	1	Durezza	a	Piega
	Specimens no.			Temp.	Y.stress/strength	Tensile strength	-	Red. of area	Unit	taria - Si	ngle	Media - Average		Hardness	s	Bend
n°	Con	trasse	egno	°C	Rs Mpa	Rm Mpa	A4 %	Z %		J		J		HB		α/D
		5577	/ 	20	>=550	>=750	>=25							<=27(	0	L
				121	>=470											<u> </u>
			<del></del>	-46		Ĺ				>=35		>=45	L			
Prov. n°.	Form	a	Sez.					r	r	enuti - Obtained Unitaria - Single Media - Average						
Specimens no.	Shape		Section	°C	Rp 0,2%	Rm	A4	Z	Unit	.J	ngle		<u> </u>			
	Dermm Xm	ım Di	mm²	┟──┘	Мра	Мра	%	%			<sup>_</sup>		<del>ا ا</del>	HB		
5577-1	Ø12,	5	122,7	20	599,6	812,4	39,6						245	242	242	
5577-2	Ø12,	5	122,7	121	476,6		+									
5577-3	10,0 x	10		-46					84	104	85	91,0				
Osservazio			<b>I</b>	L	<u>.                                    </u>	<u> </u>	· · · · ·						<u> </u>			<b></b>
Remarks																
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Tecnici Organizzati al Servizio delle Imprese





		Ordine n° 581/07 Order no.	dei 09/10/07 of	Rapporto di prova Test report no.	n°07H2368
Cliente: IB! Customer	F SpA	Bolia nº Delivery note	del	Data 18/10/07	
Colata nº.	04347	Materiale ASTM A Material	790 UNS S32760	Foglio 1 page	di <u>3</u> of
Materiale ricevuto	· • • • • • • • •	••••	•	Prove eseguite Tests date	18/10/07
			MICROGRAFICO aphic Examination	1832 (316	
•		Sample No. <b>5567</b> N. 3 Pipes OD 10"	item 1 - P.O. 14008 sch 120 HT Lot H10000		
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	£ 4		-		
	fig. 1 Mic	rographic Examinatio		Magnification : 500 X Satisfactory	
	The grain b	oundaries are free of c	arbide precipitation ar	nd intermetallic phas	e
		TM E562 - Determining Errore % : 2.24	volume fraction of fe	errite = 48,4 % Deviazione standa	wd - 2 07
ntervallo di confide: Confidence interval	nza: 0,82	Server % : 2,24		Standard deviation	ru . 2,97
Campi esaminati N°:	: 30	Dimensione griglia	1: 30 points	Attacco: ASTM E4	07 #98
Examinated fields N*		Dimension grille		Etching	
		l risultati del rapporto di pro lest report values	ova si riferiscono ai soli camp relate to the tested speciment only	RIO	
Enter Autorization		Esecutore Examiner	ID LOIS	Responsabile L	
WILDES	CALLINI	L AGOILLE	Manapriller >	ACK - /	
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	In Alton		14 (		7//





Tecnici Organizzati al Servizio delle Imprese



	Ordine n° 581/07 del 09/10/ Order no. of	07 Rapporto di prova n° 07H2368 Test report no.
Cliente: IBF SpA Customer	Bolla n°	Data 18/10/07 date
Colata nº. 04347 Heel no.	Materiale ASTM A790 UNS S3276 Material	0 Foglio 2 di 3
Materiale ricevuto Material recived on		Prove eseguite 18/10/07 Tests date
	ESAME MICROGRAF Micrographic Examination	ICO
	Sample No. 5567, item 1 - P.O. 1 N. 3 Pipes OD 10" sch 120 HT Lot H	40080 rev.1 1100000245
The grain bo	ographic Examination (Half thickness undaries are free of carbide precipitation	on and intermetallic phase
Intervallo di confidenza : 0,82	M E562 - Determining volume fraction Errore % : 1,73	Deviazione standard : 2,25
Confidence interval	% Error	Standard deviation
Campi esaminati Nº: 30	Dimensione griglia : 30 points	Attacco: ASTM E407 # 98
Examinated fields N°	Dimension grille	Etching
	I risultati del rapporto di prova si riferiscono ai sol Lest report values relate to the tested speciment	i cample di
Enter WIT.	Esecutore	Responsabile Laboratorio
Author WILDES CALLINI	Examiner MBalavelle	O Responsible
apprentix-		2 TV al MALL
Wod.13.1 rev. 0 Questo documento non può essere	riprodotto parzialmente senza autorizzazione acritta del Labora	atorio T.Q.S.I. an





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			del 09/10/07 of	Rapporto di prova n Test report no.	• 07H2368
Cliente: IBI Customer	SpA		del of	Data 18/10/07 <sub>date</sub>	
Colata nº.	04347	Materiale ASTM A79 Material	0 UNS S32760	Foglio <u>3</u> page	di <u>3</u> of
Ateriale ricevuto				Prove eseguite	18/10/07
			CROGRAFICO ic Examination		
	· · · · · · · · · · · · · · · · · · ·	Sample No. 5567, it		) rev 1	
		N. 3 Pipes OD 10" sch			
					ļ
					1
	fig. 3		4	Magnification: 500 X	
		rographic Examination			
	The grain b	oundaries are free of carl	bide precipitation ar	nd intermetallic phase	
		ME562 - Determining vo	plume fraction of fe		
ntervallo di confi		Errore % : 1,56		Deviazione standa Standard deviation	rd : 2,06
Confidence interva Campi esaminati		% Error Dimensione griglia	· 30 points	Attacco: ASTM E407	# 98
Examinated fields		Dimension grille		Etching	
		I risultati del rapporto di prova I est report values relati	si riferiscono ai soli camp	<del></del>	
				Responsabile La	boratorio
Ente AutoRizaki		Esecutore		tratoratory responsib	
Authorzeville	5 CALLINI		Bawkella		
			N JUN		





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Annex cert. 07H2368

#### ASTM E562 DETERMINAZIONE METALLOGRAFICA DELLA FERRITE

FERRITE VOLUME FRACTION METALLOGRAPHIC DETERMINATION ASTM E562

Sample No. 5567, item 1 Esternal surface

N° FIELDS	<u> </u>	2	3	4	5	6	7	8	9	10	11	12	13	14	15
N° FIELDS POINT COUNT	14	15	14	13	14	16	15	14	16	16	14	15	15	16	16
POINT FRACT.	46.7	50.0	46,7	43.3	46.7	53.3	50,0	46,7	53,3	53,3	46,7	50,0	50,0		53,3
(Ppi-Pp) <sup>2</sup>	31	2.4	3.1	26.1	3.1	24,0	2,4	3,1	24,0	24,0	3,1	2,4	2,4	24,0	24,0
(r h-r h)	L_,,,	- <u>,</u> -	_,_			· · · · ·									
N° FIELDS	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
POINT COUNT	14	13	13	14	14	15	14	15	13	15	14	15	15	14	15
POINT FRACT.	46.7	43.3	43.3	46.7	46.7	50,0	46,7	50,0	43,3	50,0	46,7	50,0	50,0		50,0
(Ppi-Pp) <sup>2</sup>	31	26,1	26.1	3.1	3,1	2,4	3,1	2,4	26,1	2,4	3,1	2,4	2,4	3,1	2,4
Volume frction		risco				48,4			Errore% % Error <b>2,</b> 2	242	Confidence	di confidenz interval 1,086		eviazione stan landard deviation 2,974	dard

Sa	ample	No. <b>55</b> 6	67, iter	n 1	Half t	hickne	SS								
N° FIELDS	<u> </u>		3	4	5	6	7	8	9	10	11	12	13	14	15
N° FIELDS POINT COUNT	14	14	13	15	13	14	14	15	13	15	14	13	14	15	14
	46.7	46.7	43.3	50.0	43.3	46.7	46.7	50.0	43,3	50,0	46,7	43,3	46,7	50,0	46,7
POINT FRACT.	0.6	0.6	16.9	6,6	16.9	0.6	0,6	6.6	16,9	6,6	0,6	16,9	0,6	6,6	0,6
(Ppi-Pp)²	0,0	0,0	10,5	0,0			-,-								
NO PUPI DO	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Nº FIELDS	14	14	15	15	14	15	14	15	14	15	14	15	14	15	14
POINT COUNT	46.7	46,7	50.0	50.0	46.7	50.0	46,7	50,0	46,7	50,0	46,7	50,0	46,7	50,0	46,7
POINT FRACT.			,-	6.6	0,6	6.6	0.6	6.6	0,6	6.6	0,6	6,6	0,6	6,6	0,6
(Ppi-Pp)²	0,6	0,6	6,6	0,0	0,0	0,0	0,0	0,0		•,•					
															——————————————————————————————————————

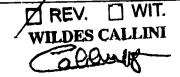
Volume % di ferrite riscontrato (vv):	47.4
Volume frction of the ferrite	

		Deviazione standard Standard deviation			
1,735	0,823	2,254			

#### Sample No. 5567, item 1

Internal surface

N° FIELDS	<u> </u>	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POINT COUNT	14	15	15	15	14	15	14	16	15	15	14	14	15	14	13
POINT COUNT POINT FRACT.	46.7	50,0	50.0	50.0	46.7	50.0	46,7	53,3	50,0	50,0	46,7	46,7	50,0		43,3
(Ppi-Pp) <sup>2</sup>	1.8	4.0	4,0	4,0	1.8	4,0	1,8	28,5	4,0	4,0	1,8	1,8	4,0	1,8	21,7
(r.hh).	<u> </u>				<u>_</u>	<u> </u>									
		47	18	19	20	21	22	23	24	25	26	27	28	29	30
Nº FIELDS	16	15	14	14	15	14	13	14	15	14	15	14	15	14	14
POINT COUNT	14	50.0	46.7	46,7	50,0	46,7	43.3	46,7	50,0	46,7	50,0	46,7	50,0	) 46,7	46,7
POINT FRACT.	46,7	4.0	1.8	1.8	4.0	1.8	21.7	1.8	4.0	1.8	4,0	1,8	4,0	1,8	1,8
(Ppi-Pp) <sup>2</sup>	1,8	4,0		<u></u> ,,		<u> </u>		<u> </u>		· · · · ·					
							1		<b>—</b>			di se eficience		eviazione star	
Volume % d	di ferrite	e risco	ntrato	(vv):		48,0			Errore%		Intervallo			andard deviation	
Volume frction	of the fer	rite							% Error		Confidence	Interval	30		
									1					0.004	



Errore% % Error		Deviazione standard Standard deviation				
1,568	0,753	2,061				



### Laboratorio T.O.S.I. s.r.l. Tecnici Organizzati al Servizio delle Imprese





		Ordine n° 581/07 del Order no. of	09/10/07	Rapporto di prova Test report no.	n° 07H2369
Cliente: Customer	IBF SpA	Bolla n° del Delivery note of		Data 18/10/07	
Colata nº. Heat no.	04354	Materiale ASTM A790 U Material	NS S32760	Foglio 1	di <u>3</u> of
Materiale ricevu Material recived on	ito		• • •	Prove eseguite Tests date	18/10/07
		ESAME MICR Micrographic E			
		Sample No. <b>5568,</b> item N. 3 Pipes OD 10" sch 120			
				• • • • • • • • • • • • • • • • • • •	
	The grain t	rographic Examination (Est boundaries are free of carbide TM E562 - Determining volum	ernal surface) : Sate precipitation and i	ntermetallic phase	9
Intervallo di cor Confidence interval		Errore % : 1,87 % Error	<u> </u>	Deviazione standar	d : 2,48
Campi esamina	ti N°: 30	Dimensione griglia : 30 pc	pints	Attacco: ASTM E40	)7 # 98
Examinated fields N*		Dimension grille		Etching	
		I risultati dei rapporto di prova si rife I est report velues relate to th	e tested speciment only	- <u> </u>	
Ente Materiz	ES CALLINI	Esecutore Examiner MB	auatally S	Responsabile L	
Med.13.1 ray, Q Ques	sto documento non può esse	are riprodotto parzialmente senza autorizzazione	scritta del Laboratorio T C	srl srl	<u> </u>









	Ordine n° 581/07 del 09/10/07	Rapporto di prova nº 07H2369 Test report no.
iente: IBF SpA	Bolla n° del Delivery note of	Data 18/10/07 date
olata n°. 04354 at no.	Materiale ASTM A790 UNS S32760	Foglio 2 di 3 page of
teriale ricevuto		Prove eseguite 18/10/07 Tests date
erial recived on	ESAME MICROGRAFICO	
	Micrographic Examination	
	Sample No. 5568, item 1 - P.O. 14008 N. 3 Pipes OD 10* sch 120 HT Lot H1000	
	and a start of the	
		la Statistics Statistics
		ibn Fr
		19
		and the second
	_	Magnification : 500 X
fig. 2	2 Micrographic Examination (Half thickness)	: Satisfactorv
	in boundaries are free of carbide precipitation	and intermetallic phase
The gra		ferrite = 48.2 %
The gra	ASTM E562 - Determining volume fraction of	
The gra	ASTM E562 - Determining volume fraction of	Deviazione standard : 2,03
The gra tervallo di confidenza : 0,7 onfidence interval	ASTM E562 - Determining volume fraction of Frore % : 1,53 % Error	Standard deviation
The gra ntervallo di confidenza : 0, confidence interval ampi esaminati N°: 30	ASTM E562 - Determining volume fraction of 74 Errore % : 1,53 % Error Dimensione griglia : 30 points	Standard deviation Attacco: ASTM E407 #98
The gra tervallo di confidenza : 0,7 onfidence interval ampi esaminati N°: 30	ASTM E562 - Determining volume fraction of 74 Errore % : 1,53 % Error Dimensione griglia : 30 points Dimension grille	Deviatione standard : 2,03         Standard deviation         Attacco: ASTM E407 #98         Etching
The gra itervallo di confidenza : 0,7 onfidence interval ampi esaminati N°: 30 xaminated fields N°	ASTM E562 - Determining volume fraction of 74 Errore % : 1,53 % Error Dimensione griglia : 30 points Dimension grille I risultati del rapporto di prova si riferiscono ai soli ca Lest report velues relete to the tested speciment o	Deviazione standard : 2,03         Standard deviation         Attacco: ASTM E407 #98         Etching         amploni toetati         INV ORIO
The gra ntervallo di confidenza : 0, confidence interval ampi esaminati N°: 30 (xaminated fields N° inte Kutorizzato	ASTM E562 - Determining volume fraction of 74 Errore % : 1,53 % Error Dimensione griglia : 30 points Dimension grille I risultati del rapporto di prova si riferiscono ai soli ca lest report velues relete to the tested speciment o T. Esecutore	Deviazione standard : 2,03 Standard deviation Attacco: ASTM E407 # 98 Etching ampioni testati NV OR /O
The gra ntervallo di confidenza : 0,7 confidence interval campi esaminati N°: 30 examinated fields N°	ASTM E562 - Determining volume fraction of 74 Errore % : 1,53 % Error Dimensione griglia : 30 points Dimension grille I risultati del rapporto di prova si riferiscono ai soli ca lest report values relate to the tested speciment o T. Esecutore	Attacco: ASTM E407 #98 Etching
The gra ntervallo di confidenza : 0,1 confidence interval campi esaminati N°: 30 examinated fields N° Ente Kutorizzeto	ASTM E562 - Determining volume fraction of 74 Errore % : 1,53 % Error Dimensione griglia : 30 points Dimension grille I risultati del rapporto di prova si riferiscono ai soli ca lest report velues relete to the tested speciment o T. Esecutore	Deviazione standard : 2,03 Standard deviation Attacco: ASTM E407 #98 Etching ampioni testati NV ORIO





Tecnici Organizzati al Servizio delle Imprese



		Ordine n <sup>e</sup>	581/07 det	09/10/07	Rappol Test repor	r <b>to di prova n</b> tino.	• 07H2369
Cliente: Customer	I <b>BF</b> SpA	Bolla nº Delivery note	del of		. Data	18/10/07	
<b>Colata nº.</b> Heat no.	04354	Materiale	ASTM A790 L	INS S32760	Foglio page		di <u>3</u> of
Materiale ricev Material recived on	ruto			• · · · · · · · · · · · · · · · · · · ·	Prove ( Tests date	eseguite	18/10/07
Material recived on		E	SAME MICR	OGRAFICO			
	• · · · · · · · · · · · · · · · · · · ·		Micrographic	Examination			
		•	No. <b>5568,</b> item es OD 10" sch 12				
	The grain	boundaries a STM E562 - D	xamination (ir re free of carbic etermining volu	le precipitation	: Satisfac and intermo ferrite = 47	etallic phase ,7 %	
	confidenza: 0,88	Errore	» % : 1,85		Devia	zione stand lard deviation	
Confidence i Campi esam		<u> </u>	or nsione griglia : :	30 points		co: ASTM E4	
Examinated			sion grille	· • • • • • • • • • • • • • • • • • • •	Étchin	9	
-7		l risultati del	rapporto di prova si i est report values relate to	riferiscono ai soli ca	mpioni testati		1
C	PES CALLINI	Esec Examin	utore her MC	awhile	Resi	atory Respons	aboratorio ible





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Annex cert. 07H2369

### DETERMINAZIONE METALLOGRAFICA DELLA FERRITE ASTM E562

FERRITE VOLUME FRACTION METALLOGRAPHIC DETERMINATION ASTM E562

Sample No. 5568, item 1 Esternal surface

INT COUNT INT FRACT.       Id       14       15       14       15       14       14       15       14       14       15       14       14       14       15       13       14       14       14       14       15       13       14       14       14       15       14       13       15       15       13       14       14       14       15       14       15       14       15       14       15       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1 <th></th> <th>•</th> <th></th> <th>·</th> <th></th>		•		·													
$\begin{array}{rrrr} \begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	FIELDS	1	-	-		-	-	7	-	-						15	
Image: system       3.5       2.1       3.5       2.1       3.5       2.1       3.5       2.1       3.5       2.1       2.5       2.6       2.7       2.8       2.9         FIELDS INT COUNT 15       16       17       18       19       20       21       22       23       24       25       26       27       28       29         INT COUNT 15       16       14       15       16       14       15       16       14       15       13       15       14         SOL 53.3       46.7       50.0       53.3       46.7       50.0       43.3       50.0       44.7       50.0       63.3       46.7       50.0       43.3       50.0       44.7       50.0       63.3       46.7       50.0       44.7       50.0       50.0       44.7       50.0       50.0       48.7       50.0       50.0       48.7       50.0       50.0       48.7       50.0       50.0       48.7       50.0       50.0       48.7       50.0       50.0       48.7       50.0       50.0       48.7       50.0       50.0       48.7       50.0       48.8       50.0       48.7       50.0       46.7	INT COUNT						1									15	
FIELDS         16       17       18       19       20       21       22       23       24       25       26       27       28       29         INT COUNT         INT COUNT         INT COUNT         16       17       18       19       20       21       22       23       24       25       26       27       28       29         116       14       15       13       14       15       16       19       2,1       2,2,1       2,2,1       2,2,1       2,2,1       2,2,1       2,2,1       2,1       2,2,2       2,1       2,2,2       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1       2,1 <th colspa="&lt;/td"><td>INT FRACT.</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>50,0</td></th>	<td>INT FRACT.</td> <td></td> <td>50,0</td>	INT FRACT.															50,0
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	i-Pp)²	3,5	2,1	3,5	2,1	3,5	3,5	2,1	3,5	27,2	2,1	2,1	27,2	3,5	3,5	2,1	
INT FRACT.       50,0       53,3       46,7       50,0       53,3       2,1       23,3       2,1       23,3       2,1       23,3       2,1       23,3       2,1       23,3       20,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       44,7       50,0       50,0       44,7       50,0       50,0       44,7       50,0       50,0       44,7       50,0       50,0       44,7       50,0       50,0       44,7       50,0       50,0       44,7       50,0       50,0       50,0       50,0       50,0       44,7       50,0       50,0       44,7       50,0       50,0       44,7       50,0       50,0       44,7       50,0       50,0       50,0       50,0       50,0       50,0       50,0       50,0	FIELDS	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
$\frac{1}{4^{2}p_{P}} = \frac{2,1}{22,9} = \frac{2,2}{3,5} = \frac{2,1}{2,1} = \frac{3,5}{2,1} = \frac{2,1}{22,9} = \frac{2,1}{2,1} = \frac{2,1}{27,2} = \frac{2,1}{2,1} = \frac{3,5}{2,1} = \frac{2}{2}$ $\frac{1}{22,9} = \frac{2,1}{2,1} = \frac{2,1}{27,2} = \frac{2,1}{2,1} = \frac{3,5}{2,1} = \frac{2}{2}$ $\frac{1}{22,9} = \frac{2,1}{2,1} = \frac{2,1}{27,2} = \frac{2,1}{2,1} = \frac{3,5}{2,1} = \frac{2}{2}$ $\frac{1}{22,9} = \frac{2,1}{2,1} = \frac{2,1}{27,2} = \frac{2,1}{2,1} = \frac{3,5}{2,1} = \frac{2}{2}$ $\frac{1}{22,9} = \frac{2,1}{2,1} = \frac{2,1}{27,2} = \frac{2,1}{2,1} = \frac{3,5}{2,1} = \frac{2}{2}$ $\frac{1}{22,9} = \frac{2,1}{2,1} = \frac{2,1}{2,2} = \frac{2,1}{2,1} = \frac{2,1}{2,1} = \frac{3,5}{2,1} = \frac{2}{2}$ $\frac{1}{2,1} = \frac{1}{22,9} = \frac{1}{2,1} = \frac{1}{2,1$	INT COUNT	15	16	14	15	14	15	16	14	15	16	15	13	15	14	16	
Intervalio di ferrite riscontrato (vv):       48,6         Errore%       Intervalio di confidenza       Deviazione standard         Sample No. 5568, item 1       Half thickness         FIELDS         1       2       3       9       10       11       Deviazione standard         No. 5568, item 1       Half thickness         FIELDS       1       2       3       9       10       11       1       2       48,7       6       7       8       9       10       11       1       2,488         Sample No. 5568, item 1       Half thickness         FIELDS       1       1       1       1       1         1       2       2       10       11       1         1       1       1       1        Intervalio di	INT FRACT.	50,0	53,3	46,7	50,0	46,7	50,0	53,3	46,7	50,0	53,3	50,0	43,3	50,0	46,7	53,3	
40,0         blume frction of the ferrite       40,0         blume frction of the ferrite       considence interval       Standard deviation         Sample No. 5568, item 1       Half thickness         Sample No. 5568, item 1       Half thickness         FIELDS       1       2       Standard deviation       2,488         INT COUNT       INT FRACT.       46,7 50,0 11       11       12       3       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15	pi-Pp)²	2,1	22,9	3,5	2,1	3,5	2,1	22,9	3,5	2,1	22,9	2,1	27,2	2,1	3,5	22,9	
Sample No. 5568, item 1 Half thickness         Sample No. 5568, item 1 Half thickness         FIELDS         INT COUNT         1       2       3       4       5       6       7       8       9       10       11       12       13       14         INT COUNT       14       15       15       14       14       15       14       14       15       14       14       15       14       14       15       14       13       14       13       14       13       14       13       14       13       14       13       14       13       14       13       14       13       14       13       14       13       14       13       14       13       14       13       14       13       14       13       14       13       14       13       14       13       14       13       14       14       14       14       14       14       15       14       14       15       14       14       15       14       14       15       14       14       15       14       14       15       14       14       16       14				ntrato	(vv):		48,6	]						1		dard	
FIELDS INT COUNT INT COUNT INT FRACT. HT COUNT INT FRACT. HT RACT. HT RACT. H										1,8	372	1	0,909		2,488		
FIELDS INT COUNT INT FRACT.       16       17       18       19       20       21       22       23       24       25       26       27       28       29       33         INT COUNT INT FRACT.       14       16       14       16       14       16       14       15       14       15       16       14       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       16       14       16       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15       14       15	DINT COUNT DINT FRACT.		15	15	14	14	15		14	15	14	14	15	14	13	15 14 46,7	
$\frac{14}{46,7} \frac{16}{53,3} \frac{14}{46,7} \frac{14}{53,3} \frac{16}{46,7} \frac{14}{53,3} \frac{16}{46,7} \frac{14}{50,0} \frac{15}{53,3} \frac{16}{46,7} \frac{14}{50,0} \frac{14}{53,3} \frac{14}{46,7} \frac{15}{50,0} \frac{16}{46,7} \frac{14}{4,15} 14$			,	,				,		,	,					2,4	
Image: NT COUNT NT FRACT.       Image:	71F1 DS	16	1 17	18	1 10	20	21	22	23	1 24	25	1 26	27-1	28	1 20	30	
INT FRACT.       46,7       53,3       46,7       50,0       46,7       50,0       53,3       46,7       46,7       50,0       46,7       50,0       46,7       46,7       50,0       46,7       46,7       50,0       46,7       46,7       50,0       46,7       46,7       50,0       46,7       46,7       50,0       46,7       46,7       50,0       46,7       46,7       46,7       50,0       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7       46,7							1									14	
Image: Ppp2       2,4       26,2       2,4       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       2,4       3,2       2,4       2,4       3,2       2,4       2,4       3,2       2,4       2,4       3,2       2,4       2,4       3,2       2,4       2,4       3,2       2,4       2,4       3,2       2,4       2,4       3,2       2,4       2,4       3,2       2,4       2,4       3,2       2,4       2,4       3,2       2,4       2,4       3,2       2,4       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4       3,2       2,4																46.7	
Iume frction of the ferrite     48,2     % Error     Confidence interval     Standard deviation       1,537     0,741     2,030								,	,							2,4	
Sample No. 5568, item 1 Internal surface				ntrato	(vv):	<u>.</u>	48,2									dard	
				<b>60</b> ika		1-1				1,5	537		0,741		2,030		
FIELDS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 5	58	ampie	10. <b>35</b>	סס, ונפ	m 1	men	nai sun	ace									
	FIELDS	<u> </u>	2	3	4	5	6	7	8	9	10	1 11	12	13	14	15	

POINT COUNT	14	14	15	14	13	15	14	15	13	15	14	14	13	14	15
POINT FRACT.	40,7	46,7	50,0	46,7	43,3	50,0	40,7	50,0	43,3	50,0	46,7	46,7	43,3	40,7	50,0
(Ppi-Pp)²	1,0	1,0	5,5	1,0	18,7	5,5	1,0	5,5	18,7	5,5	1,0	1,0	18,7	1,0	5,5
														-	
N° FIELDS	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
POINT COUNT	14	15	-14	15	14	15	15	14	15	16	15	14	14	14	13
POINT FRACT.	46,7	50,0	46,7	50,0	46,7	50,0	50,0	46,7	50,0	53,3	50,0	46,7	46,7	46,7	43,3
(Ppi-Pp)²	1,0	5,5	1,0	5,5	1,0	5.5	5.5	1.0	5.5	32.2	5.5	1.0	1.0	1.0	18,7

Volume % di ferrite riscontrato (vv): Volume frction of the ferrite	47,7
WILDES CALLINI	
Callenge	

Errore%	Intervallo di confidenza	Deviazione standard
% Error	Confidence interval	Standard deviation
1,855	0,884	2,421

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Tecnici Organizzati al Servizio delle Imprese



			del 10/10/07 of	Rapporto di prova n° 07 Test report no.	H2371
liente:	IBF SpA	Bolla n° Delivery note	del	Data 18/10/07 <sub>date</sub>	
olata n°. Patino	04347	Materiale ASTM A79 Material	0 UNS S32760	Foglio 1 di 3 <sub>page of</sub>	<b>,</b>
ateriale rice				Prove eseguite 18/10 Tests date	0/07
Henral Lectvert of	·	ESAME MI	CROGRAFICO		
			nic Examination		
		Sample No. <b>5577,</b> ite N. 1 Pipe OD 10" sch	em 1 - P.O. 140080 ( 120 HT Lot H100000250		
	1.57				
	fig. 1		Mag	mification : 500 X	
	Mi	crographic Examination	(Esternal surface) : S	atisfactory	
	Mic The grain	boundaries are free of car	(Esternal surface): S	a <b>tisfactory</b> intermetallic phase	
tervallo di d	Mi The grain AS	crographic Examination boundaries are free of car STM E562 - Determining vo Errore % : 2,12	(Esternal surface): S	a <b>tisfactory</b> intermetallic phase	
	Mi The grain AS confidenza: 1,03	boundaries are free of car <u>6TM E562 - Determining vertices</u> <u>Errore % : 2,12</u> % Error	(Esternal surface) : S bide precipitation and olume fraction of ferrit	atisfactory intermetallic phase te = 48,8 % Deviazione standard : 2,84 Standard deviation	
nfidence interva ampi esami	Mid The grain AS confidenza: 1,03 ai inati N°: 30	boundaries are free of car <u>STM E562 - Determining v</u> <u>Errore % : 2,12</u> <u>% Error</u> <u>Dimensione griglia : 3</u>	(Esternal surface) : S bide precipitation and olume fraction of ferrit	atisfactory intermetallic phase le = 48,8 % Deviazione standard : 2,84 Standard deviation Attacco: ASTM E407 # 98	
ampi esami	Mid The grain AS confidenza: 1,03 ai inati N°: 30	boundaries are free of car STM E562 - Determining vi Errore % : 2,12 % Error Dimensione griglia : 3 Dimension grille	(Esternal surface) : S bide precipitation and olume fraction of ferrit 30 points	tatisfactory intermetallic phase te = 48,8 % Deviazione standard : 2,84 Standard deviation Attacco: ASTM E407 # 98 Etching	
onfidence interva ampi esami xaminated fields	Mid The grain AS confidenza: 1,03 at inati N°: 30	boundaries are free of car GTM E562 - Determining ver Errore % : 2,12 % Error Dimensione griglia : 3 Dimension grille I risultati del rapporto di prova Lest report values rela	(Esternal surface) : S bide precipitation and olume fraction of ferrit 30 points	atisfactory intermetallic phase te = 48,8 % Deviazione standard : 2,84 Standard deviation Attacco: ASTM E407 # 98 Etching i testati	
onfidence interva campi esami xaminated fields	Mic The grain AS confidenza: 1,03 al inati N°: 30 N'	boundaries are free of car STM E562 - Determining va Errore % : 2,12 % Error Dimensione griglia : : Dimension grille I risultati del rapporto di prova lest report values rela Esecutore	(Esternal surface) : S bide precipitation and olume fraction of ferrit 30 points	atisfactory intermetallic phase te = 48,8 % Deviazione standard : 2,84 Standard deviation Attacco: ASTM E407 # 98 Etching i testatt Responsabile Laborato	rio
onfidence interva campi esami xaminated fields	Mid The grain AS confidenza: 1,03 at inati N°: 30	boundaries are free of car STM E562 - Determining va Errore % : 2,12 % Error Dimensione griglia : : Dimension grille I risultati del rapporto di prova lest report values rela Esecutore	(Esternal surface) : S bide precipitation and olume fraction of ferrit 30 points	atisfactory intermetallic phase te = 48,8 % Deviazione standard : 2,84 Standard deviation Attacco: ASTM E407 # 98 Etching i testati	rio





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Sede legale e Uffici: 20025 Legnano (MI) - Via Pisacane, 46 - Tel. 0331.487210 - Fax 0331.522970 Sede operativa: 20025 Legnano (MI) - P.zza Monumento, 12 - Tel. 0331.522374-3 - Fax 0331.522462 Internet: www.laboratoriotosi.it - E-mail: labtosi@tiscalinet.it - Partita IVA e Codice Fiscale 12805730152



		Ordine n° 58 Order no.	7/07 del 10/10/0	7 Rapporto di prova Test report no.	n° 07H2371
Cliente:	IBF SpA	Bolla n° Delivery note	del of	Data 18/10/07 <sub>date</sub>	
Colata n°. Heat no.	04347	Materiale AS Material	STM A790 UNS S3276	) Foglio 2 Page	di <u>3</u> of
Materiale rice Material recived or	· • • • • • • • • • • • • • • • • • • •	•		Prove eseguite Tests date	18/10/07
Material recived o			ME MICROGRAFI		
		Sample No. N. 1 Pipe C	5577, item 1 - P.O. 1 DD 10" sch 120 HT Lot HT	40080 rev.1 100000250	
	The grain	<b>licrographic Exa</b> boundaries are f	amination (Half thickn free of carbide precipita ermining volume fractio	ation and intermetallic pha	
Intervallo	di confidenza : 0,9		: 1,91	Deviazione sta	
Confidenc	e interval	% Error		Standard devia Attacco: ASTM	
Campi es	aminati N°: 30		one griglia : 30 points	Attacco: As Thi	
Examinate	ed fields N°	Dimension	grille		
	/	i risultati del rapp Testre	porto di prova si riferiscono ai eport values relate to the tested speci	(1) C (1) V TT	
Ente Authorized	LDES CALLIN	- Esecuto Examiner		C Responsabil	e Laboratorio
	a Plante-		te senza autorizzazione scritta del La	boratorio T.O.S.I.SI	-/

Mod.13.1 rev. 0 Questo documento nen può essere riprodotto parzialmente senza autorizzazione scritta del Laboratono 1.0.5.1. st



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### Laboratorio T.O.S.I. s.r.l. Tecnici Organizzati al Servizio delle Imprese





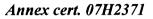
	Ordine n° 587/07 del 10/10/07 Order no. of	Rapporto di prova inº 07H2371 Test report no.
Cliente: IBF SpA Customer	Bolla n° del	Data 18/10/07 <sub>date</sub>
Colata n°. 04347 Heat no.	Materiale ASTM A790 UNS S32760 <sup>Material</sup>	Foglio 3 di 3 page of
Materiale ricevuto		Prove eseguite 18/10/07 Tests date
	ESAME MICROGRAFICO Micrographic Examination	
	Sample No. <b>5577,</b> item 1 - P.O. 140080 N. 1 Pipe OD 10" sch 120 HT Lot H1000002	
	Carles Carles 2 5	
		State of the second
fig. 3		agnification : 500 X
	crographic Examination (Internal surface) : :	
	boundaries are free of carbide precipitation and TM E562 - Determining volume fraction of ferr	
Intervallo di confidenza: 0,77	Errore % : 1,62	Deviazione standard : 2,11
Confidence interval	% Error	Standard deviation
		Attacco: ASTM E407 #98
Campi esaminati N°: 30	Dimensione griglia : 30 points	ALCOUS ASTIN LAST # 20
•	Dimensione griglia : 30 points Dimension grille	Etchir.g
-	Dimension grille	Etcf:ir.g
-	Dimension grille	Etchir.g
Examinated fields N°	Dimension grille I risultati del rapporto di prova si riferiscono al soli campio Lest report values relate to the tested speciment only Esecutore	Etchir.g
	Dimension grille I risultati del rapporto di prova si riferiscono al soli camplo lest report values relate to the tested speciment only Esecutore	Etchir.g





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Sede legale e Uffici: 20025 Legnano (MI) - Via Pisacane, 46 - Tel. 0331.487210 - Fax 0331.522970 Sede operativa: 20025 Legnano (MI) - P.zza Monumento, 12 - Tel. 0331.522374-3 - Fax 0331.522462 Internet: www.laboratoriotosi.it - E-mail: labtosi@tiscalinet.it - Partita IVA e Codice Fiscale 12805730152



Laboratorio di Prova Approvato

OUA 041 S

Attestato N. 004 L

#### DETERMINAZIONE METALLOGRAFICA DELLA FERRITE ASTM E562

FERRITE VOLUME FRACTION METALLOGRAPHIC DETERMINATION ASTM E562

Sample Nc. 5577, item 1

Esternal surface

Volume %			ntrato	(vv):		48,8			Errure% % Error	-	Intervallo o Confidence i			iazione stan dard deviation	dard
Ррі-Рр)²	1,5	4,4	62,3	1,5	1,5	4,4	20,8	4,4	20,8	4,4	1,5	20,8	4,4	4,4	1,5
POINT FRACT.	50,0	46,7	56,7	50,0	50,0	46,7	53,3	46,7	53,3	46,7	50,0	53,3	46,7	46,7	50,0
OINT COUNT	15	14	17	15	15	14	16	- 14 -	16	14	15	16	14	14	15
° FIELDS	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ppi-Pp)²	1,5	4,4	4,4	29,6	1,5	4,4	4,4	29,6	4,4	1,5	1,5	4,4	4,4	20,8	1,5
OINT FRACT.	50,0	46,7	46,7	43,3	50,0	46,7	46,7	43,3	46,7	50,0	50,0	46,7	46.7	53,3	50,0
OINT COUNT	15	14	14	13	15	14	14	13	14	15	15	14	14	16	15
° FIELDS	1	2	3	4	5	6	7	8	Э	10	11	12	13	14	15

Sa	ample	No. 55	77, ite	m 1	Half	thickne	SS								
Nº FIELDS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POINT COUNT	13	14	13	14	15	15	14	14	15	14	15	15	14	13	15
PUINT FRACT.	43,3	46,7	43,3	46,7	50,0	50,0	46,7	46,7	50,0	46,7	50,0	50,0	46,7	43,3	50,0
(Ppi-Pp)²	19,7	1,2	19,7	1,2	5,0	5,0	1,2	1,2	5,0	1,2	5,0	5,0	1,2	19,7	5.0
		•													
N° FIELDS	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
POINT COUNT	15	14	[ 16	15	13	13	15	14	15	13	15	14	15	14	16
POINT FRACT.	50,0	46,7	53,3	50,0	43,3	43,3	50,0	46,7	50,0	43,3	50,0	46,7	50,0	46,7	53,3
(Ppi-Pp)²	5,0	1,2	30,9	5,0	19,7	19,7	5,0	1,2	5,0	19,7	5,0	1.2	<b>5</b> ;0	1,2	30,9
													,		

Volume % di ferrite riscontrato (vv):47,8Volume frction of the ferrite

Errore%	Intervallo di confidenza	Deviazione standard
% Error	Confidence interval	Standard deviation
<b>1,918</b>	0,916	2,509

Sample No. 5577, item 1

Internal surface

Nº FIELDS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POINT COUNT	14	14	13	15	14	15	14	14	15	15	14	-14	15	14	13
POINT FRACT.	46,7	46,7	43,3	50,0	46,7	50,0	46,7	46,7	43,3	50,0	46,7	46,7	50,0	46,7	43,3
(Ppi-Pp)²	0,6	0,6	16,9	6,6	0,6	5,6	0,6	0,6	16,9	6,6	0,6	0.6	6,3	0,6	16,9
													<u> </u>	-	r——,
N° FIELDS	16	17	18	19	20	21	22	23	24	25	26	27	<u></u> 28	29	<u>30`</u>
POINT COUNT	16	14	15	14	15	15	14	13	15	14	15	14	13	15	14
POIP T FRACT.	53,3	46,7	50,0	46,7	50,0	50,0	46,7	43,3	50,0	46,7	50,0	46,7	43,3	. 50.0	46,7
Ppi-Pp)²	34,7	0,6	6.5	-0,6	6,6	6,6	0,6	16,9	6,6	0,6	6.6	0,6	16,9	6,6	0,6



### Laboratorio T.O.S.I. s.r.l. Tecnici Organizzati al Servizio delle Imprese





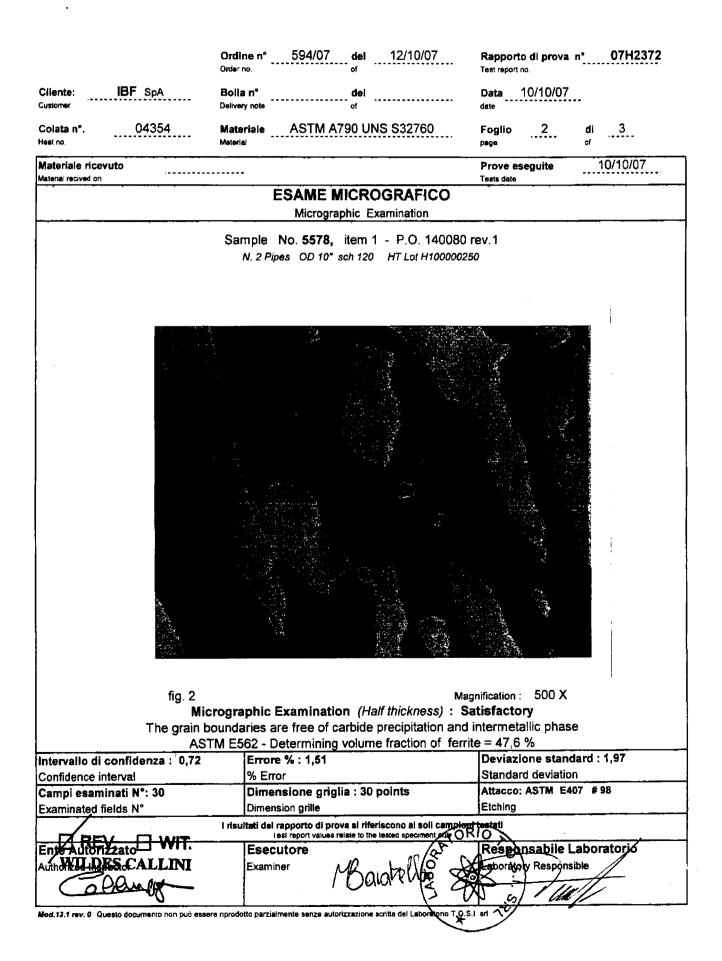
		Ordine n° 594/07 del 12, Order no. of	/10/07 Rapporto di prova nº 07H2372 Test report no.
liente:	IBF SpA	Bolla n° del	Data 10/10/07
<b>olata n°.</b> nat no.	04354	Materiale ASTM A790 UNS S3 Material	32760 Foglio 1 di 3 page of
ateriale ricevu	uto		Prove eseguite 10/10/07 Tests date
		ESAME MICROGR	
,		Micrographic Examination	ation
		Sample No. <b>5578,</b> item 1 - P <i>N. 2 Pipes</i> OD 10" sch 120 HT I	.O. 140080 rev.1 Lot H100000250
	÷		·
			· 그는 사람이 아파 가지 않는 것이다. - 사람이 같은 것은 사람이 있는 것이다. - 사람이 같은 것은 것은 사람이 있는 것이다.
		The LEW Control of the	
	د <del>او</del>	-	
	fig. 1 Mic	crographic Examination (Esternal s	Magnification : 500 X
		boundaries are free of carbide precip	
	AS	TM E562 - Determining volume fract	tion of ferrite = 49,1 %
	nfidenza: 1,06	Errore % : 2,16	Deviazione standard : 2,91
mpiesaminat	H Nº - 30	Dimensione griglia : 30 points	Standard deviation Attacco: ASTM E407 #98
implesaminan minated fields N*	u m . JV		Attacco; ASIM E407 # 30 Etching
		I risultati del rapporto di prova si riferiscono	ai soli campioni testati
	WIT.	lest report values relate to the tested sp Esecutore	A TOR/ Rasponsabile Laboratorio
ZAREV.			AN CAURI ( Dependencie Laboratorio
AUGYZ	GALLINI	Examiner (D)	Laboratory Responsible
	ALLINI	Examiner Babtel	a Laboratory Responsible



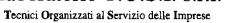


Tecnici Organizzati al Servizio delle Imprese













	Ordine n° 594/07 del 12/10/07 Order no. of	Rapporto di prova nº 07H2372 Test report no.
Cliente: IBF SpA Customer	Bolla n° del Delivery note of	Data 10/10/07 date
Colata n°. 04354 Heat no.	Materiale ASTM A790 UNS S32760	Foglio 3 di 3 Page of
Materiale ricevuto	·····	Prove eseguite 10/10/07 Tests date
	ESAME MICROGRAFICO Micrographic Examination	
	Sample No. 5578, item 1 - P.O. 140 N. 2 Pipes OD 10" sch 120 HT Lot H100	
2. 1		
fig. 3		Magnification : 500 X
Mić The grain h	rographic Examination (Internal surface, oundaries are free of carbide precipitation	and intermetallic phase
AST	M E562 - Determining volume fraction of	ferrite = 48,3 %
Intervallo di confidenza: 0,98	Errore % : 2,03	Deviazione standard : 2,69
Confidence interval	% Error	Standard deviation Attracco: ASTM E407 # 98
Campl esaminati Nº: 30	Dimensione griglia : 30 points Dimension grille	Etching
Examinated fields N°	i risultati dei rapporto di prova si riferiscono ai soli ca	Ing on Restor
Enternato WIT.	Lest report values relate to the tested speciment of Esecutore	Responsabile Laboratorio
Auth WILDES CALLINI	Examiner MBALLER	Apporatory Responsible
appulit		S S - Mar
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#### Annex cert. 07H2372

### DETERMINAZIONE METALLOGRAFICA DELLA FERRITE ASTM E562

FERRITE VOLUME FRACTION METALLOGRAPHIC DETERMINATION ASTM E562

Sample No. 5578, item 1 E

Esternal surface

N° FIELDS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POINT COUNT	15	14	15	14	13	15	14	14	15	14	14	16	15	14	15
POINT FRACT.	50,0	46,7	50,0	46,7	43,3	50,0	46,7	46,7	50,0	46,7	46,7	53,3	50,0	46,7	50,0
(Ppi-Pp)²	0,8	6,0	0,8	6,0	33,3	0,8	6,0	6,0	0,8	6,0	6,0	17,9	0,8	6,0	0,8
							_								
N° FIELDS	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
POINT COUNT	14	15	14	15	13	15	14	16	14	16	16	16	16	15	16
OINT FRACT.	46,7	50,0	46,7	50,0	43,3	50,0	46,7	53,3	46,7	53,3	53,3	53,3	53,3	50,0	53,3
(Ppi-Pp) <sup>2</sup>	6,0	0,8	6,0	0,8	33,3	0,8	6,0	17,9	6,0	17,9	17,9	17,9	17,9	0,8	17,9
Volume % d			ntrato	(vv):		49,1			Errore% % Error		Intervallo c Confidence i	li confidenz nterval		eviazione stan andard deviation	dard
									2,1	68	· /	1.065		2.916	

#### Sample No. **5578**, item 1 *Half thickness*

• FIELDS		2	3	4	5	6	7	8	9	10	11	12	13	14	15
OINT COUNT	14	14	15	14	14	14	15	14	15	14	15	14	15	14	14
OINT FRACT.	46.7	46.7	50,0	46,7	46,7	46,7	50,0	46,7	50,0	46,7	50,0	46,7	50,0	46,7	46,7
pi-Pp)²	0.8	0.8	6,0	0.8	0,8	0,8	6,0	0,8	6,0	0,8	6,0	0,8	6,0	0,8	0,8
FIELDS	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	16 15	17 14	18 <b>1</b> 5	19 <b>14</b>	20 13	21 15	22 14	23 15	24 13	25 14	26 15	27 14	28 14	29 15	30 13
FIELDS INT COUNT INT FRACT.		17 14 46.7			42							27 14 46,7			

Volume % di ferrite riscontrato (vv): Volume frction of the ferrite	47,6

Errore%		Deviazione standard
% Error		Standard deviation
1,518	0,722	1,976

Sample No. 5578, item 1

Internal surface

N° FIELDS		2	3	4	5	6	7	8	9	10	11	12	13	14	15
POINT COUNT	14	15	13	14	13	14	15	14	13	14	15	13	14	15	15
POINT FRACT.	46.7	50.0	43,3	46,7	43,3	46,7	50,0	46,7	43,3	46,7	50,0	43,3	46,7	50,0	50,0
(Ppi-Pp) <sup>2</sup>	2,8	2,8	25,0	2,8	25,0	2,8	2,8	2,8	25,0	2,8	2,8	25,0	2,8	2,8	2,8
N° FIELDS	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
POINT COUNT	15	15	16	15	15	15	14	15	15	14	15	16	14	15	15
POINT FRACT.	50,0	50,0	53,3	50,0	50,0	50,0	46,7	50,0	50,0	46,7	50,0	53,3	46,7	50,0	50,0
Ppi-Pp) <sup>2</sup>	2,8	2,8	25,1	2,8	2,8	2,8	2,8	2,8	2,8	2,8	2,8	25,1	2,8	2,8	2,8
			·				_								
Volume % c	ti ferrite	e risco	ntrato	(vv):		48,3			Errore%		Intervallo	di confidenza	Dev	viazione stan	dard
Volume frction				• •		40,3			% Error		Confidence	interval	Star	dard deviation	
			17 14	//T					2	038		0,985		2,698	
	<u> Z</u> R	EV.		/IT.					2,						
	/wn	DES (	ALT.	INI											





Tecnici Organizzati al Servizio delle Imprese



		Ordine n° 571/07 del	08/10/07	Rapporto di prova n° 07H2307 Test report no.
Cliente:	IBF SpA	Bolla n° # del	#	Data 12/10/07
Colata nº. Heat no.	04336	Materiale ASTM A790 UN	IS S32760	Foglio 1 di 3 page of
Materiale rice	-10001100110101010			Prove eseguite 12/10/07 Tests date
		ESAME MICRO		162/2 Uale
	<u> </u>	Micrographic Ex		
		Sample No. 5512, item 1 N. 5 Pipes OD 10" sch 120		
		20 X		-
			194-11 	CANE OF THE OWNER
			e vê ware	
				And a state of the second
			-	
	م مراجع محموم م			
A				
	fig. 1	icrographic Examination (Estor		agnification : 500 X
	M	icrographic Examination (Ester	rnal surface):	Satisfactory
ł	M The grain	boundaries are free of carbide p	rnal surface):S	Satisfactory
tervallo di c	M The grain		rnal surface):S	Satisfactory
nfidence interval	M The grain A confidenza: 0,57	boundaries are free of carbide p STM E562 - Determining volume Errore % : 1,18 % Error	rnal surface) : Sorecipitation and recipitation of ferr	Satisfactory I intermetallic phase ite = 48,7 % Deviazione standard : 1,57 Standard deviation
ampi esamir	M The grain A confidenza: 0,57 nati N°: 30	boundaries are free of carbide p STM E562 - Determining volume Errore % : 1,18 % Error Dimensione griglia : 30 poin	rnal surface) : Sorecipitation and recipitation of ferr	Satisfactory         Intermetallic phase         ite = 48,7 %         Deviazione standard : 1,57         Standard deviation         Attacco: ASTM E407 # 98
ampi esamir	M The grain A confidenza: 0,57 nati N°: 30	boundaries are free of carbide p STM E562 - Determining volume Errore % : 1,18 % Error Dimensione griglia : 30 poin Dimension grille	rnal surface) : Sorecipitation and fraction of ferr	Satisfactory I intermetallic phase ite = 48,7 % Deviazione standard : 1,57 Standard deviation Attacco: ASTM E407 # 98 Etching
ampi esamir	M The grain A confidenza: 0,57 nati N°: 30	boundaries are free of carbide p STM E562 - Determining volume Errore % : 1,18 % Error Dimensione griglia : 30 poin Dimension grille I risultati del rapporto di prova si riferis lest report values relate to the te	rnal surface) : Sorecipitation and fraction of ferr	Satisfactory I intermetallic phase ite = 48,7 % Deviazione standard : 1,57 Standard deviation Attacco: ASTM E407 # 98 Etching ni testati
ampi esamir	M The grain A confidenza: 0,57 nati N°: 30	boundaries are free of carbide p STM E562 - Determining volume Errore % : 1,18 % Error Dimensione griglia : 30 poin Dimension grille I risultati del rapporto di prova si riferis Test report values relate to the te Esecutore	rnal surface) : Sorecipitation and precipitation and fraction of ferr ts scono ai soli campion ested speciment only	Satisfactory I intermetallic phase ite = 48,7 % Deviazione standard : 1,57 Standard deviation Attacco: ASTM E407 # 98 Etching ni testati Responsabile Laboratorio
ntervallo di c onfidence interval ampi esamir caminated fields N	M The grain A confidenza: 0,57 nati N°: 30	boundaries are free of carbide p STM E562 - Determining volume Errore % : 1,18 % Error Dimensione griglia : 30 poin Dimension grille I risultati del rapporto di prova si riferis Test report values relate to the te Esecutore	rnal surface) : Sorecipitation and fraction of ferr	Satisfactory I intermetallic phase ite = 48,7 % Deviazione standard : 1,57 Standard deviation Attacco: ASTM E407 # 98 Etching ni testati





Tecnici Organizzati al Servizio delle Imprese



		Ordine n° 571/07 del 08 Order no. of	8/10/07 Rapporto di prova n° 07H2307 Test report no.
Cliente:	IBF SpA	Bolla n° # del	# Data <u>12/10/07</u> date
<b>Colata n°.</b> Heat no.	04336	Materiale ASTM A790 UNS S3	
Wateriale ricev	ruto		Prove eseguite 12/10/07 Tests date
	<u> </u>	ESAME MICROGR	AFICO
		Micrographic Examin	pation
		Sample No. <b>5512,</b> item 1 - P. <i>N. 5 Pipes OD 10" sch 120 HT Lo</i>	
		6	•
,			
A CAR		crographic Examination (Half thic)	
	AS	coundaries are free of carbide precip TM E562 - Determining volume fract	tion of ferrite = 47.9 %
	nfidenza: 0,89	Errore % : 1,85	Deviazione standard : 2,43
ampi esamina	ti N°: 30	% Error Dimensione griglia : 30 points	Standard deviation Attacco: ASTM E407 # 98
aminated fields N°	·····	Dimension grille	Attacco: ASIM E407 #98 Etching
		I risultati del rapporto di prova si riferiscono a I est report values relate to the tested sp	ai soli campioni testati
nte REViz	zato WIT.	Esecutore	Responsabile Laboratorio
			Laboratory Responsible
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		Ordine n°	571/07	of del	08/10/07	Rappo Test report	<b>rto di prova</b> rt no.	n°	07H2307
Cliente: Customer		Bolla n° Delivery note	#	del	#	<b>Data</b> date	12/10/07		
Colata nº. Heat no.	04336	<b>Materiale</b>	ASTM A	790 UN	S S32760	Foglio <sub>page</sub>	3	di of	3
Materiale rice	vuto		÷			Prove of Tests date	eseguite	1	2/10/07
waterial recived on		 E	SAME N	IICRO	GRAFICO	Tests date			
					amination				<u> </u>
		•			- P.O. 140080 HT Lot H10000002				
25 15 5 5 5	fig. 3				Ma	agnification	: 500 X		
Art				-	nal surface):		ory		
An	Mi The grain	boundaries ar	e free of ca	arbide p	nal surface):: recipitation and	Satisfact	<b>ory</b> allic phase	2	
An	Mi The grain As	boundaries ar STM E562 - De	e free of ca	arbide p	nal surface):	Satisfact 1 intermet rite = 47,9	ory allic phase ) %		
	Mi The grain	boundaries ar STM E562 - De	e free of ca	arbide p	nal surface):: recipitation and	Satisfact 1 intermet rite = 47,9	ory allic phase ) % one standard		
Confidence interval	Mi The grain As onfidenza: 0,98	boundaries ar STM E562 - De Errore % Error	e free of ca	arbide p volume	nal surface) : recipitation and fraction of ferr	Satisfact d intermel rite = 47,9 Deviazi Standard d	ory allic phase ) % one standard	d : 2,69	
Confidence interval	Mi The grain As onfidenza: 0,98 ati N°: 30	boundaries ar STM E562 - De Errore % Error	e free of ca etermining % : 2,05 sione griglia :	arbide p volume	nal surface) : recipitation and fraction of ferr	Satisfact d intermel rite = 47,9 Deviazi Standard d	ory allic phase ) % one standard	d : 2,69	
Confidence interval Campi esamina	Mi The grain As onfidenza: 0,98 ati N°: 30	boundaries ar STM E562 - De Errore % Error Dimension I risultati del ra	e free of ca etermining % : 2,05 sione griglia : grille apporto di prov	arbide p volume : 30 poin va si riferis	nal surface) : S recipitation and fraction of ferr ts	Satisfact intermet rite = 47,9 Deviazi Standard d Attacco Etching	ory allic phase ) % one standard	d : 2,69	
Confidence interval Campi esamina	Mi The grain As onfidenza: 0,98 ati N°: 30	boundaries ar STM E562 - De Errore % Error Dimension I risultati del ra	e free of ca etermining % : 2,05 sione griglia : grille apporto di prov st report values re itore	arbide p volume : 30 poin ra si riferis	nal surface) : S recipitation and fraction of ferr ts cono ai soli campio sted speciment only	Satisfact d intermet rite = 47,9 Deviazi Standard d Attacco Etching	ory allic phase % one standard leviation : ASTM E40	d : 2,69 7 # 98	}
Intervallo di co Confidence interval Campi esamina Examinated fields N° Ente Auger Authorized Insp	Mi The grain As onfidenza: 0,98 ati N°: 30	boundaries ar STM E562 - De Errore % Error Dimension I risultati del ra Ier	e free of ca etermining % : 2,05 sione griglia : grille apporto di prov st report values re itore	arbide p volume : 30 poin ra si riferis	nal surface) : S recipitation and fraction of ferr ts	Satisfact d intermet rite = 47,9 Deviazi Standard d Attacco Etching mi testatl	ory allic phase ) % one standard	1 : 2,69 7 # 98 abora	}

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Annex cert. 07H2307

### DETERMINAZIONE METALLOGRAFICA DELLA FERRITE ASTM E562

FERRITE VOLUME FRACTION METALLOGRAPHIC DETERMINATION ESTM E562

Sample No. 5512, item 1 Esternal surface

N° FIELDS	1	2	3	4	5	6	7	8	9	10	1 11	12	13	14	15
POINT COUNT	14	15	15	14	15	14	15	15	14	15	15	14	15	15	16
POINT FRACT.	46,7	50,0	50,0	46,7	50,0	46,7	50,0	50,0	46,7	50,0	50,0	46,7	50,0	50,0	53,3
(Ppi-Pp)²	4,0	1,8	1,8	4,0	1,8	4,0	1,8	1,8	4,0	1,8	1,8	4,0	1,8	1,8	21,8
NO FIEL DC	16	17	1 10	- 10 -	<u> </u>	T 04									
Nº FIELDS	14	17	18	19	20	21	22	23	24	25	26	27	28	29	30
POINT COUNT	46.7	50,0	14 46,7	15 50.0	14	16	14	15	13	14	15	15	14	15	14
POINT FRACT.	40,7	1,8	40,7	,	46,7	53,3	46,7	50,0	43,3	46,7	50,0	50,0	46,7	50,0	46,7
(Ppi-Pp)²	4,0	1,0	4,0	1,8	4,0	21,8	4,0	1,8	28,4	4,0	1,8	1,8	4,0	1,8	4,0
Volume % d			ntrato	(vv):	,	48,7	]		Errore% % Error		intervallo Confidence	di confidenz interval		iazione star lard deviation	dard
									1,	183	í .	0,576		1,576	
Sa	ample			m 1	Half	thickne	SS		L <u></u>		<u> </u>		<u> </u>		
N° FIELDS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POINT COUNT	16	14	13	15	15	14	15	15	14	15	14	14	15	14	14
POINT FRACT.	53,3	46,7	43,3	50,0	50,0	46,7	50,0	50,0	46,7	50,0	46,7	46,7	50,0	46,7	46,7
(Ppi-Pp)²	29,7	1,5	20,7	4,5	4,5	1,5	4,5	4,5	1,5	4,5	1,5	1,5	4,5	1,5	1,5
		45	40 -						-						
N° FIELDS	16 14	17 14	18 13	19 15	20	21	22	23	24	25	26	27	28	29	30
POINT COUNT	46.7	46,7			14	15	14	15	14	18	14	13	14	15	14
POINT FRACT.	40,7		43,3	50,0	46,7	50,0	46,7	50,0	46,7	53,3	46,7	43,3	46,7	50,0	46,7
(Ppi-Pp)²		1,5	20,7	4,5	1,5	4,5	1,5	4,5	1,5	29,7	1,5	20,7	1,5	4,5	1,5
Volume frction of						47,9			% Error <b>1,8</b>	159	Confidence i	li confidenz nterval ),890	Stand	azione stan ard deviation 2,438	
	imple I					nal surf	ace								
N° FIELDS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POINT COUNT	14	15	13	14	15	16	14	15	14	15	15	14	15	16	15
POINT FRACT.	46,7 2,4	50,0 3,2	43,3	46,7	50,0	53,3	46,7	50,0	46,7	50,0	50,0	46,7	50,0	53,3	50,0
(Ppi-Pp)²	2,4	3,2	23,9	2,4	3,2	26,2	2,4	3,2	2,4	3,2	3,2	2,4	3,2	26,2	3,2
N° FIELDS	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
POINT COUNT	14	15	13	14	15	14	14	16	14	13	14	15	14	14	15
POINT FRACT.	46,7 2,4	50,0	43,3	46,7	50,0	46,7	46,7	53,3	46,7	43,3	46,7	50,0	46,7	46,7	50,0
(Ppi-Pp)²	<u></u>	3,2	23,9	2,4	3,2	2,4	2,4	26,2	2,4	23,9	2,4	3,2	2,4	2,4	3,2
Volume % d			ntrato (	vv):	4	18,2			Errore% % Error		Intervallo di Confidence in			zione stand	ard
، سر	REV.		VIT.			I			2,0	60	0	,993	2	,720	
ʻwii	IDES OPP	CALL				F									







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		Ordine n° Order no.	571/07 del of	08/10/07	Rapporto di prova n Test report no.	° 07H2308
Cliente:	IBF SpA	Bolla n°	del		Data 12/10/07	
Customer	na sa na	Delivery note	of		date	
<b>Colata n°.</b> Heat no.	04335	Materiale Material	ASTM A790 U	NS S32760	Foglio 1	di <u>3</u> of
Materiale rice	······				Prove eseguite Tests date	12/10/07
		ES	SAME MICR	OGRAFICO		
			Micrographic E	xamination		<del>_</del> <del>_</del>
		•		1 - P.O. 14008 HT Lot H10000		
						<b>.</b>
			•			
			10 19 22 1 1 1 1 1 1 1 1			
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l.	····		en alle en ante en alle en all En alle en alle e			
A	<b>.</b> .					
	fig. 1 Mi	crographic Fya	mination (Fet	N : (ernal surface	lagnification: 500 X Satisfactory	
	The grain	boundaries are	free of carbide	precipitation an	d intermetallic phase	
- <del></del>				e fraction of fer		. <u> </u>
Intervallo di ( Confidence interva	confidenza: 0,90	Errore %	: 1,93		Deviazione standard Standard deviation	: 2,47
			one griglia : 30 po	ints	Attacco: ASTM E407	# 98
		1				
Campi esami		Dimension g	ille		Etching	
Campi esami		I risultati del rap	porto di prova si rife	riscono ai soli campi		. <u> </u>
Campi esami Examinated fields		I risultati del rap	porto di prova si rife report values relate to th			boratorio
Campi esami	N° WIT.	I risultati del rap	porto di prova si rife report values relate to th DFC		oni testati	

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		Ordine n° 571/07 del 08/1 Order no. of	0/07 Rapporto di prova nº 07H2308 Test report no.
Cliente:	IBF SpA	Bolla n° del del	Data 12/10/07 date
<b>Colata n°.</b> Heat no.	04335	Materiale ASTM A790 UNS S32	760 Foglio 2 di 3 page of
Materiale rice			Prove eseguite 12/10/07
Material recived on	) 	ESAME MICROGRA	Tests date
		Micrographic Examinat	tion
		Sample No. <b>5513,</b> item 1 - P.C <i>N. 5 Pipes OD 10" sch 120 HT Lo</i>	
		·	
	and the second se		
		-	· L
		·	
	13		
1	•		
- <u>A</u> -			
71 ~			
N IS	fig. 2		Magnification : 500 X
	-	licrographic Examination (Half thick	
		boundaries are free of carbide precipi	· ·
		STM E562 - Determining volume fraction	
Intervallo di c	onfidenza: 0,99	Errore % : 1,98	Deviazione standard : 2,72
Confidence interval	l	% Error	Standard deviation
Campi esamii	nati N°: 30	Dimensione griglia : 30 points	Attacco: ASTM E407 #98
Examinated fields N	۹°	Dimension grille	Etching
/		I risultatì del rapporto di prova si riferiscono al I est report values relate to the tested sper	
Ente Auto	tzyato 🗌 WIT.	Esecutore	Responsabile Laboratorio
	DESCALLINI		Laboratory Responsible
		examiner / Caloton	

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		Ordine n° 571/07 del 08 Order no. of	8/10/07 Rapporto di prova nº 07H2308 Test report no.
Cliente:	IBF SpA	Bolla n° det	Data 12/10/07
Customer		Delivery note of	date
Colata n°. Heat no.	04335	Materiale ASTM A790 UNS S3	32760 Foglio <u>3</u> di <u>3</u> page of
Materiale rice	evuto	·	Prove eseguite 12/10/07
Material recived or	۰		Tests date
		ESAME MICROGR	
		Micrographic Examin	
		Sample No. <b>5513,</b> item 1 - P <i>N. 5 Pipes OD 10" sch 120 HT I</i>	
		·····	
	and the second		
			···
		6	
		- N	
	÷ K	•	
	·		
	angen kan samara siya sa katasa		
4-			
A	fig. 3		Magnification : 500 X
		icrographic Examination (Internal s	
C. J.Y.		boundaries are free of carbide preci	
	A	STM E562 - Determining volume frac	
		Errore % : 2,05	Deviazione standard : 2,62
	confidenza: 0,95	lov ranne	Observed and the state
Confidence interva	it	% Error	Standard deviation
Confidence interva Campi esami	nati N°: 30	Dimensione griglia : 30 points	Attacco: ASTM E407 #98
	nati N°: 30	Dimensione griglia : 30 points Dimension grille I risultati del rapporto di prova si riferiscono	Attacco: ASTM E407 # 98 Etching
Confidence interva Campi esami Examinated fields I	nati N°: 30 N°	Dimensione griglia : 30 points Dimension grille I risultati del rapporto di prova si riferiscono Lest report values relate to the tested s	Attacco: ASTM E407 # 98 Etching p ai soli campioni testati speciment only
Confidence interva Campi esami Examinated fields I Ente Auto	nati N°: 30 N° 122/ato [_] WIT.	Dimensione griglia : 30 points Dimension grille I risultati del rapporto di prova si riferiscono Lest report values relate to the tested s Esecutore	Attacco: ASTM E407 # 98 Etching D ai soli campioni testati speciment only Responsabile Laboratorio
Confidence interva Campi esami Examinated fields I Ente Auto	nati N°: 30 N°	Dimensione griglia : 30 points Dimension grille I risultati del rapporto di prova si riferiscono Lest report values relate to the tested s	Attacco: ASTM E407 # 98 Etching D ai soli campioni testati speciment only Responsabile Laboratorio







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#### Annex cert. 07H2308

#### **DETERMINAZIONE METALLOGRAFICA DELLA FERRITE ASTM E562**

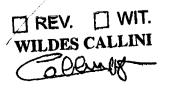
FERRITE VOLUME FRACTION METALLOGRAPHIC DETERMINATION ASTM E562

Sample No. 5513, item 1 Esternal surface

N° FIELDS		2	3	4	5	6	7	8	9	10	1 11	12	13	14	15
POINT COUNT	14	13	15	13	15	14	14	15	15	13	14	13	14	14	13
POINT FRACT.	46.7	43.3	50.0	43.3	50.0	46.7	46.7	50,0	50,0	43,3	46,7	43,3	46,7	46,7	43,3
(Ppi-Pp) <sup>2</sup>	0.0	11,1	11,1	11,1	11,1	0,0	0,0	11,1	11,1	11,1	0,0	11,1	0,0	0,0	11,1
<b>V-FF</b>	<u> </u>						<b></b>	· · · ·		<u> </u>		· · · ·	·		
N° FIELDS	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
POINT COUNT	15	14	15	14	14	15	15	14	13	13	13	15	13	13	15
POINT FRACT.	50.0	46.7	50,0	46,7	46,7	50,0	50,0	46,7	43,3	43,3	43,3	50,0	43,3	43,3	50,0
(Ppi-Pp) <sup>2</sup>	11.1	0.0	11.1	0,0	0,0	11,1	11,1	0,0	11,1	11,1	11,1	11,1	- 11,1	11,1	11,1
Volume % d	i ferrite	e risco	ntrato	(vv):		46,7			Errore%		Intervalio o	di confidenz	a De	eviazione stan	dard
Volume frction	of the ferr	ite			•	40,7	1		% Error		Confidence i	interval	Sta	andard deviation	
•							-		1 10	38	1	0,904	1	2,476	
												0,004		2,410	
Sa	mple	No. <b>55</b> '	<b>13</b> , itei	m 1	Half t	hickne	SS						-		
N° FIELDS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POINT COUNT	15	14	14	13	12	13	15	14	14	13	13	14	14	13	14
POINT FRACT.	50,0	46,7	46,7	43,3	40,0	43,3	50,0	46,7	46,7	43,3	43,3	46,7	46,7	43,3	46,7
(Ppi-Pp)²	15,2	0,3	0,3	7,7	37,3	7,7	15,2	0,3	0,3	7,7	7,7	0,3	0,3	7,7	0,3
Nº FIELDS	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
POINT COUNT	13	14	15	14	15	15	13	14	13	15	13	14	15	14	13
POINT FRACT.	43,3	46,7	50,0	46,7	50,0	50,0	43,3	46,7	43,3	50,0	43,3	46,7	50,0		43,3
(Ppi-Pp)²	7,7	0,3	15,2	0,3	15,2	15,2	7,7	0,3	7,7	15,2	7,7	0,3	15,2	2 0,3	7,7
Volume % d			ntrato	(vv):		46,1			Errore% % Error		Intervalio d Confidence i	di confidenz		eviazione stan andard deviation	dard
									2,1	61		0,996		2,728	
Sa	ample	No. <b>55</b>	<b>13</b> , itei	m 1	Interna	l surfac	ce				4	·····			<u></u>
N° FIELDS	1-1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
POINT COUNT	13	14	15	13	13	14	15	14	13	15	14	13	14	15	14
POINT FRACT.	43,3	46,7	50,0	43,3	43,3	46,7	50,0	46,7	43,3	50,0	46,7	43,3	46,7	50,0	46,7
(Ррі-Рр)²	11,1	0,0	11,1	11,1	11,1	0,0	11,1	0,0	11,1	11,1	0,0	11,1	0,0	11,1	0,0
N° FIELDS	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
POINT COUNT	15	14	15	14	13	15	14	13	15	15	13	14	13	15	13
POINT FRACT.	50,0	46,7	50,0	46,7	43,3	50,0	46,7	43,3	50,0	50,0	43,3	46,7	43,3		43,3
(Ppi-Pp)²	11,1	0,0	11,1	0,0	11,1	11,1	0,0	11,1	11,1	11,1	11,1	0,0	11,1	11,1	11,1

46,7

Volume % di ferrite riscontrato (vv): Volume frction of the ferrite









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		Ordine n° 570/05 del 08/ Order no. of	10/07 Rapporto di prova n° 07H2311 Test report no.
Cliente: Customer	IBF SpA	Bolla n° del	Data 15/10/07 date
<b>Colata nº.</b> Heat no.	04327	Materiale ASTM A790 UNS S3	2760 Foglio 1 di 3 page of
Materiale rice Material recived or			Prove eseguite 15/10/07 Tests date
	· · · · · · · · · · · · · · · · · · ·	ESAME MICROGRA Micrographic Examina	AFICO
		Sample No. <b>5551,</b> item 1 - P. N. 3 Pipes OD 10" sch 120 HT L	
			<b> </b>
	7	<i>z</i>	
	1		
	× 4		
	fig. 1		Magnification : 500 X
	Mi	icrographic Examination (Esternal su	urface) : Satisfactory
and the	Mi The grain	boundaries are free of carbide precipi	urface): Satisfactory itation and intermetallic phase
Intervallo di ci	Mi The grain		urface) : Satisfactory itation and intermetallic phase on of ferrite = 47,3 %
Confidence interval	Mi The grain A onfidenza: 1,02	boundaries are free of carbide precipi STM E562 - Determining volume fracti	urface): Satisfactory itation and intermetallic phase
Confidence interval	Mi The grain A onfidenza: 1,02	boundaries are free of carbide precipi STM E562 - Determining volume fracti Errore % : 2,17 % Error Dimensione griglia : 30 points	urface) : Satisfactory itation and intermetallic phase on of ferrite = 47,3 % Deviazione standard : 2,81 Standard deviation Attacco: ASTM E407 # 98
Confidence interval	Mi The grain A onfidenza: 1,02	boundaries are free of carbide precipi STM E562 - Determining volume fracti Errore % : 2,17 % Error Dimensione griglia : 30 points Dimension grille	urface) : Satisfactory         itation and intermetallic phase         on of ferrite = 47,3 %         Deviazione standard : 2,81         Standard deviation         Attacco: ASTM E407 # 98         Etching
Confidence interval Campi esamin Examinated fields N	Mi The grain A onfidenza: 1,02 nati N°: 30	boundaries are free of carbide precipi STM E562 - Determining volume fracti Errore % : 2,17 % Error Dimensione griglia : 30 points Dimension grille I risultati del rapporto di prova si riferiscono a Jest report values relate to the tested spe	Inface) : Satisfactory itation and intermetallic phase on of ferrite = 47,3 % Deviazione standard : 2,81 Standard deviation Attacco: ASTM E407 # 98 Etching i soli campioni testati cument only
Confidence interval Campi esamin Examinated fields N Ente Autor	Mi The grain A onfidenza: 1,02 nati N°: 30	boundaries are free of carbide precipi STM E562 - Determining volume fracti Errore % : 2,17 % Error Dimensione griglia : 30 points Dimension grille I risultati del rapporto di prova si riferiscono a lest report values relate to the tested spe	Inface) : Satisfactory itation and intermetallic phase on of ferrite = 47,3 % Deviazione standard : 2,81 Standard deviation Attacco: ASTM E407 # 98 Etching i soli campioni testati ciment only Pasponsabile Laboratorio
Confidence interval Campi esamin Examinated fields N Ente Autor	Mi The grain A onfidenza: 1,02 nati N°: 30	boundaries are free of carbide precipi STM E562 - Determining volume fracti Errore % : 2,17 % Error Dimensione griglia : 30 points Dimension grille i risultati del rapporto di prova si riferiscono a l'est report values relate to the tested spe Esecutore	Inface) : Satisfactory itation and intermetallic phase on of ferrite = 47,3 % Deviazione standard : 2,81 Standard deviation Attacco: ASTM E407 # 98 Etching i soli campioni testati ciment only Responsabile Laboratorio

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Cliente:		Ordine n° 570/05 del 08/10/07 Order no. of	Rapporto di prova nº 07H2311 Test report no.
Customer	BF SpA	Bolla n° del Delivery note of	<b>Data 15/10/07</b>
Colata n°. Heat no.	04327	Materiale ASTM A790 UNS S32760	Foglio 2 di 3 page of
Materiale ricevuto	)		Prove eseguite 15/10/07 Tests date
	·	ESAME MICROGRAFICO	
		Micrographic Examination	
		Sample No. <b>5551,</b> item 1 - P.O. 140080 N. 3 Pipes OD 10" sch 120 HT Lot H1000002	
Λ			
A	fig. 2		agnification : 500 X
A	Mic	rographic Examination (Half thickness): S	Satisfactory
A	Mic The grain b	rographic Examination (Half thickness) : S oundaries are free of carbide precipitation and	atisfactory I intermetallic phase
Intervallo di confi	Mic The grain be AST	rographic Examination (Half thickness) : S oundaries are free of carbide precipitation and M E562 - Determining volume fraction of ferr	atisfactory I intermetallic phase
	Mic The grain be AST	rographic Examination (Half thickness) : S oundaries are free of carbide precipitation and	atisfactory I intermetallic phase ite = 46,9 %
Confidence interval	Mic The grain bo AST idenza: 0,85	rographic Examination (Half thickness) : S oundaries are free of carbide precipitation and M E562 - Determining volume fraction of ferr Errore % : 1,82	intermetallic phase ite = 46,9 % Deviazione standard : 2,34
Confidence interval Campi esaminati	Mic The grain bo AST idenza: 0,85	rographic Examination (Half thickness) : S bundaries are free of carbide precipitation and M E562 - Determining volume fraction of ferr Errore % : 1,82 % Error Dimensione griglia : 30 points Dimension grille	Gatisfactory         I intermetallic phase         ite = 46,9 %         Deviazione standard : 2,34         Standard deviation         Attacco: ASTM E407 # 98         Etching
Confidence interval Campi esaminati	Mic The grain bo AST idenza: 0,85	rographic Examination (Half thickness) : S oundaries are free of carbide precipitation and M E562 - Determining volume fraction of ferr Errore % : 1,82 % Error Dimensione griglia : 30 points	Gatisfactory         I intermetallic phase         ite = 46,9 %         Deviazione standard : 2,34         Standard deviation         Attacco: ASTM E407 #98         Etching
Intervallo di confi Confidence interval Campi esaminati Examinated fields N° Ente AutoEX	Mic The grain be AST idenza: 0,85 N°: 30	rographic Examination (Half thickness) : S oundaries are free of carbide precipitation and M E562 - Determining volume fraction of ferr Errore % : 1,82 % Error Dimensione griglia : 30 points Dimension grille	Gatisfactory         I intermetallic phase         ite = 46,9 %         Deviazione standard : 2,34         Standard deviation         Attacco: ASTM E407 #98         Etching

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Laboratorio di Prova Approvato

Attestato

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		Ordine n°	570/05	dei	08/10/07	Rapport Test report	<b>o di prova n°</b>	07H2311
iente:	BF SpA	Bolla nº		del		Data	15/10/07	
plata nº.	04327	Materiale	ASTM A7	'90 UN	S S32760	<b>Foglio</b> page		di <u>3</u> of
teriale ricevut	0					Prove e Tests date	seguite	15/10/07
erial recived on					GRAFICO amination	10013 4410		
		N. 3 Pi	pes OD 10" s	:ch 120	HT Lot H10000			
A.W.	fig. 3	licrographic	Examinatio	on (inte	rnal surface) :	Magnificatior		
	The grain	n boundaries a	are free of c	arbide	precipitation a	nd interme	tallic phase	
tervallo di con			Determining e % : 2,16	volum	e fraction of fe		/ % ione standard	: 2,83
nfidence interval	niutnza. 1,03	% Error				Standard		. <u></u>
ampi esaminat	ti N°: 30	Dime	nsione griglia	1 : 30 poi	nts	Attacc	o: ASTM E407	7 # 98
aminated fields N°			ion grille			Etching		
		l risultati de	I rapporto di pro	ova si rifer relate to the	riscono ai soli cam tested speciment only	pioni testati		
nte Abita	zato WIT.	Ese	cutore		:) (		onsabile La	boratorio
	S'CALLINI	Exam	liner	1.K	achtle.	Labora	tory Responsit	ole

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Annex cert. 07H2311

#### DETERMINAZIONE METALLOGRAFICA DELLA FERRITE ASTM E562

FERRITE VOLUME FRACTION METALLOGRAPHIC DETERMINATION ASTM E562

Sample No. 5551, item 1 Esternal surface

pan

N° FIELDS															
		2	3	4	5	6	7	8	9	10	11	12	13	14	15
POINT COUNT	46.7	16 53,3	15	13	15	14	14	15	15	13	14	13	14	14	13
POINT FRACT.	0.4		50,0	43,3	50,0	46,7	46,7	50,0	50,0	43,3	46,7	43,3	46,7	46,7	43,3
(Ppi-Pp)²	0,4	36,1	7,1	16,0	7,1	0,4	0,4	7,1	7,1	16,0	0,4	16,0	0,4	0,4	16,0
N° FIELDS	16	17	1 18	1 19	20	21	22	23	24	25	26	27	1 28	29	1 20
POINT COUNT	15	14	15	14	14	15	15	14	16	13	13	15	13	13	30 15
POINT FRACT.	50,0	46.7	50.0	46.7	46,7	50.0	50.0	46.7	53,3	43.3	43.3	50.0	43,3	43,3	50.0
(Ppi-Pp) <sup>2</sup>	7,1	0,4	7,1	0,4	0.4	7,1	7,1	0.4	36,1	16,0	16,0	7,1	16,0	16.0	7,1
	<b>L</b>				I			1,	1		1		1. 10,0	1 10,0	
							_								
Volume %			ontrato	(vv):		47,3			Errore%		Intervallo	di confiden:	za Dev	iazione star	Idard
Volume frction	of the fer	rite				47,J			% Error		Confidence	interval	Stan	dard deviation	
					-		-		2	174		1,029		2,818	
									<b></b> ,			1,023		2,010	
S	ample	No. 55	51, ite	m 1	Half	thickne	SS								
N° FIELDS	1	2	3	4	5	6	7	8	9	10	1 11	12	13	1 14	15
POINT COUNT	15	14	14	15	14	13	15	14	14	13	13	14	14	13	14
POINT FRACT.	50,0	46,7	46,7	50,0	46,7	43,3	50,0	46,7	46,7	43,3	43,3	46,7	46,7	43,3	46,7
(Ppi-Pp)²	9,7	0,0	0,0	9,7	0,0	12,6	9,7	0,0	0,0	12,6	12,6	0,0	0,0	12,6	0,0
NO FIEL DO	16	17	1 40	- 10	<u> </u>										
N° FIELDS POINT COUNT	13	17 14	18 15	19 14	20 15	21 15	22 13	23	24	25	26	27	28	29	30
POINT FRACT.	43.3	46.7	50.0	46.7	50.0	50.0	43.3	14 46,7	16	15	13	14	15	14	13
(Ppi-Pp)²	12,6	0,0	9.7	0.0	9.7	9.7	43,3	40,7	53,3 41.6	50,0 9.7	43,3	46,7	50,0	46,7	43,3
(	,•	0,0	•,,	0,0		- 3,1	12,0	0,0	41,0	9,1	12,0	0,0	9,7	0,0	12,6
Volume %	di ferrite	risco	ntrato	(vv).					Errore%						
Volume frction				(••).	4	46,9						li confidenz		azione stan	dard
Volume inclion	or the left		·						% Елтог		Confidence i	nterval	Stand	lard deviation	
									1,8	328	(	),857		2,347	
S	ample	No 55	51 iter	m 1	Interna	l surfac	סי								
•			•1, 10			/ Sunde									
NA PIPE DO		<u> </u>	<u> </u>			<u> </u>									
N° FIELDS POINT COUNT	13	2	3 15	4	5 14	6 14	7	8	9	10	11	12	13	14	15
POINT FRACT.	43,3	46,7	50.0	53,3	46,7	46.7	15 50,0	14 46,7	13	15	14	13	14	15	14
		· · · · ·				· · · · ·			43,3	50,0	46,7	43,3	46,7	50,0	46,7
(Ppi-Pp)²	18,7	1,0	5,5	32,2	1,0	1,0	5,5	1,0	18,7	5,5	1,0	18,7	1,0	5,5	1,0
Nº FIELDS	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
POINT COUNT	15 50.0	14 46.7	15	14	13	15	14	13	15	15	13	14	15	15	16
DODIT ED LOT	5,5		50,0	46,7	43,3	50,0	46,7	43,3	50,0	50,0	43,3	46,7	50,0	50,0	53,3
POINT FRACT.	1 3.3 1	1,0	5,5	1,0	18,7	5,5	1,0	18,7	5,5	5,5	18,7	1,0	5,5	5,5	32,2
POINT FRACT. (Ppi-Pp) <sup>2</sup>															
(Ppi-Pp) <sup>2</sup>		ricoc	ntroto	<u></u>		ı		1			<u></u>				
(Ppi-Pp) <sup>2</sup> Volume % c	li ferrite		ntrato	(vv):		47.7		l	Ептоге%		Intervalio d	i confidenza	a Devi	azione stanc	lard
(Ppi-Pp) <sup>2</sup>	li ferrite		ntrato	(vv):	4	47,7			Errore% % Error		Intervallo d Confidence in			azione stanc	lard
(Ppi-Pp) <sup>2</sup> Volume % c	<b>Ji ferrite</b> of the ferri	te				47,7			% Error	69	Confidence in	terval	Stand	ard deviation	lard
(Ppi-Pp) <sup>2</sup> Volume % c	di ferrite	rev.		WIT.		47,7	A			69	Confidence in		Stand		lard



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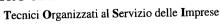
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		Ordine n°	571/07	of	08/10/07	 Test report no.	n° 07H2309
Cliente: IBF	= SpA	Bolla n°		del		Data 12/10/07	
Customer		Delivery note		of		date	
Colata nº. Heat no.	04336	<b>Materiale</b>	ASTM A79	90 UN	S S32760	Foglio <u>1</u>	di <u>1</u> of
Materiale ricevuto	galdered (1) out (1) built (1)					Prove eseguite Tests date	12/10/07
PROVA D	DI RESISTEI	NZA ALLA Pitting Co	CORRO	SION stance (	E PER PI ASTM G48 N	TTING (ASTM G4 flethod A)	8 Metodo A)
	512 item 1 OD 10" sch 12	20 HT Lot H	100000242				
1)	Preparazion Specimen prepa		a) b) c)	dimens posiz positio lucid	rione Tra	27 x 12 x 2 asversale sversal, including external a te n. 120 a umido papers n. 120	
2)	<u>Prova:</u> <sub>Test</sub>		a)		zione : solu	uzione cloruro ferrico	o 6%
	1851		b)		eratura:	50 °C	
			C)	temp time	00	24 h	
3)	Valutazion Evaluation	<u>e</u>	•	rdita d ight loss	i peso:0,	0014 g.	0,52 g/m <sup>2</sup> ( < 4,0 g/m <sup>2</sup> )
BF 9-4 N.LANEN R.E.					-	: CONFORME	agnification
			rapporto di pro				
Ente Autorizzat Autholized Read to WILDES			rest report values re <b>Lutore</b> iner	. 6	and the nor	Responsabile Laboratory Respo	/

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		Ordine n°	571/07	del	08/10/07	Rapporto di prova Test report no.	n° <u>07H2310</u>
<b>O1</b>	IBF SpA	Bolia n°		del		Data 12/10/07	
Cliente:	IDF SPA	Delivery note		of	9999 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 -	date	
<b>Colata nº.</b> Heat no.	04335	Materiale	ASTM A79	0 UNS	S32760	Foglio <u>1</u> <sub>page</sub>	di <u>1</u> of
Materiale ric	evuto					Prove eseguite	12/10/07
Material recived o	n			<u> </u>	·	Tests date	<u></u>
PRC	OVA DI RESIST	ENZA ALLA Pitting Corro	CORRO	SIONI stance (A	E PER PI ASTM G48 M	TTING (ASTM G4 ethod A)	8 Metodo A)
<u>Sam</u> N. 5	ple <b>5513</b> item Pipes OD 10" sch	<u>1</u> 120 HT Lot H10	00000243				
	1) <u>Preparaz</u> Specimen p	zione provino reparation	a)	dimensi		26 x 12 x 2	25 (W Thk) mm
			b)	posizi	Tras	sversale <sup>versal, including external a</sup> e n. 120 a umido	and internal surfaces
			C)		g wetemery pa		
	2) <u>Prova:</u>		a)		ione : solu	zione cloruro ferrico	o 6%
	Test		b)		eratura:	50 °C	
			C)	temper time		24 h	
	3) <u>Valutazi</u>	one	pe	rdita di	peso : 0,0	0012 g.	0,48 g/m <sup>2</sup>
	Evaluation		wei	ight loss			( < 4,0 g/m²)
TB N	F AP.A					: CONFORME	agnification
		l risultati del ra					
Ente Aut	orizzato	Esecu		elate to the t	ested speciment or	Responsabile	Laboratorio
Autholized				ı Ki	ı m	Laboratory Respo	
• است	LDES CALLIN	II		TP.	aiatella		du /.
	POQ Ald	1					4.6/

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		<b>Ord</b> Order	<b>ine n° 570/C</b> <sup>no.</sup>	,	<b>del</b>	08/10/07		Rapporto di prova rest report no.	n°	07H2314
Cliente:	IBF	SpA Bol			del	and a start of Coldense and The Local of Participation		Data 15/10/07 late		
Customer		Delive	ery note		of		ū	ale		
Colata n°. Heat no.	(	04327 Mat	provident to the second s	1 A79	10 UN	NS S32760		Foglio <u>1</u> Page	<b>di</b> of	
Materiale ricev Material recived on	uto							Prove eseguite		15/10/07
		<b>RESISTENZA</b> P 151 item 1	ALLA COF	Resis	SIOI tance	NE PER I (ASTM G48	PITTIN Method	<b>G (ASTM G4</b> <sup>A)</sup>	8 Me	etodo A)
N. 3 Pij	oes (	OD 10" sch 120 H	IT Lot H10000	0244						
	1)	Preparazione p Specimen preparatio		a) b) c)	dime pos posit	ion T	T <b>rasvers</b> Trasversal, arte n. 1	including external a 20 a umido		
	2)	<u>Prova:</u>		a)		uzione : so		e cloruro ferrico	o 6%	
		Test		b)	tem	p <b>eratura</b> : perature		50 °C		
				C)	ten time	וpo		24 h		
	3)	Valutazione Evaluation		•	rdita ght los	<b>di peso</b> : s	0,0009	g.		0,48 g/m <sup>2</sup> (<4,0 g/m <sup>2</sup> )
A BI						visivo (20 amination: sat		NFORME no pitting at 20x ma	agnific	ation
	<u></u>	lr	isultati del rapporto					testati		
Ente Autor Authorized Ins WIL		° [] WIT. CALLINI	Test report Esecutore Examiner	values n		he tested specime	_	Responsabile		oratorio

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		Ordine n° 5	81/07 <b>del</b> 09/10/07 of	Rapporto di prova n° 07H237 Test report no.	76
Cliente:	IBF SpA	Bolla n°	del	Data 19/10/07	
Customer		Delivery note	of	date	
Colata n°. Heat no.	04347	Materiale A	STM A790 UNS S32760	Foglio <u>1</u> di <u>1</u> page of	
Materiale ricevul Naterial recived on	to		· · · · · · · · · · · · · · · · · · ·	Prove eseguite 19/10/07 Tests date	
PROVA	A DI RESISTI		ORROSIONE PER PIT ion Resistance (ASTM G48 Me	TING (ASTM G48 Metodo A thod A)	.)
	<b>5567</b> item as OD 10" sch	<u>1</u> 120  HT Lot H100	000245		
	1) <u>Preparazio</u> Specimen pre	one provino paration	dimension b) posizione Tras		
:	2) <u>Prova:</u> <sub>Test</sub>		a) soluzione : soluzio ferric chloride solution	one cloruro ferrico 6%	
	1631		b) temperatura: temperature	50 °C	
			c) tempo time	24 h	
:	3) <u>Valutazior</u> Evaluation	le	perdita di peso : 0,00 weight loss	08 g. 0,42 g/r ( < 4,0 g/m <sup>2</sup> )	
			esame visivo (20x) : C visual examination: satisfacto	ONFORME	
—— <b>,</b> <u>.</u> .			rto di prova si riferiscono ai soli campi	oni testati	
		Esecutor Examiner	e MBawh	Responsabile Laboratorio	1

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Cliente: IBF SpA <sup>Customer</sup> Colata n°. 0435	Delivery note	07 del 09/10/07 of del of A A790 UNS S32760	Rapporto di prova n°       07H2377         Test report no.       Data       19/10/07         date       foglio       1       di       1
Heat no.	Material		page of
Materiale ricevuto Material recived on			Prove eseguite 19/10/07 Tests date
	Pitting Corrosion	RROSIONE PER PITTI Resistance (ASTM G48 Metho	NG (ASTM G48 Metodo A) <sup>od A</sup> )
Sample <b>5568</b> N. 3 Pipes OD 1	0" sch 120 HT Lot H10000	0248	
	parazione provino cimen preparation	dimension b) posizione Trasve	al, including external and internal surfaces 120 a umido
2) <u>Pro</u> Test		<ul> <li>a) soluzione : soluzion ferric chloride solution</li> <li>b) temperatura: temperature</li> <li>c) tempo time</li> </ul>	e cloruro ferrico 6% 50 °C 24 h
	<u>utazione</u> <sup>uation</sup>	perdita di peso : 0,0009 weight loss esame visivo (20x) : CO visual examination: satisfactory	(< 4,0 g/m <sup>2</sup> )
		li prova si riferiscono ai soli campion alues relate to the tested speciment only	i testati
WILDES CAL	WIT. Examiner	Maratella	Responsabile Laboratorio Laporatory Responsible

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Cliente: II Customer Colata n°. Heat no.	BF spa 04347	Order no. Bolla nº	7/07 TM A7	del 10/10/07 of del of 90 UNS S32760	Rapporto di prov         Test report no.         Data 19/10/0         date         Foglio 1         page	7 di <u>1</u>
Material recived on					Prove eseguite Tests date	19/10/07
PROVA				SIONE PER P stance (ASTM G48 M	TTING (ASTM GA	48 Metodo A)
	0 <b>577</b> item 1 0D 10" sch 120	HT Lot H10000	0250			
1)	Preparazion		a)	dimensione :	20 x 13 x 2	23 (W Thk) mm
	Specimen prepa	auon	b)	dimension posizione Tra	asversale	
			,	•	versal, including external	and internal surfaces
			C)	lucidatura : cart	e n. 120 a umido	
				polishing wetemery p	apers n. 120	
2)	<u>Prova:</u> <sub>Test</sub>		a)	soluzione : solu	zione cloruro ferrico	o 6%
			b)	temperatura: temperature	50 °C	
			c)	tempo	24 h	
				time		
3)	Valutazione		ner	dita di peso:0,0	0009 a	0,44 g/m <sup>2</sup>
•,	Evaluation			the loss		(<4,0 g/m <sup>2</sup> )
				ime visivo (20x) :		
			visu	ai examination: <b>satista</b>	ctory no pitting at 20x ma	gnification
			-	a si riferiscono ai soli can		
Ente Autorizzat	0	Esecutore	values rel	ate to the tested speciment only	Responsabile	Laboratorio /
AuthorizeRES	WIT.	Examiner		NR as Volks	Laboratory Respon	
WILDES (	CALLINI		i	Maiahille	VIR 1	
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Rapporto di prova nº 07H2380 Ordine n° 594/07 del 12/10/07 Test report no. Order no. Data 19/10/07 Bolla n° del IBF SpA Cliente: date Delivery note Customer Materiale ASTM A790 UNS S32760 Foglio di 1 1 04354 Colata nº. Material page Heat no 19/10/07 **Prove eseguite** Materiale ricevuto Tests date Material recived on PROVA DI RESISTENZA ALLA CORROSIONE PER PITTING (ASTM G48 Metodo A) Pitting Corrosion Resistance (ASTM G48 Method A) Sample 5578 item 1 N. 2 Pipes OD 10" sch 120 HT Lot H100000250 20 x 12 x 22 (W Thk) mm a) dimensione : 1) Preparazione provino dimension Specimen preparation b) posizione Trasversale Trasversal, including external and internal surfaces position lucidatura : carte n. 120 a umido C) polishing wetemery papers n. 120 soluzione : soluzione cloruro ferrico 6% a) Prova: 2) ferric chloride solution Test 50 °C b) temperatura: temperature 24 h tempo C) time  $0,42 \text{ g/m}^2$ perdita di peso: 0,0008 g. 3) Valutazione  $(< 4.0 \text{ g/m}^2)$ weight loss Evaluation esame visivo (20x) : CONFORME visual examination: satisfactory no pitting at 20x magnification I risultati del rapporto di prova si riferiscono ai soli campioni testati ORIG Test report values relate to the tested speciment only Responsabile Laboratorio Esecutore rizzato [~~] WIT. aboration Responsible Examiner Malari DES CALLINI 111

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IMP / NTNU Prof. Roy Johnsen Richard Birkelandvei 2b

12345 Trondheim Norwegen

Prüfbescheinigungsart: Inspection document: Bescheinigungs-Nr.: Document number: Rev.-Nr.: Rev. no.: Ausstellungsdatum: Date of issue? Seite: Page: Auftrags-Nr.: Order no.: Lieferschein-Nr.: Delivery note no.: Fertigungs-Nr.: *Production no:* KK-Artikel-Nr.: KK part no.: Bescheinigungsaussteller: Originator of the document: Ansprechpartner: Contact person: Telefon: Telephone: Herstellerkennzeichen: Symbol of the manuf. work: Werksachverständigenkennzeichen: Inspector's Stamp:

cert. acc. to EN 10204: 2005 - 3.1

00046446

02.03.2017 1 / 2 LS QS01/2017 Pos. 1 LM 00172373 Pos. 10 P1-00643455-178996 Qualitätsstelle

Karina Nitz

+49 (2195) 671-690



#### Umfang der Lieferung Extend of delivery

Bestellnummer: Purchaser's order no.:	Prof.Roy Johnsen	Bestelldatum: Date of order:	01.03.2017
Menge: <i>Quantity:</i>	0,25 ST	Kunden-Nr.: Customer no.:	12559
Gegenstand: <i>Part:</i>	High-grade steel rings	Zeichnungsnummer: Drawing no.:	Segment <i>segment</i>
Abmessungen: Dimensions:	273.0 mm / 213.0 mm x 150.0 mm	Kunden-Artikel-Nr.: Customer article no.:	
Werkstoffnummer: Material no.:	1.4471.02	Werkstoff: <i>Material:</i>	GX3CrNiMoWCuN 27-6-3-1
Spezifikation: Specification:	SEW 410 : 1998-07	Lieferzustand: Delivery condition:	+AT
Spezifikation 2: Specification 2:	Erstmustermaterial first sample material	Erzeugnisform: Casting process:	Schleuderguss <i>Centrifugal casting</i>
Spezifikation 3: Specification 3:		Erschmelzungsart: Steel making process:	E

#### Chemische Zusammensetzung: Schmelzanalyse [Gew.-%]

Chemical composition: Ladle analysis [wt.-%]

Anzahl <i>Qty.</i>	Schmelzennr. <i>Cast number</i>	С	Si	Mn	Р	S	Cr	Ni	Мо	Cu	W	N	PRE	
	Min						25,50	5,50	3,00	0,80	0,90	0,150	42,0	
	Max	0,030	1,00	2,00	0,030	0,020	28,00	8,00	4,00	1,30	1,10	0,280		
1	F10689	0,018	0,44	0,47	0,015	0,006	27,26	7,21	3,72	1,09	1,04	0,224	43,1	

cert. acc. to EN 10204: 2005 - 3.1 Prüfbescheinigungsart: Inspection document: 00046446 Bescheinigungs-Nr.: Document number: Rev.-Nr.: Rev. no.: Ausstellungsdatum: 02.03.2017 Date of issue: Seite: 2/2

#### Probennummer und Wärmebehandlung

Test no. and neat treatment no.									
Anzahl <i>No of pcs.</i>	Schmelzen-Nr. <i>Melting number</i>	Probennr. <i>Test no.</i>							
1	F10689	151680							

#### Zugversuch

Tensile test

Probennr. <i>Test no.</i>	Т	E-Modul	Rp 0.2	Rp 1.0	Rm	А	Z	Т	K2 [J]			Härte <i>Hardness</i>				
	°C	GPa	MPa	MPa	MPa	%	%	°C	1	2	3	Ø	1	2	3	Ø
Min	RT		480		650	22										
Max	RT				850											
151680	RT		606	686	827	27	46	RT	155	132	126	137				
151680	100		549	597	700	30	62	-46	139	138	139	138				
151680	150		461	518	670	31	56	-80	56	40	62	52				
151680	200		418	475	663	34	62									

Die Prüfungen wurden nach den folgenden Normen durchgeführt: The tests were executed acc. to the following standards:

Zugversuch: Tensile test: Probenform: Ø 10 mm Shape of test piece:

Probenrichtung: tangential Direction of test piece: DIN EN ISO 6892-2:2011-05

DIN EN ISO 6892-1: 2009-12 Kerbschlagbiegeversuch: *Charpy impact test:* Probenform: V Shape of test piece:

#### DIN EN ISO 148-1: 2011-01

Probenrichtung: tangential Direction of test piece:

Warmzugversuch: Hot tensile test: Probenform: Ø 10 mm Shape of test piece:

Probenrichtung: Direction of test piece:

- G48-Test Methode A-50°C-24h - OK / G48-Test Method A-50°C-24h - OK

- Schliff / Microsection (Austenite grain spacing acc. to DVN-RPF112) - OK 15,5µm = fine

#### Die Lieferung wurde geprüft und entspricht den oben genannten Spezifikationen.

The products are tested and are found to be in accordance with the above specification.