ANNEXURE
01 Research Publication in IIW-IWJ

An Experimental Comparative Review of Ferrite Measurement Techniques used in Duplex Stainless Steel (UNS S32205) Welds

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ABSTRACT

Duplex stainless steels (DSS) have proven to be very promising engineering materials as substitutes to conventional austenitic stainless steels for structure of off-shore platforms, parts and equipment in petrochemicals and refinery industries, predominantly for sour service applications where corrosion resistance including stress corrosion cracking (SCC) resistance is required in aggressive chloride and/or sulphide environments. Resistance to SCC in chloride containing environment depends on the available ferrite content in the carefully welded duplex (ferritic-austenitic) stainless steel structure. There is, of course, a degree of variation in weld metal ferrite content and in reproducibility of measurement which deserve a review and comparative study on different weld metal ferrite measurement techniques being widely used. So, present work has been carried out by collaborating with a reputed filler metal manufacturer who deliberately produced special batches of standard DSS compositions matching SMAW electrodes with nickel varied content in the range of 9-9.5 %, 9.5 -10.5, 10.5-11.5 and 11.5 to 12.5 % to obtain weld deposits in varied ferrite content range15% to 40%, or 20 FN to 50 FN to be experimentally investigated by (1) Feritscope® instrument method, (2) ASTM E 562-11 volume fraction measurement by systematic manual point count method and (3) theoretically by WRC-1992 Diagram. The purpose of this paper is to give a comparative overview of above methods. According to the findings of the study, readings on the top surface of weld metal were consistent with those on the cross section, this indicates proper guidelines can be given for selecting location of testing Feritscope® instrument measurement. FN estimates in predictive methods like image analysis / manual point count methods depends on proper placement of the points on ferrite grains morphology, fineness, discreteness and its irregularity.

Keywords: Duplex Stainless steels; % Ferrite; Ferrite Number; Feritscope®; Volume fraction measurements; WRC-1992 Diagram; Weld metal dilution; grain morphology

1.0 INTRODUCTION

An annealed structure of duplex stainless steel has proportionately equal 50/50 amounts of ferrite and austenite, although the ratios often varying from approximately 35/65 to 55/45. Most petrochemical refinery applications, chemicals, waste water, and marine engineering fields and desalination industries are having sour and corrosive atmosphere, where DSSs or other higher alloys are required for tolerable corrosion resistance [1].

Duplex stainless steels have successful performance service record in corrosive and erosive environments up to 315°C (600°F), along with high immunity to stress corrosion cracking (SCC) in chloride environment [2].

DSSs are often used as an alternative to austenitic SS in services where the common austenitic would have problems with chloride pitting or chloride stress corrosion cracking (CSCC) [2].

Most of the industrial fabrications made of these duplex stainless steels are by welding using almost all the conventional welding processes like Shielded Metal Arc Welding (SMAW), Gas Metal Arc Welding (GMAW), Gas Tungsten Arc Welding (GTAW), Submerged Arc Welding (SAW) and Flux Cored Arc Welding (FCAW) [3].

The increasing usage of DSS in fabrications of corrosive industrial environment has made it very essential to control process parameters in fabrication processes and the necessity to measure precisely the amounts of the phases before the end use [4].

Unfortunately, the amount of phase determination can be influenced by the adopted techniques of measurements. Studies on the ferrite content measurement of DSS by Arnaldo Forgas Junior et al. [4-6] by means of two dissimilar techniques: quantitative examination of microstructure after suitably etched reagent and magnetic method of measurements with a Feritscope results revealed significant disagreements between the results obtained by these two industrially most practised methods[4-6].

As suggested in review work by M. Asuncion Valiente Bermejo [7], magnetic determination methods are more accurate than predictive methods, whose dependency is on chemical composition. While selecting suitable electrode out of many alternative welding consumables, for an approximation purpose, one can attempt WRC-1992, or numerical model FNN-1999, etc.

Issue of ferrite content is more severe with flux shielded metal (SMAW, FCAW, SAW), because the higher oxygen content (approx. 600 ppm or more) reduces CVN impact properties. The issue does not involve GTAW / GMAW processes because of controlled oxygen content (approx. less than 150 ppm).

Many times duplex stainless steel filler metal manufacturers have to balance between the required ferrite in weld deposits and CVN impact properties requirements as 27 J, 34 J or 47 J at -40°C,asper various codes imposed on the fabricators through their clients.

So it happens very often that a fabricator measures a little less or more than the specified ferrite requirement (35/65), while his consumer measures value below the specified limit ferrite content (less than 35) for the same batch of filler metal which put question mark whether this filler metal is to be acceptable or not. At the same time, it results in suspension in the execution of the project.

Duplex stainless steels welding consumables are often enriched with more nickel content than the parent metal composition, because nickel being one of the elements that promotes the formation of austenite. A duplex filler metal may contain up to 9% nickel, such as in standard AWS E2209-16 SMAW filler metal.

In any carefully welded duplex (ferritic-austenitic) stainless steel structure there will be degree of variation in weld metal ferrite content and in reproducibility of measurement which deserve a review of comparative study on different weld metal ferrite measurement techniques being widely used.

Above all literature mentions that no one reports metallographic % ferrite at the top surface to compare with FN measurements that are not altered by reheating due to multiple weld passes.

So, the present work has been carried out by collaborating with a reputed filler metal manufacturer who deliberately produced special batches of standard DSS composition matching SMAW electrodes with nickel varied content in the range of 9-9.5 %, 9.5-10.5, 10.5-11.5 and 11.5 to 12.5 % to obtain weld deposits in varied ferrite content range 15% to 40%, or 20 FN to 50 FN to be experimentally investigated by (1) Fischer-Feritscope® instrument method, (2) point count method and theoretically by (3) WRC-1992 Diagram.

The attempt of this paper is to present comparisons of routinely used techniques for ferrite measurement on duplex stainless steel welds.

Table 1 : Chemical Composition of UNS S32205 as per PMI Spectroscopy

C	Si	Mn	P	S	Cr	Ni	Mo	Nb	Cu	Co	N
0.023	0.37	1.50	0.018	0.001	22.37	5.72	3.21	0.11	0.14	0.08	0.177

Table 2 : Chemical compositions of the undiluted weld metals carried out on weld pad as per ASME SEC II C.

SMAW Electrode with Nickel content	C	Mn	Si,	S	P	Cr	Ni	Mo	Cu	N
Standard 2209 Electrode E2209	0.031	1.08	0.59	0.007	0.025	22.38	9.15	3.35	0.096	0.18
9.0 -9.5 % wt	0.031	0.98	0.61	0.007	0.022	22.32	9.20	3.32	0.089	0.19
9.5-10.5 % wt.	0.019	0.99	0.61	0.005	0.027	22.29	9.80	3.19	0.068	0.17
10.5-11.5 %wt.	0.021	0.99	0.58	0.007	0.028	22.35	10.20	3.16	0.075	0.16
11.5-12.5 %wt.	0.017	1.11	0.62	0.008	0.028	22.33	12.55	3.20	0.069	0.18

2.0 EXPERIMENTAL METHOD

2.1 Base Metal

The material procured for this investigation is standard 22 Cr 5 Ni duplex stainless steel designated as UNS S32205 procured from M/s Shanti Metal Suppler, Mumbai, India.

2.2 Filler Metal Consumables

Ms. GEE Ltd, Kalyan (West) Thane Mumbai, India deliberately produced special batches of standard DSS composition matching SMAW electrodes in standard size 3.15 X 350 mm length with nickel varied content in the range of 9-9.5 %, 9.5 - 10.5%, 10.5-11.5 % and 11.5 to 12.5 % to obtain weld deposits in varied ferrite content range15% to 40%, or 20 FN to 50 FN to be experimentally investigated by 1) Fischer-Feritscope® instrument method, 2) Point count method and 3) theoretically by WRC-1992 Diagram.

The objective is to deposit various ferritic-austenitic duplex weld metal having a ferrite content approximately 15% to 40%, or 20 FN to 50 FN in wide range covering the normal ferrite specification limit, 30 % to 60 % or 35 to 60 FN. Chemical compositions of the undiluted weld metals are shown in **Table 2.**

2.3 Welding Process and Test Coupon Preparation

Weld test coupons of UNS S32205 duplex stainless steel material of standard size 300 mm (L) X 150 mm(W) 25 mm (T) welded in flat position with 60° included angle, were produced using shielded metal arc welding (SMAW) process on international quality Miller Make XMT 350 OS Auto line welding machine. Backing plate material used was also prepared from UNS S32205 parent material. Preheating was not applied as per duplex stainless steel standard welding practices. Voltage and current range were maintained as 20-22 V & 100-120 A respectively, as per duplex stainless steel standard welding practice, heat input in the range of 0.5-2.5 kJ/mm, average 0.8kJ/mm. Interpass temperature was measured for each pass below 150 °C max using digital thermometer and temperature indicating crayons. Weld deposited with stringer bead technique with average travel speed 150-160 mm/min was employed. The plates of the test piece were restrained with "C"-clamp below so that sufficiently flat test piece can be extracted for ferrite measurement.

2.4 Measurement of Ferrite Content

The amount of ferrite content was measured by three different techniques:

i. Magnetic determination based instrument by Feritscope®, designed to be portable and provide the operator with a user-friendly interface, which readily provides ferrite content on the Ferrite Number as well as ferrite percentage after elaborate surface preparation of the specimens, five readings of the of ferrite percentage and Ferrite Number of each sample were taken with a FISCHER MAKE Feritscope 2531 ®Instrument; being calibrated with suitable standards. The Feritscope is a magnetic induction based instrument that quantifies the amount of the ferromagnetic phase [8-9], as shown in **Fig. 1.**

The measurement of ferrite was taken in both the ways, on

Fig 1 : Calibrated Fisher Feritscope Instrument Model Fischer 2531

weld cross section at different 10 points locations from cap, fill and root region, and on the top surface of the weld deposits across centre line of the weld bead at suitable 10 points locations.

ii. Quantitative optical metallography: ASTM Standard E562-11, "Standard Practice for Determining Volume Fraction by Systematic Manual Point Count method" [10]. This specification may be applied to any micro constituent or phase, which is metallographically identifiable. The principles governing this method are clearly defined in the specification. A two-dimensional metallographic sample is prepared and examined at an appropriate magnification. A grid is then superimposed over the image and the operator counts the number of points which fall within the desired phase or microconstituent. Statistical analysis reveals the fraction of points, which fall within the desired phase, and the volume fraction is then calculated. When correctly implemented, this technique is an excellent method for determining the volume fraction of a desired phase or micro constituent. All weld composition samples were examined after polishing to a 0.05 micron finish and etching with 10 % NaOH, using an image analysis routine with Microstructure Characterizer Software version 2.0 TCR Advanced Engineering, Mumbai Make, software, connected to optical microscope. 30 fields per sample were analysed at 400X magnification [10].

iii. WRC-1992 Diagram

Ferrite prediction and measurement is very important in duplex stainless steel. In DSS ferrite prediction can be done by WRC 1992 Diagram. Schaeffler and WRC constitution

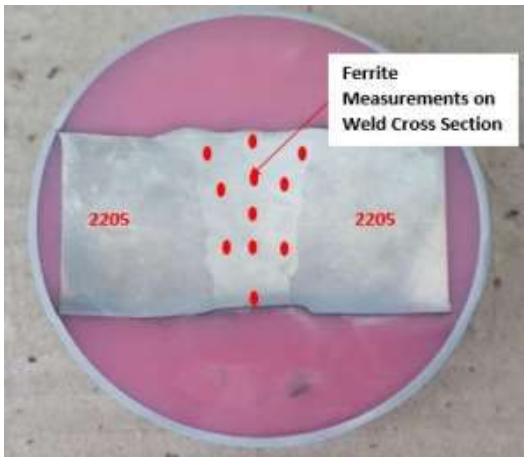


Fig. 2 : Ferrite measurement on 2205 weld cross section using Feritscope Instrument.

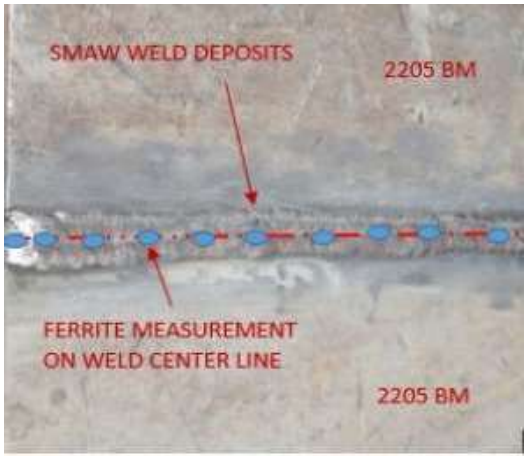
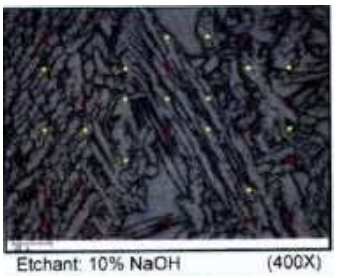


Fig. 3 : Ferrite measurement on 2205 weld deposits centre line using Feritscope Instrument



Frames	% Ferrite	Frames	% Ferrite	Frames	% Ferrite
1	45.9	11	37.8	21	40.8
2	40.8	12	43.9	22	34.7
3	35.7	13	43.9	23	39.8
4	40.8	14	38.8	24	42.9
5	39.8	15	40.8	25	44.9
6	42.9	16	38.8	26	40.8
7	42.9	17	39.8	27	41.8
8	44.9	18	45.9	28	26.0
9	48.0	19	42.9	29	40.8
10	45.9	20	37.8	30	37.8

Average of 30 Frames: 40.94 %

Requirement:

Fig. 4 : Micro observed under point count and statistical table of average 30 frame. DSS 2205, 10 % NaOHetched at 400 X magnification.

diagrams introduced a non-destructive method to relate alloy composition to the amount of ferrite present in an alloy. There are certain useful diagram like Schaeffler, WRC-DeLong diagrams and WRC 1992 Diagram. Among these, WRC-1992 Diagram is now latest and more precise for higher alloys and some special alloys like manganese-austenitic or duplex, ferritic-austenitic alloys [11, 12].

Regardless of long use, the Schaeffler Diagram is now obsolete since it does not take into account effect of nitrogen as austenite promoter and because it has failed to provide consistent result among several measures [11, 12].

These limitations associated with the Schaeffler Diagram were taken care of in the development of 1973 WRC-DeLong Diagram, which otherwise, could be used to predict ferrite content. The noteworthy differences between them are that as DeLong Diagram included nitrogen (N) in the Ni equivalent (% Ni + 30 x % C x 30x % N + 0.5 x % Mn) and suggests Ferrite Numbers in addition to "percent ferrite." Ferrite Numbers at low content may approximate "percent ferrite" [11, 12].

WRC-1992 Diagram has substituted the WRC-DeLong Diagram in the ASME

Code. Its Ni equivalent (% Ni + 35 x % C + 20 x % N + 0.25 Cu) and Cr equivalent (% Cr + % Mo + 0.7 x % Cb) became widely changed from those of Schaeffler and WRC-DeLong [11, 12].

The various alloying elements are known in terms of nickel or chromium equivalents (i.e. elements, like nickel, Carbon, nitrogen and copper tend to promote austenite phase and elements like chromium, molybdenum and niobium (Columbium) tend to promote ferrite phase).

By plotting the total values for the nickel and chromium equivalents on these diagrams, with help of filer metal and base metal composition, considering dilution of 15 % or 20 % from base metal and 70 % or 60 % contribution from filler metal, a suitable point can be decided that indicates the main phases present in the stainless steel in terms of % ferrite and Ferrite Number (FN) respectively [11-15].

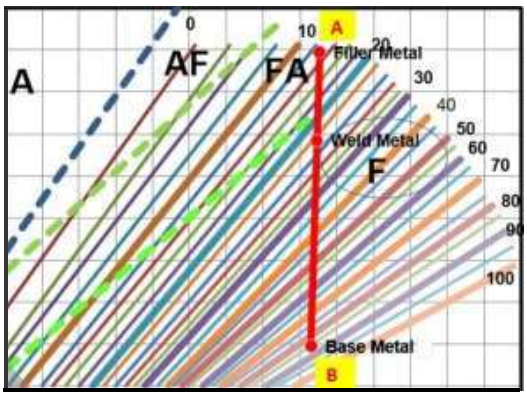


Fig. 5 : Weld coupon Id 12 Ni 22 Cr, considering total 30 % Dilution (15 +15 from each side of Base metal faying surface) Weld Metal is predicted with Ferrite Number 22.7 using WRC 1992 Diagram.

3.0 DISCUSSIONS OF RESULTS

3.1 Comparisons of Ferrite Measurement Results between ASTM E 562-11: Volume Fraction Measurement Method and Feritscope ® Instrument

As can be observed from above data, ASTM E-562 method depends on the grain morphology, distribution of ferrite and austenite grains in resultant weld deposits. As nickel being austenite promoter, in 11 Ni 22 Cr sample, more fine grained structure makes placement of the points on respective grains little difficult, moreover, the discrete and discontinuous type ferritic and austenitic grains impose limitations on the "statistical analysis" used by the program. So volume fraction

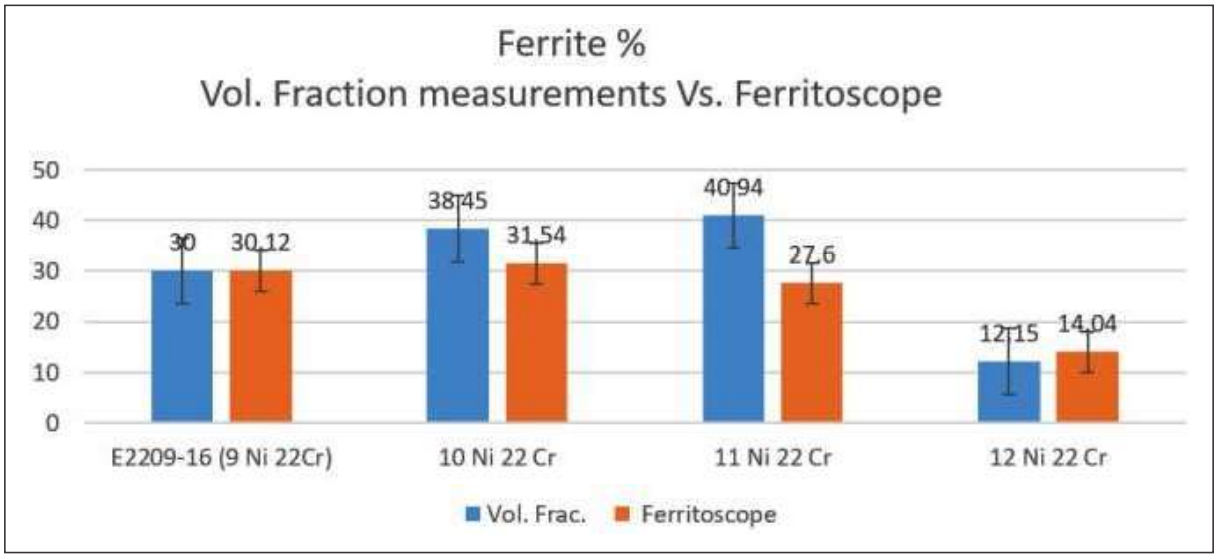


Fig. 6 : Comparative data of Ferrite measurement by Volume fraction measurement, point count method and Ferritscope instrument.

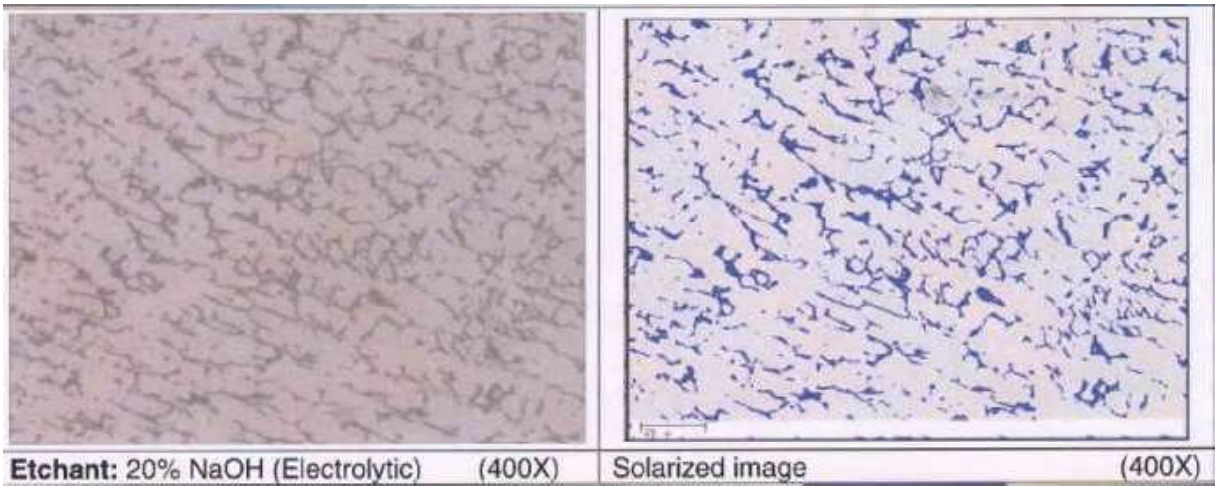


Fig. 7 : Fine grain weld metal zone microstructure of 11 Ni 22 Cr weld coupon. Dark phase is ferrite and light phase is austenite.

measurement by employing colour differentiations on micro structure overestimates the ferrite % as 40.94 while, using Feritscope, actual measured value is 27.6 ferrite % as can be seen from **Fig. 7** micrograph of 11 Ni 22 Cr weld coupon.

On the contrary, for the "favourable" grain morphology, i.e. which simply allows the placement of the points on the ferrite and austenite grains (as shown in **Fig. 8**), yellow points on light austenite grains and maroon points on dark ferrite grains) for weld sample 9 Ni 22 Cr gives approximate equal % ferrite reading 30 % by both methods, volume fraction method and Feritscope instrument. This metallographic method of ferrite measurement depends on many critical factors such as quality of sample preparations, magnification of image, identification of grains morphology, placement of points and more importantly operator's ability to interpret the microstructure.

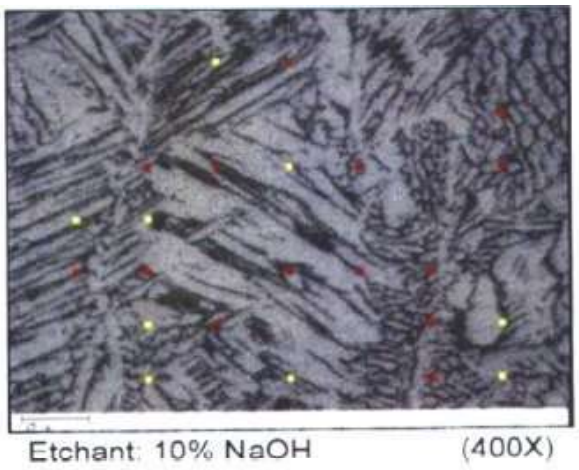


Fig. 8 : Photomicrograph of 9 Ni 22 Cr Weld coupon 10 % NaO Hetched at 400 X magnification reveals dark phase as ferrite and light phase as austenite.

3.2 Comparisons of Ferrite Measurement Results between Top Surface of Weld Deposits and Cross Section of Weld

Above results of % ferrite measurement on cross sections of all weld compositions by ASTM E 562, metallographic means show considerable variation with results obtained from Feritscope instrument, taken on weld centre line top surface, this is due to reason that in weld cross sections, the weld metal which has been subjected to reheating by subsequent weld passes, results in some loss of ferrite. This can also be revealed through scatter plots of Ferrite Number measurement data taken on centre line of weld deposit top surface and weld cross section for all weld compositions using Feritscope instrument only. As shown in **Fig. 10, Fig. 11, Fig. 12** and **Fig. 13.**

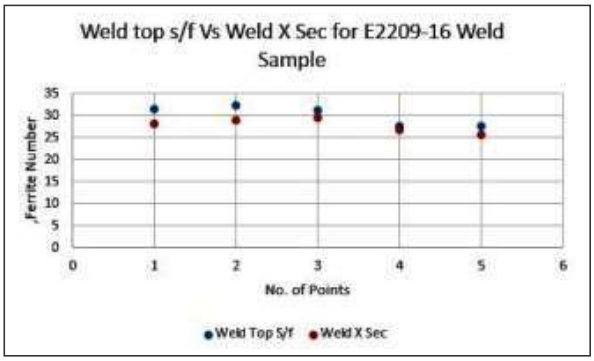


Fig. 10 : Scatter plot of FN measurement on weld top surface centre line and on weld cross section for E2209-16 weld sample.

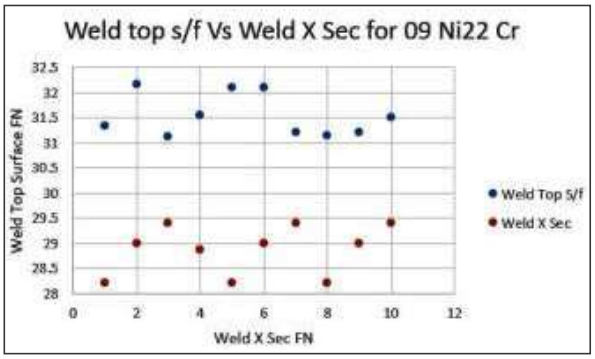


Fig. 11 : Scatter plot of FN measurement on weld top surface centre line and on weld cross section for 9 Ni 22 Cr weld sample.

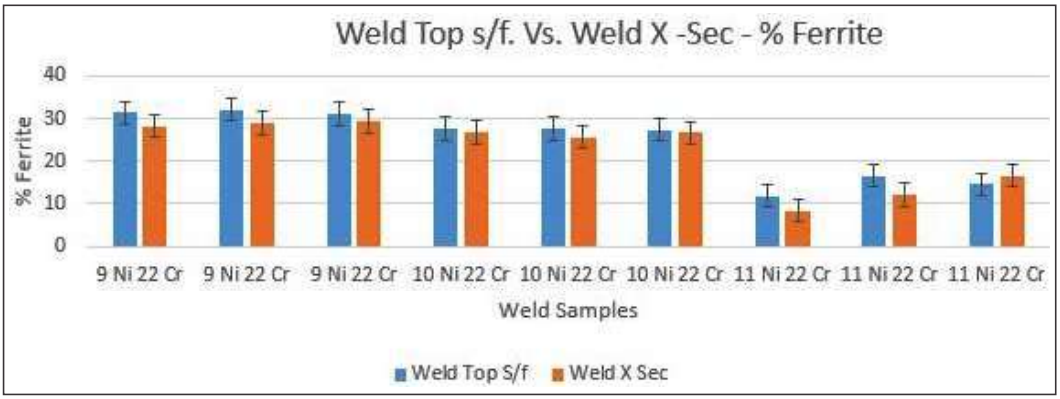


Fig. 9 : Comparisons of ferrite measurement results between top surface of weld deposits and cross section of weld for different weld compositions considered under study.

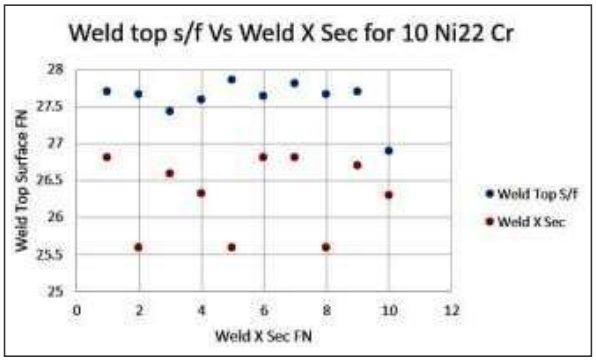


Fig. 12 : Scatter plot of FN measurement on weld top surface centre line and on weld cross section for 10 Ni 22 Cr weld sample.

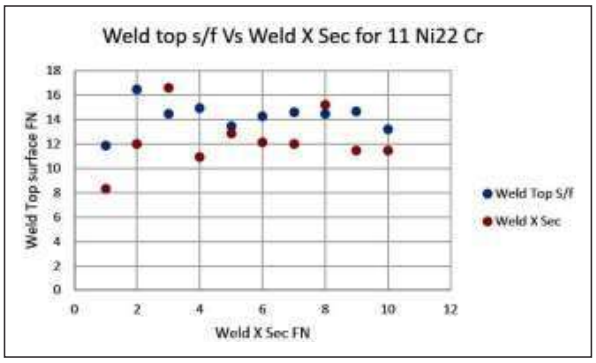


Fig. 13 : Scatter plot of FN measurement on weld top surface centre line and on weld cross section for 11 Ni 22 Cr weld sample.

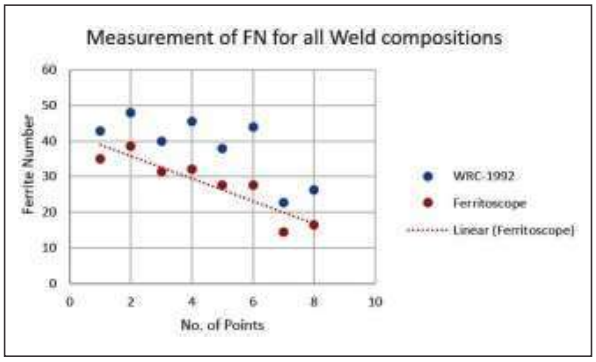


Fig. 14 : Scatter Plot of FN measurement results comparing WRC-1992 (predicted value) and Feritscope instrument (measured value) for all weld compositions (E2209-16, 9 Ni 22 Cr, 10 Ni 22 Cr and 11 Ni 22 Cr).

Table 3 : FN measurement results of WRC-1992 (predicted value) and Feritscope Instrument (measured value) for all weld compositions

Weld coupon ID	WRC-1992	Feritoscope
E2209-16	42.7	35
E2209-16	48	38.5
9 Ni 22 Cr	39.9	31.34
9 Ni 22 Cr	45.5	32.16
10 Ni 22 Cr	37.9	27.7
10 Ni 22 Cr	44	27.66
11 Ni 22 Cr	22.7	14.5
11 Ni 22 Cr	26.3	16.52

3.3 Comparisons of Ferrite Measurement Results between WRC-1992 Diagram (Predictive Method) and Feritscope Instrument (Actual Measurement Method)

By considering the 15-20% contributions from weld faying surfaces and 60-70 % contributions from filler metals, taking two different scenario of weld metal dilutions, WRC-1992 Diagrams prepared for all weld compositions can be compared with the Feritscope instrument methods. The **Fig. 14.** Scatter plots show that Feritscope results are more consistent, and displays rather linear trends, values being less scattered from the mean value than those of the WRC 1992 (predictive) method. This difference is due to any changes in weld metal dilutions during actual welding process.

4.0 CONCLUSIONS

- Ferrite % measurement by metallographic methods seems to be highly variable, depends on the ferrite - austenite grains morphology, distribution of phases, metallographic techniques and expertise of the user.
- The final weld metal composition, i.e. ferrite content and hence properties, mainly depend on the quantity of dilution that takes place during welding.
- Ferrite measurements taken on the top surface centre line of any given weld pass shows more consistent and accurate results than reading taken on weld cross section.

- The accuracy of predictive methods such as WRC 1992 Diagram depends on a chemical composition of base metal, filler metal and weld metal dilution.
- Predictive methods can be applied where different filler metals of varied chemical composition are to be tested for the weld metal composition before actual welds.
- Ferrite measurement, with an instrument calibrated according to ISO 8249, is preferred to ferrite prediction.
- Suitable guideline regarding location and method of ferrite measurement should be provided from the customer to the fabricator/ filler metal manufacturers to avoid any disagreements in ferrite measurement values.

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ATTACHMENT : 2

The 71st IIW

Annual Assembly & International Conference
Bali Nusa Dua Convention Center, Bali - Indonesia
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No. : 130/71IIW/III/2018 Jakarta, 15 March 2018

Dear Prof. Purvesh Nanavati,

The **71st IIW International Conference 2018** committee has completed the reviewing process of submitted abstracts and we are pleased to inform you that your abstract,

Paper ID 1807095

Author(s) : Prof. Purvesh Nanavati

Title : Some Pitfalls in Ferrite Measurement Techniques Used in Duplex Stainless Steel (UNS S32205) Welds

has been **ACCEPTED** for presentation at the conference in Bali, Indonesia on 19-20 July 2018. We cordially invite you to attend this event.

Please prepare your full paper manuscript according to the **attached template** to be considered for publication after reviewing process. The deadline for full paper submission is **30 May 2018** and subsequent camera-ready manuscript submission deadline is **1 June 2018**.

Full paper submission is open through the member area (https://www.iiw2018.com/member)

To reserve your participation at **The 71st IIW ANNUAL ASSEMBLY & INTERNATIONAL CONFERENCE 2018** please make your payment in advance. Early bird registration is available until 01 April 2018. Detail information about registration can be found here https://www.iiw2018.com/registration.

We look forward to host you and your delegates and enjoy the The 71st IIW ANNUAL ASSEMBLY & INTERNATIONAL CONFERENCE 2018 in Bali.

Best Regards,

Prof. Dr. Ir. Muhammad Anis, M.Met
Professor (Universitas Indonesia) – International Conference Chairman

Secretariat API-IWS
Jl. Bendungan Hilir Raya Blok G.II/13, Jakarta 10210, Indonesia
www.api-iws.org | P. +62 21-5732233 | F. +62 21-5712835 | E. sekretariat@api-iws.orf & info@iiw2018.com

Attachment: 03

GUJARAT COUNCIL ON SCIENCE AND TECHNOLOGY

Department of Science & Technology, Government of Gujarat

Block: B, 7th Floor, M.S. Building, Nr.Pathikashram, Sector-11
Gandhinagar, Gujarat-382011.
Phone: (079) 23259362-65 Fax: (079) 23259363
E-mail: sciof-gujcost@gujarat.gov.in
URL: www.gujcost.gujarat.gov.in

सत्यमेव जयते

Dr. Narottam Sahoo
Advisor & Member Secretary

No: GUJCOST/ MRP/ 2014-15/2546 30th March, 2015

Prof. P. K. Nanavati
Assist. Prof.
Dept. of Metallurgy Engg.
Government Engg. College
Sec-28,Gandhinagar-382028

Sub: Award of GUJCOST Minor Research Project Grant for the proposal on "Studies on Effect of welding parameters on Corrosion and Mechanical behaviour of Duplex Stainless welds" By Prof. P. K. Nanavati

Dear Sir,

Warm Greetings from Gujarat Council on Science and Technology (GUJCOST), Gandhinagar.

With reference to your project proposal on Studies on Effect of welding parameters on Corrosion and Mechanical behaviour of Duplex Stainless welds and subsequent presentation before the Expert Committee, GUJCOST is pleased to inform you that your proposal has been sanctioned for an amount of Rs. 1,10,000/- for two years' time period.

As per the GUJCOST guidelines and for the disbursement of the grant, a Memorandum of Understanding (M.O.U) has to be signed between the Principal/ Head of the Institute, Principal Investigator of the project and GUJCOST on Rs. 100/- stamp paper with Notary registration. A draft MOU has been enclosed herewith for your reference.

We request you to please send us the signed copy of the MOU at the earliest so that necessary financial assistance may be released.

Tanking you and with best regards.

Yours sincerely,

Encl.: As above

(Narottam Sahoo)

ATTACHMENT : 34

presentation of your paper in IIW Commission II
5 messages

damian@damiankotecki.com <damian@damiankotecki.com> Sun, Mar 11, 2018 at 3:20 AM
To: PK Nanavati <pknanavati@gecg28.ac.in>

Dear Professor Nanavati,

Attached is a summary of the comments received after my presentation, and my thoughts about those comments. The manuscript was accepted for presentation in Bali, but a decision was not taken immediately on publication in Welding in the World. I expect that will come in Bali. We have until the end of May to finalize the manuscript. I think that is easily done by addressing the comments on Table 5 and Figures 5 and 6.

Best Regards,
Damian

Summary of Comments on Effect of Ferrite in DSS Presentation.docx
23K

Summary of Comments on Effect of Ferrite in DSS Presentation

I made the presentation during the morning of Tuesday, 6 March. About 30 persons were present for the presentation. Reactions and comments were mostly positive. The document was accepted for presentation at the IIW Annual Assembly in Bali during the afternoon session Tuesday, 17 July, 14:00 to 18:00

Damian Kotecki

ATTACHMENT: 5

PK Nanavati <pknanavati@gecg28.ac.in>

updated version of II-C-548-18

7 messages

damian@damiankotecki.com <damian@damiankotecki.com> Fri, Mar 16, 2018 at 7:45 PM
To: Gerhard Posch <posch.gerhard@fronius.com>, Zhuyao Zhang <zhuyao.zhang@metrode.com>
Cc: PK Nanavati <pknanavati@gecg28.ac.in>

Dear Gerhard and Zhuyao,

After the II-C meeting, Professor Nanavati revised II-C-548-18 according to the discussions in Genoa. Attached is the revised manuscript ready for Bali.

If there are any problems with this, please advise.

Best Regards,
Damian

Research Paper_DSS_12-03-2018 revised.docx
5316K

Zhang, Zhuyao <Zhuyao.Zhang@metrode.com> Fri, Mar 16, 2018 at 11:36 PM
To: "damian@damiankotecki.com" <damian@damiankotecki.com>, Gerhard Posch <posch.gerhard@fronius.com>
Cc: PK Nanavati <pknanavati@gecg28.ac.in>

Dear Damian,

Thank you very much for the revised document.

Best regards,

Dr Zhuyao Zhang
Technical Director
Metrode Products Ltd.
T: +44 (0) 1932 580066
M: +44 (0) 7789 391 617
F: +44 (0) 1932 566449
E: zhuyao.zhang@metrode.com

www.metrode.com

METRODE
A Lincoln Electric Company

From: damian@damiankotecki.com [mailto:damian@damiankotecki.com]
Sent: 16 March 2018 14:16
To: Gerhard Posch; Zhang, Zhuyao
Cc: PK Nanavati
Subject: updated version of II-C-548-18

[Quoted text hidden]

06
Test Certificate and BM Validation report

OUTOKUMPU

Avesta Works

QCM. Jan Egerstad

CERTIFICATE - ZEUGNIS - CERTIFICAT 1/1

EN 10204-3.1

Date - Datum	Load - Ladung - Chargem No	Cert. No. - Zeugnis No
09-Dec-2010	SE7O-0110	1517093-EN

Your order - Ihre Bestellung - Votre commande
174565

Avesta order - Auftrag - Order Invoice - Rechnung - Facture
661/619101 661/0663791

Purchaser - Besteller - Acheteur
OUTOKUMPU NORDIC AB
BOX 1134
SE-631 80 ESKILSTUNA
SWEDEN

Requirements - Anforderungen - Exigences
ASTM A 240-06
ASME SA-240 2004 A05
EN 10051/ASTM A 480

Dest
OUTOKUMPU NORDIC AB

Product - Erzeugnisform - Produit
Stainless Steel Hot Rolled, Coil-Plate
finish 1D, cut edge

Grade - Werkstoff - Nuance
Outokumpu 2205
UNS S31803/UNS/1.4462

Brand mark Herstellerzeichen Signe du producteur	Inspectors stamp Abname Stempel Estamp de l' expert	Melting process Erschmeltzungsart Procede de fusion
OUTOKUMPU	AJA	E + AOD

Extent of delivery - Lieferumfang - Etendue de livre

Item Pos Poste	Pcs Anzahl Nombre	Kg.	Dimensions Abmessungen mm	Dimensions	Heat No. Schmelze Nr. Coulee No.	Lot No. Los Nr. Lot Nr.
4	1	903	25.00 1500 3000		31803 -	005

Chemical composition - Chemische Zusammensetzung - Composition chimique

	C	Si	Mn	P	S	Cr	Ni	Mo	Nb	Cu	Co	N
Heat	.023	.37	1.50	.018	.001	22.37	5.72	3.21	.011	.14	.08	.177

Radioactive contamination check acc. IAEA recommendations: Satisfactory

Test result s - Prufergebnisse - Results dessais (1N/mm 2 = 1 MPa) F = Front - Anfang - Debut B = Back - Ende - Fin T = Transverse - Quer - Travers

	Test Ref Probe Ref Eprouv Ref		Temp C	RP 0.2 N/MM2	RP 1.0 N/MM2	RM N/MM2	A5 %	2* %	HB HB	SING-1 J/CM2	SING-2 J/CM2	SING-3 J/CM2	MEAN J/CM2	FEH %
Min			+20	480		660	25	25		100	100	100	100	
Max						950								
	F	T	+20	659	705	822	30	30	265	334	343	350	342	51.0
	B	T		668	714	819	26	27	268	347	401	385	378	

Microstructure acc to ASTM A 923-A: Satisfactory
PRE: Cr + 3,3Mo + 16N = 35.7
Corrosion acc. EN ISO 3651-2C: Satisfactory
Heat treatment : Material temperature 1100 cel / Quenched (forced air + water)
Steel grade verification (PMI-spectroscopic): OK
Insp. and gauge measurement: Satisfactory
Certified acc. Pressure Equipment Directive (97/23/EC) by TUV CERT-Certification body for pressure equipment of the TUV NORD GROUP; notified body, reg-no. 0045.

Otokumpu Stainless AB
Avesta Works
BOX 74
S-774 22 AVE37A
SWEDEN
Regoffice Stockholm Reg No: 556001-8748

Telephone : + 46 (O)226 813 57
fax : + 46 (O)226 813 16
V. A. T. no : SE556001874801

This material is found to comply with order requirements

Authorized Inspector

EN ISO 9001
EN ISO 14001

AADHYA ENGINEERING

AADHYA ENGINEERING SERVICES

ISO 9001:2008 Certified

Office : D/34, Madhav Nagar Society, Sahajanand Marg, Mujmahuda, Vadodara-20.
Works: 48/2, GIDC, Makarpura, Vadodara-390010

CHEMICAL TEST REPORT

Doc. No. AES/F/02

Test Report No. : AES/SA/18/110	Date of Receipt: 15.10.2018	Date of Test: 15.10.2018	Page No. : 1 of 1

Name of The Customer	**Purvesh Nanavati** Government Engg.College , SEC-28 , Gandhinagar
Test Performed At	Aadhya Enginering Services
Material Specification	ASTM A 240 UNS 32205
Material Description	Cut Piece of 25 mm Wrought Duplex stainless steel
Sample Identification	--
Sample Condition	Test Pc
Sample Drawn By	Party
Test Method	AES/SOP/02-Chemical Test (ASTM E - 1086 : 2014)
Customer's Reference No.	Dt: 15.10.2018

TEST RESULTS

Lab ID	Element	Required Value in %	Observed Value in %
SA/18/110	Carbon	0.03 Max	0.023
	Manganese	2.0 max	1.510
	Silicon	1.0 max	0.370
	Phosphorus	0.030 max	0.018
	Sulphur	0.020 max	0.001
	Chromium	22.0 - 23.0	22.370
	Nickel	4.5 - 6.5	5.720
	Molybdenum	3.0 - 3.5	3.210
	Nitrogen	0.14 - 0.20	0.177

Equipment Sr no : 17 269 SCP 11 , Make : GNR Analytical Instruments Group

Remarks : Above results are meeting with chemical requirments of ASTM A 240 UNS 32205 with respect of test carried out.

Tested by	Authorised Signatory	Witnessed By
	AADHYA ENGINEERING SERVICES VADODARA Rakesh Vasava	

Note: (a) Sample(s) not drawn by AES. The results relate only to the sample(s) tested. (b) This certificat shall not be reproduced, except in full, without the written approval of AES. (c) If balance material is available after testing, it will be retained for 15 days maximum. If customer wants to retain it for one month from this date, he has to inform in writing or he can collect the same. (d) While ' AES' has made their best endeavors to provide accurate and reliable information, 'AES' is not responsible for any financial liability due to any act of omission or error made.

Rakesh H. Vasava M: 9537530900 Raghavendra P Joshi M: 8000296579
aadhya.engineers@gmail.com

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Works: 48/2, GIDC, Makarpura, Vadodara-390010

TENSILE TEST REPORT

Doc. No. UMS/F/01

Test Report No. : UMS/T/111	Date of Receipt : 15.10.2015	Date of Test : 15.10.2018	Page No. : 1 of 1

Name of The Customer	**Purvesh Nanavati** Government Engg.College , SEC-28 , Gandhinagar
Test Performed At	Aadhya Enginering Services
Material Specification	ASTM A 240 UNS 32205
Material Description	Cut Piece of 25 mm Wrought Duplex stainless steel
Sample Identification	--
Sample Condition	Sample
Sample Drawn By	Party
Test Method	AES/SOP/03 - Tensile (ASTM A370)
Customer's Reference No.	Dt: 15.10.2018

TEST RESULTS

Sr. No.	Lab ID	OD / Width	Thk	Area	Gauge Length	Final Length	(0.2%)Yield Load	Ultimate Load	(0.2%)Yield Strength	Tensile Strength	Elongation	R.A.
		mm	mm	mm^2	mm	mm	kN	kN	MPa	MPa	%	%
Acceptance Criteria							Minimun		450	655	25	---
							Maximum		---	--	---	---
1	T 111	12.52	25.01	313.13	50.00	68.32	170.40	248.50	544.2	793.6	36.64	--

Remarks : Above results are meeting with Tensile requirments of ASTM A 240 UNS 32205 with respect of test carried out.

Tested On : UTM 1000kN	Sr. No : 2012/04
Calibrated On : 11.02.2017	Next Calibration Due Date : 11.02.2018

Tested by	Authorised Signatory	Witnessed By
	Rakesh Vasava	

Note: (a) Sample(s) not drawn by AES. The results relate only to the sample(s) tested. (b) This certificat shall not be reproduced, except in full, without the written approval of AES. (c) If balance material is available after testing, it will be retained for 15 days maximum. If customer wants to retain it for one month from this date, he has to inform in writing or he can collect the same. (d) While ' AES' has made their best endeavors to provide accurate and reliable information, 'AES' is not responsible for any financial liability due to any act of omission or error made.

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aadhya.engineers@gmail.com

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Works: 48/2, GIDC, Makarpura, Vadodara-390010

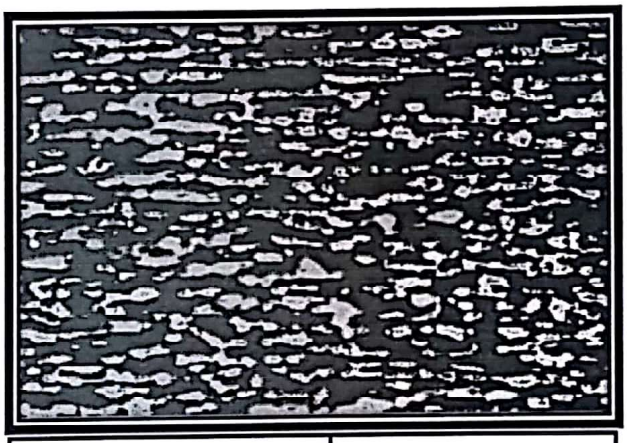
MICRO TEST REPORT

Doc. No. UMS/F/04

Test Report No. : UMS/M/114	Date of Receipt : 01.10.2018	Date of Test : 01.10.2018	Page No.: 1 of 1

Name of The Customer	**Purvesh Nanavati** Government Engg.College , SEC-28 , Gandhinagar
Test Performed At	Aadhya Enginering Services
Material Specification	ASTM A 240 UNS 32205
Material Description	Cut Piece of 25 mm Wrought Duplex stainless steel
Sample Identification	--
Sample Condition	Sample
Sample Drawn By	Party
Test Method	UMS/SOP/04 - Ferrite Content & Phase Balance Measurmtnt (ASTM E : 562)
Customer's Reference No.	On : 01.10.2018

Microstructure



Parent Metal	100 x

Observation : Ferrite Content : 50% - 55% For Parent Metal.
(Quantitative Metallography by Image Analyser)

Tested by	Authorised Signatory	Witnessed By
	Rakesh Vasava	

Note: (a) Sample(s) not drawn by AES. The results relate only to the sample(s) tested. (b) This certificat shall not be reproduced, except in full, without the written approval of AES. (c) If balance material is available after testing, it will be retained for 15 days maximum. If customer wants to retain it for one month from this date, he has to inform in writing or he can collect the same. (d) While ' AES' has made their best endeavors to provide accurate and reliable information, 'AES' is not responsible for any financial liability due to any act of omission or error made.

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Works: 48/2, GIDC, Makarpura, Vadodara-390010

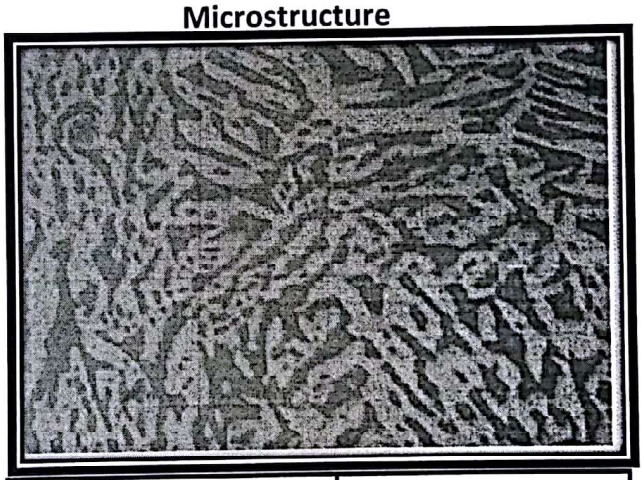
MICRO TEST REPORT

Doc. No. UMS/F/04

Test Report No. : UMS/M/113	Date of Receipt : 15.10.2018	Date of Test : 15.10.2018	Page No.: 1 of 1

Name of The Customer	**Purvesh Nanavati** Government Engg.College , SEC-28 , Gandhinagar
Test Performed At	Aadhya Enginering Services
Material Specification	ASTM A 240 UNS 32205
Material Description	Cut Piece of 25 mm Wrought Duplex stainless steel
Sample Identification	--
Sample Condition	Sample
Sample Drawn By	Party
Test Method	UMS/SOP/04 - Micro Test
Customer's Reference No.	On : 15.10.2018

Microstructure



Parent Metal	400 x

Observation : Microstructure shows a typical duplex microstructure of ferrite and austenite.

Tested by	Authorised Signatory	Witnessed By
	Rakesh Vasava	

Note: (a) Sample(s) not drawn by AES. The results relate only to the sample(s) tested. (b) This certificat shall not be reproduced, except in full, without the written approval of AES. (c) If balance material is available after testing, it will be retained for 15 days maximum. If customer wants to retain it for one month from this date, he has to inform in writing or he can collect the same. (d) While ' AES' has made their best endeavors to provide accurate and reliable information, 'AES' is not responsible for any financial liability due to any act of omission or error made.

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AADHYA ENGINEERING SERVICES

ISO 9001:2008 Certified

Office : D/34, Madhav Nagar Society, Sahajanand Marg, Mujmahuda, Vadodara-20.
Works: 48/2, GIDC, Makarpura, Vadodara-390010

HARDNESS TEST REPORT

Doc. No. UMS/F/04

Test Report No. : UMS/H/112	Date of Receipt : 15.10.2018	Date of Test : 15.10.2018	Page No. : 1 of 1

Name of The Customer	**Purvesh Nanavati** Government Engg.College , SEC-28 , Gandhinagar
Test Performed At	Aadhya Enginering Services
Material Specification	ASTM A 240 UNS 32205
Material Description	Cut Piece of 25 mm Wrought Duplex stainless steel
Sample Identification	--
Sample Condition	SAMPLE
Sample Drawn By	Party
Test Method	UMS/SOP/06 - Brinnel Hardness Test
Customer's Reference No.	Dt: 15.10.2018

TEST RESULTS

Lab ID	Load / Type	Location	Reading					Min.	Max.
			1	2	3	4	5		
Required Value as per specification								-	-
H 112	BHN	--	224	226	224	--	--	--	293

Remarks : Above results are meeting with Hardness requirments of ASTM A 240 UNS 32205 with respect of test carried out.

Tested by	Authorised Signatory	Witnessed By
	AADHYA ENGINEERING VADODARA Rakesh Vasava	

Note: (a) Sample(s) not drawn by AES. The results relate only to the sample(s) tested. (b) This certificat shall not be reproduced, except in full, without the written approval of AES. (c) If balance material is available after testing, it will be retained for 15 days maximum. If customer wants to retain it for one month from this date, he has to inform in writing or he can collect the same. (d) While ' AES' has made their best endeavors to provide accurate and reliable information, 'AES' is not responsible for any financial liability due to any act of omission or error made.

Rakesh H. Vasava M: 9537530900 Raghavendra P Joshi M: 8000296579

aadhya.engineers@gmail.com

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Works: 48/2, GIDC, Makarpura, Vadodara-390010

IMPACT TEST REPORT

Doc. No. UMS/F/07

Test Report No. : UMS/I/115	Date of Receipt : 15.10.2018	Date of Test : 15.10.2018	Page No.: 1 of 1

Name of The Customer	**Purvesh Nanavati** Government Engg.College , SEC-28 , Gandhinagar
Test Performed At	Aadhya Enginering Services
Material Specification	ASTM A 240 UNS 32205
Material Description	Cut Piece of 25 mm Wrought Duplex stainless steel
Sample Identification	--
Sample Condition	Sample
Sample Drawn By	Party
Test Method	UMS/SOP/07 - Impact Test (ASTM A370)
Customer's Reference No.	Dt: 15.10.2018

TEST RESULTS

Lab ID	Size (mm)	Temp. (°C)	Location		Readings				Acceptance Criteria	
					1	2	3	Avg.	Individual	Average
I 115	10 X 10 X 55	-20 °C	PARENT	Energy (J)	62	65	60	62.3	--	--
				L.E (mm)	--	--	--	--	--	--
				% S.A	--	--	--	--	--	--

Remarks : - Above results are meeting with Impact requirments of ASTM A 240 UNS 32205 with respect of test carried out.
- Zero Value Checked Before & After Tesing.

Tested by	Authorised Signatory	Witnessed By
	AADHYA ENGINEERING SERVICES VADODARA Rakesh Vasava	

Note: (a) Sample(s) not drawn by AES. The results relate only to the sample(s) tested. (b) This certificat shall not be reproduced, except in full, without the written approval of AES. (c) If balance material is available after testing, it will be retained for 15 days maximum. If customer wants to retain it for one month from this date, he has to inform in writing or he can collect the same. (d) While ' AES' has made their best endeavors to provide accurate and reliable information, 'AES' is not responsible for any financial liability due to any act of omission or error made.

Rakesh H. Vasava M: 9537530900 Raghavendra P Joshi M: 8000296579
aadhya.engineers@gmail.com

DATE: 08.03.2017

07
All weld test reports

To,
TCR ADVANCED ENGINEERING PVT LTD.
250-252/9,
GIDC Estate,
Makarpura,
Vadodara - 390010

Subject: Testing
Coupon ID. : E2209(12Ni22Cr)
Material : DSS
Welding Process : SMAW
Filler Wire : E2209-16 (GRINOX-2209)
Test Coupon : 500L * 300W * 25T mm
Heat treatment : NA
Welding Position : Flat
Type of testing : ***RT (Radiography) : No indication – Acceptance criteria and as per below table***

PQR No. E2209(12Ni22Cr)							
Sr. No	**Heat Treatment**	**Types of Test**	**Orientation**	**Location**	**No. of Test Spec.**	**Test Temp. (°C)**	**Acceptance Criteria**
1	NA	Chemical Analysis	Transverse	T/2	1 No. per location	RT	C%,Mn%,Si%,S%,P%,Cr %,Ni%,Mo%,Cu%,N% : to report
		Tensile Test	Transverse	Full Thickness	2 Nos.	RT	UTS: To report % EL & % RA to be reported
		Hardness Test	Transverse	WELD,BM,HAZ	3 Readings per Location	RT	To report
		Tensile Test	Longitudinal	All weld	2 Nos.	RT	UTS, Y.S : To report % EL & % RA to be reported
		FN	Transverse	WM	1	RT	Ferrito scope and point count method
		Macro Examination	Transverse	On the cross section of weld	1 No.	RT	Free from defect

- **Remaining test coupon and base material to be given back after testing**
- **Testing to be witness by Mr. Purvesh Nanavati (9879332449)**

Terms:
1) Payment will be done after receipt of Original Invoice & Test Results within 7 days through RTGS / NEFT.

Thanking you,
Purvesh Nanavati (9879332449)
GOVERNMENT ENGG.COLLEGE,
SEC-28, GANDHINAGAR

TCR ADVANCED ENGINEERING PVT. LTD.

Regd. Off. : 250-252/9, GIDC Estate, Makarpura, Vadodara – 390010
Ph. No. : (0265) 2657233, 7574805594-96, 8511117993
E-mail : accounts@tcradvanced.com **Website :** www.tcradvanced.com

NABL ACCREDITED LABORATORY AS PER ISO/IEC 17025 FOR CHEMICAL, MECHANICAL & NDT TESTING

INVOICE

To.	Purvesh Nanavati	Invoice No.:	ST/16-17/9593
	Government Engg. College	Date :	24.03.2017
	SEC-28,	T. C. No.:	P-08252-53
	Gandhinagar	T. C. Date :	24.03.2017
	Contact Person:		
	Your Ref. No. & Sample Letter Date: 08.03.2017		

Sr. No.	ITEM	DESCRIPTION	QTY	RATE	AMOUNT
1		Chemcal Analysis (10 Elements-Ferrous)	1	450.00	450.00
2		Tensile Test	4	180.00	720.00
3		Hardness profile for welded sample (Up to 10 Locations)	1	800.00	800.00
4		Ferrite measurement by ferritoscope (Up to 3 measurements)	1	500.00	500.00
5		Macro Structure Examination	1	375.00	375.00
6		Cutting Charge (12 cut)	12	340.00	4,080.00
7		Machining Charge	2	375.00	750.00
8		Machining Charge	2	300.00	600.00
		Less: Discount on Rs. :	2,845.00	40.00%	1,138.00
			GROSS:		7,137.00
		Add: Service Tax on Rs. :	7,137.00	14.00%	999.00
		Add: Swachh Bharat Cess :	7,137.00	0.50%	36.00
		Add: Krishi Kalyan Cess :	7,137.00	0.50%	36.00
			Total:		**8,208.00**

AMOUNT IN WORDS: Eight Thousand Two Hundred Eight Rupees and No paise

PAYMENT TERMS: Immediate (Labour Charges Only)

PAN : AABCT 3473E
SERVICE TAX NO. AABCT3473EST001
CATEGORY OF SERVICE:
SCIENTIFIC & TECHNICAL CONSULTANCY SERVICE (00440125)
DIVISION: CITY, ACCOUNTING COLLETORATE:- VADODARA - II
Interest @ 18% P.A. will be charged if payment is not made within 30 days.
E & O. E.

For TCR ADVANCED
ENGINEERING PVT. LTD.

AUTHORISED SIGNATORY

TCR Advanced Engineering P. Ltd.

TCR ADVANCED ENGINEERING PVT. LTD.

Research Center & Testing Division:
Regd. Off. : 250-252/9, GIDC Estate, Makarpura, Vadodara – 390010

PH: (0265) 2657233, 7574805594,7574805595,8511117993
Email : testing@tcradvanced.com Website : www.tcradvanced.com

Managing Director
Paresh U. Haribhakti
BE. (Met.), M.E. (Mat. Tech.) MIE, LMIIM,LMIIW, Chartered Engineer

ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-08252.1 Page 1 of 1 Date: 29.03.2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Chemical Analysis by Optical Emission Spectrometer Method

TEST METHOD: ASTM E-1086-08, IS 9879-98

Test performed at: TCR Advanced Engineering Pvt. Ltd., Testing Division

Instrument utilized:	Optical Emission Spectrometer, SpectromaxX, TCRADV/E-1
*Customer's Reference:	Letter Dated : 08.03.2017
Sample received on:	10.03.2017
*Condition of sample:	Welded Plate Sample
*Nature of sample:	Welded Plate Sample - 500mmL X 300W X 25mm Thk
*Specification:	DSS
Date of completion of test:	29.03.2017 Sample Drawn by **Witness By Client**

***SAMPLE ID: Coupon ID - E2209(12Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Weding Position - Flat**

ELEMENT	RESULT
Carbon (%)	0.023
Sulfur (%)	0.002
Phosphorous (%)	0.024
Manganese (%)	1.180
Silicon (%)	0.540
Chromium (%)	21.790
Nickel (%)	12.320
Molybdenum (%)	3.060
Copper (%)	0.076
Nitrogen (%)	0.151

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Chaitanya

Authorised Signatory
K. S. RANA (T.M.)

Advanced Engineering P. Ltd.

Managing Director
Paresh U. Haribhakti
BE. (Met.), M.E. (Mat. Tech.) MIE, LMIIM,LMIIW, Chartered Engineer

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-08252.6	Page 1	Date: 25.03.2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division		
Instrument utilized:	TCRADV/E-/		
Client's Reference:	Letter Dated : 08.03.2017		
Sample received on:	10/03/2017		
Condition of sample:	Welded Plate Sample		
Nature of sample:	Welded Plate Sample - 500mmL X 300W X 25mm Thk		
Specification	-		
Date of completion of test:	25/03/2017	Sample Drawn by	**Witness By Client**

***SAMPLE ID: Coupon ID - E2209(12Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Weding Position - Flat**

Transverse Tensile Test:

Test Method: ASME sec IX Ed 2015

Sample Mark:	**Sample 1**	**Sample 2**	**Minimum Required**
Thickness (mm)	25.15	22.90	
Width (mm)	19.29	19.13	
Area (mm^2)	485.14	438.08	
Ultimate Load (N)	370590	340620	
UTS (N/mm^2)	764	778	-
Fracture	AT P.M.	AT P.M.	
Fracture Type	Ductile	Ductile	

Bend Test

Test method: -

Type of Bend Test	**Face Bend**		**Root Bend**		**Maximum Allowed**
	1	2	1	2	
Bending Dia. (mm)	-	-	-	-	
Bending Angle	-	-	-	-	
Observation	-	-	-	-	- mm
Result	-	-	-	-	

Remarks: -

Checked By: Ankur

ADVANCED ENGINEERING PVT. LTD. VADODARA

Authorised Signatory
K. S. RANA (T.M.)

TCR Advanced Engineering P. Ltd.

Managing Director
Paresh U. Haribhakti
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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-08252.2	Page 1 of 1	Date: 24/03/2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Tensile Test

TEST METHOD: AWS B4.0

Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division		
Instrument utilized:	TCRADV E-2		
*Customer's Reference:	Letter Dated : 08.03.2017		
Sample received on:	10/03/2017		
*Condition of sample:	Welded Plate Sample		
*Nature of sample:	Welded Plate Sample - 500mmL X 300W X 25mm Thk		
*Specification:	-		
Date of completion of test:	24/03/2017	Sample Drawn by	**Witness By Client**

***SAMPLE ID: Coupon ID - E2209(12Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Weding Position - Flat**

TEST	RESULT
Gauge Dia. (mm)	12.31
Area (mm^2)	119.01
Gauge Length (mm)	50.00
Final Length (mm)	63.70
Final Dia. (mm)	7.32
0.2% Proof Load (N)	76610
Ultimate Load (N)	92619
0.2% Proof Stress (N/mm^2)	644
U.T.S. (N/mm^2)	778
% Reduction in area	64.64
% Elongation	27.4
Fracture	W.G.L

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Ankur

Authorised Signatory
K. S. RANA (T.M.)

TCR Advanced Engineering P. Ltd.

TCR ADVANCED ENGINEERING PVT. LTD.

Research Center & Testing Division:
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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-08253.1	Page 1 of 1	Date: 24/03/2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Tensile Test

TEST METHOD: AWS B4.0

Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division		
Instrument utilized:	TCRADV E-2		
*Customer's Reference:	Letter Dated : 08.03.2017		
Sample received on:	10/03/2017		
*Condition of sample:	Welded Plate Sample		
*Nature of sample:	Welded Plate Sample - 500mmL X 300W X 25mm Thk		
*Specification:	-		
Date of completion of test:	24/03/2017	Sample Drawn by	**Witness By Client**

***SAMPLE ID: Coupon ID - E2209(12Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Weding Position - Flat**

TEST	RESULT
Gauge Dia. (mm)	12.40
Area (mm^2)	120.76
Gauge Length (mm)	50.00
Final Length (mm)	64.87
Final Dia. (mm)	7.55
0.2% Proof Load (N)	70971
Ultimate Load (N)	91740
0.2% Proof Stress (N/mm^2)	588
U.T.S. (N/mm^2)	760
% Reduction in area	62.92
% Elongation	29.74
Fracture	W.G.L

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Ankur

Authorised Signatory
K. S. RANA (T.M.)

Advanced Engineering P. Ltd.

Managing Director
Paresh U. Haribhakti
BE. (Met.), M.E. (Mat. Tech.) MIE, LMIIM,LMIIW, Chartered Engineer

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-08252.6	Page 1 of 1	Date: 24.03.2017

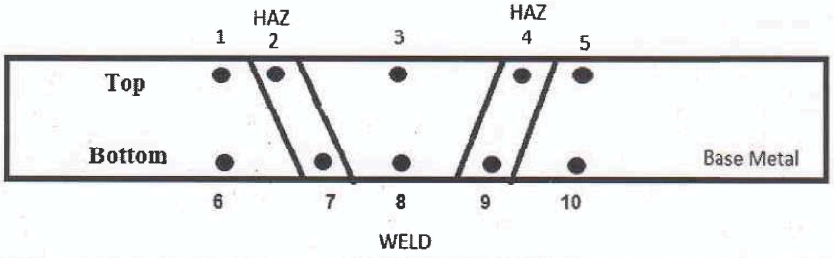
To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Welded Coupon Hardness Test

TEST METHOD: TCRADV/TM-11,E-384,EN ISO 9015-1:2011

Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division		
Instrument utilized:	Vickers cum Brinnel Hardness tester		
*Customer's Reference:	Letter Dated : 08.03.2017		
Sample received on:	10.03.2017		
*Condition of sample:	Welded Plate Sample		
*Nature of sample:	Welded Plate Sample - 500mmL X 300W X 25mm Thk		
*Specification:	-		
Date of completion of test:	24/3/2017	Sample Drawn by	**Witness By Client**

***SAMPLE ID: Coupon ID - E2209(12Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Weding Position - Flat**



LOCATION	Hardness in 'HV' at 10kg load	LOCATION	Hardness in 'HV' at 10kg load
Loc-1	238, 238, 237	Loc-6	237, 237, 235
Loc-2	251, 251, 249	Loc-7	262, 260, 260
Loc-3	228, 227, 227	Loc-8	243, 243, 245
Loc-4	251, 251, 253	Loc-9	253, 253, 254
Loc-5	243, 243, 245	Loc-10	233, 233, 232

Checked By: Ankur

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Authorised Signatory
K. S. RANA (T.M.)

Advanced Engineering P. Ltd.

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

REPORT NO: P-08252.2	Page 1 of 1	DATE : 29.03.2017

CUSTOMER : Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Ferrite Measurement

TEST PROCEDURE NO : TCRADV/TM- 62 REV. : 0

Test performed at: TCR Advanced Engineering Pvt. Ltd., Testing Division

Instrument utilized	Fischer Ferritoscope Make: Fischer, Germany SERIAL NO : [redacted] 2531	
*CLIENT REF:	Letter Dated : 08.03.2017	
*Condition of sample:	Welded Plate Sample	
*Nature of sample:	Welded Plate Sample - 500mmL X 300W X 25mm Thk	
*Specification:	DSS	
Date of completion of test:	29.03.2017	Sample Drawn by: **Witness By Client**

Coupon ID - E2209(12Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat

Observation:

Sr. No	Description	Ferrite Number	Average
01	Weld	9.9,9.8,10.0,9.3,9.6	9.72

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Vishal

Authorised Signatory
K. S. RANA (T.M.)

TCR Advanced Engineering P. Ltd.

Managing Director
Paresh U. Haribhakti
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ON APPROVED LIST OF VERIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P08252.7	Page 1 of 1	Date: 29.03.2017

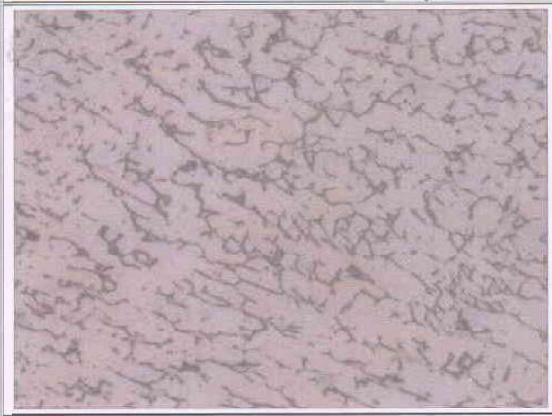
To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar.

Test: Volume Fraction of Ferrite/Austenite

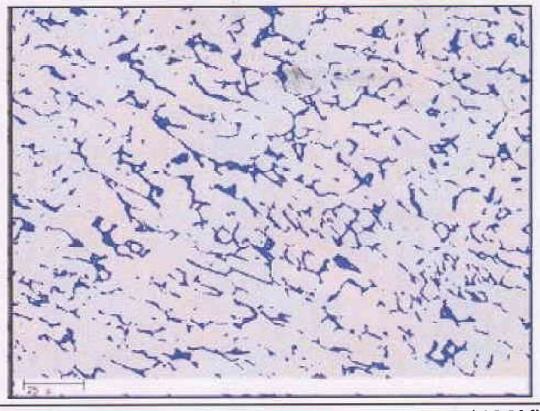
Test Method: TCRADV/TM-20 (As Per ASTM E-562)

Test Performed at	:	TCR Advanced Engineering Pvt. Ltd., Testing Division		
Instrument Utilized:	:	Optical Microscope, TCRADV/E-20		
*Customer's Reference:	:	Letter Dated : 08.03.2017		
Sample received on	:	11.08.2015		
*Condition of Sample	:	Welded Plate Sample		
*Nature of Sample	:	Welded Plate Sample - 500mmL X 300W X 25mm Thk		
*Specification	:	DSS		
Date of completion of test	:	29.03.2017	Witness: By	**Client**

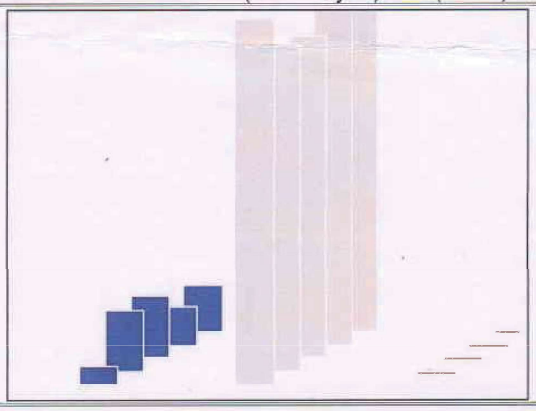
***SAMPLE ID:- Coupon ID - E2209(12Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**



Etchant: 20% NaOH (Electrolytic) (400X)



Solarized image (400X)



Frames	% Ferrite	% Austenite
1.	08.33	91.67
2.	12.04	87.96
3.	16.61	83.39
4.	10.92	89.08
5.	12.86	87.14
Average of 5 Frames	**12.15**	**87.85**

Note: Volume fraction is carried out from worst fields of the sample.

Checked by: Abhishek

Authorized Signatory
K. S. RANA (T.M.)

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

TCR Advanced Engineering P. Ltd.

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Managing Director
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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-08252.4 | Page 1 of 1 | Date: 29.03.2017

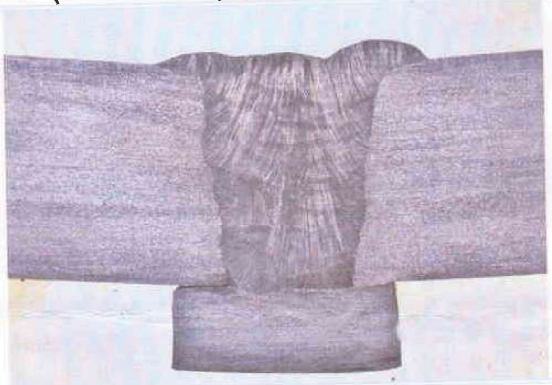
To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Macrostructure Examination

TEST METHOD: ASTM-E-381-01,E-340-13

Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division		
Instrument utilized:	Digital Camera/Stereo Microscope		
*Customer's Reference:	Letter Dated : 08.03.2017		
Sample received on:	10/3/2017		
*Condition of sample:	Welded Plate Sample		
*Nature of sample:	Welded Plate Sample - 500mmL X 300W X 25mm Thk		
*Specification:	DSS		
Date of completion of test:	29.03.2017	Sample Drawn by	**Witness By Client**

***SAMPLE ID: Coupon ID - E2209(12Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**



Sample Photograph

Observation:	Macrostructure shows good fusion without any significant defect.
Etchant:	50% HCL

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Authorised Signatory
K. S. RANA (T.M.)

Checked By: Abhishek

TCR Advanced Engineering P. Ltd.

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Managing Director
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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-27942.1	Page 1 of 1	Date: 28.09.2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Chemical Analysis by Optical Emission Spectrometer Method

TEST METHOD: ASTM E-1086-08, IS 9879-98

Test performed at: TCR Advanced Engineering Pvt. Ltd., Testing Division

Instrument utilized:	Optical Emission Spectrometer, SpectromaxX, TCRADV/E-1		
*Customer's Reference:	Letter Dated : 06.09.2017		
Sample received on:	12.09.2017		
*Condition of sample:	Welded Plate Sample - 700 mm L X 300 mm W X 25 mm Thk		
*Nature of sample:	Welded Plate Sample - 25 mm Thk		
*Specification:	-		
Date of completion of test:	28.09.2017	Sample Drawn by	**Witness By Client**

***SAMPLE ID: Coupon ID - E2209(10Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat , Location - T/2**

ELEMENT	RESULT
Carbon (%)	0.024
Sulfur (%)	0.004
Phosphorous (%)	0.023
Manganese (%)	1.250
Silicon (%)	0.600
Chromium (%)	23.320
Nickel (%)	9.280
Molybdenum (%)	3.120
Copper (%)	0.076
Nitrogen (%)	0.163

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Chaitanya

Authorised Signatory
K. S. RANA (T.M.)

1. The results relate only to the sample tested. 2. Test certificate shall not be re-produced except in full without the written approval of laboratory. 3. TCR Advanced has made their best endeavours to provide accurate and reliable information, TCR Advanced is not responsible for any financial liability due to any act of omission or error made. 4. Samples are preserved for 15 days, Any ambiguity in test results should be brought forward to the lab management within this period. 5.* Information provided by customer.

TCR Advanced Engineering P. Ltd.

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

Managing Director
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BE. (Met.), M.E. (Mat. Tech.) MIE, LMIIM,LMIIW, Chartered Engineer

TEST REPORT

Report No: P-27942.2	Page 1 of 1	Date: 28.09.2017

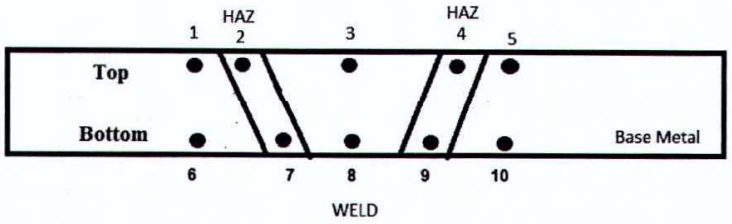
To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Welded Coupon Hardness Test

TEST METHOD: ASTM E 384 - 11

Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division		
Instrument utilized:	Vickers cum Brinnel Hardness tester		
*Customer's Reference:	Letter Dated : 06.09.2017		
Sample received on:	12.09.2017		
*Condition of sample:	Welded Plate Sample - 700 mm L X 300 mm W X 25 mm Thk		
*Nature of sample:	Welded Plate Sample - 25 mm Thk		
*Specification:	-		
Date of completion of test:	28/9/2017	Sample Drawn by	**Witness By Client**

***SAMPLE ID: Coupon ID - E2209(10Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**



LOCATION	Hardness in 'HV' at 10kg load	LOCATION	Hardness in 'HV' at 10kg load
Loc-1	274, 274, 272	Loc-6	279, 279, 281
Loc-2	294, 292, 292	Loc-7	297, 297, 299
Loc-3	309, 309, 306	Loc-8	322, 322, 319
Loc-4	297, 294, 297	Loc-9	299, 299, 297
Loc-5	268, 266, 266	Loc-10	274, 274, 272

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Karan

Authorised Signatory
K. S. RANA (T.M.)

TCR Advanced Engineering P. Ltd.

TCR ADVANCED ENGINEERING PVT. LTD.

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

Managing Director
Paresh U. Haribhakti
BE. (Met.), M.E. (Mat. Tech.) MIE, LMIIM,LMIIW, **Chartered Engineer**

TEST REPORT

Report No: P-27942.3 Page 1 of 1 Date: 28.09.2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Macrostructure Examination

TEST METHOD: ASTM-E-381-01,E-340-13

Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division
Instrument utilized:	Digital Camera/Stereo Microscope
*Customer's Reference:	Letter Dated : 06.09.2017
Sample received on:	12/9/2017
*Condition of sample:	Welded Plate Sample - 700 mm L X 300 mm W X 25 mm Thk
*Nature of sample:	Welded Plate Sample - 25 mm Thk
*Specification:	-
Date of completion of test:	28.09.2017 Sample Drawn by **Witness By Client**

***SAMPLE ID: Coupon ID - E2209(10Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**

Sample Photograph

Observation: Macrostructure shows good fusion however inclusion is observed.

Etchant: 50% HCL

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Abhishek

Authorised Signatory
K. S. RANA (T.M.)

Advanced Engineering P. Ltd.

TCR ADVANCED ENGINEERING PVT. LTD.

Research Center & Testing Division:
Regd. Off. : 250-252/9, GIDC Estate, Makarpura, Vadodara – 390010

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

Managing Director
Paresh U. Haribhakti
BE. (Met.), M.E. (Mat. Tech.) MIE, LMIIM,LMIIW, **Chartered Engineer**

TEST REPORT

Report No: P-27942.4 Page 1 of 1 Date: 28.09.2017

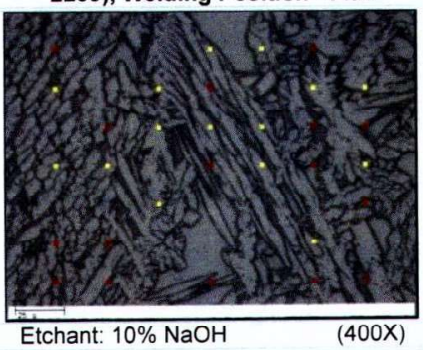
To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Volume Fraction Measurement
Test Method: ASTM E 562-2011

Test performed at: TCR Advanced Engineering Pvt. Ltd., Testing Division

Instrument utilized:	Optical Microscope, TCRADV/E-20
*Customer's Reference:	Letter Dated : 06.09.2017
Sample received on:	12.09.2017
*Condition of sample:	Welded Plate Sample - 700 mm L X 300 mm W X 25 mm Thk
*Nature of sample:	Welded Plate Sample - 25 mm Thk
*Specification:	-
Date of completion of test:	28/09/2017 Sample Drawn by **Witness By Client**

***SAMPLE ID: Coupon ID - E2209(10Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**



Etchant: 10% NaOH (400X)

Frames	% Ferrite	Frames	% Ferrite	Frames	% Ferrite
1	45.9	11	37.8	21	40.8
2	40.8	12	43.9	22	34.7
3	35.7	13	43.9	23	39.8
4	40.8	14	38.8	24	42.9
5	39.8	15	40.8	25	44.9
6	42.9	16	38.8	26	40.8
7	42.9	17	39.8	27	41.8
8	44.9	18	45.9	28	26.0
9	48.0	19	42.9	29	40.8
10	45.9	20	37.8	30	37.8

Average of 30 Frames: 40.94 % Requirement:

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Abhishek

Authorised Signatory
K. S. RANA (T.M.)

Advanced Engineering P. Ltd.

TCR ADVANCED ENGINEERING PVT. LTD.

Research Center & Testing Division:
Regd. Off. : 250-252/9, GIDC Estate, Makarpura, Vadodara – 390010

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Email : testing@tcradvanced.com Website : www.tcradvanced.com

Managing Director
Paresh U. Haribhakti
BE. (Met.), M.E. (Mat. Tech.) MIE, LMIIM,LMIIW, Chartered Engineer

ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-27942.5	Page 1 of 1	Date: 28/09/2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Tensile Test

TEST METHOD: AWS B4.0

Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division		
Instrument utilized:	TCRADV E-2		
*Customer's Reference:	Letter Dated : 06.09.2017		
Sample received on:	12/09/2017		
*Condition of sample:	Welded Plate Sample - 700 mm L X 300 mm W X 25 mm Thk		
*Nature of sample:	Welded Plate Sample - 25 mm Thk		
*Specification:	-		
Date of completion of test:	28/09/2017	Sample Drawn by	**Witness By Client**

***SAMPLE ID: Coupon ID - E2209(10Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**

TEST	RESULT
Gauge Dia. (mm)	12.69
Area (mm^2)	126.47
Gauge Length (mm)	50.00
Final Length (mm)	62.84
Final Dia. (mm)	9.28
0.2% Proof Load (N)	86843
Ultimate Load (N)	107820
0.2% Proof Stress (N/mm^2)	687
U.T.S. (N/mm^2)	853
% Reduction in area	46.52
% Elongation	25.68
Fracture	W.G.L

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Karan

Authorised Signatory
K. S. RANA (T.M.)

Advanced Engineering P. Ltd.

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-27942.7 | Page 1 of 1 | Date: 28.09.2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

Test	**Ferrite Measuremenet**
Test Method	**TCR ADV/TM-62**
Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division
*Customer's Reference:	Letter Dated : 06.09.2017
Sample received on:	12.09.2017
*Condition of sample:	Welded Plate Sample - 700 mm L X 300 mm W X 25 mm Thk
*Nature of sample:	Welded Plate Sample - 25 mm Thk
*Specification:	-
Date of completion of test:	28/09/2017 Sample Drawn by **Witness By Client**

***SAMPLE ID: Coupon ID - E2209(10Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**

Sr. No.	Description	Result
1	Equipment/Make:	Fisher ferritoscope
2	Ferrite (%):	28.2,29.0,29.4
3	Average value (%):	28.9

Remarks:

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Vishal

Authorised Signatory
K. S. RANA (T.M.)

Advanced Engineering P. Ltd.

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-27943.1	Page 1 of 1	Date: 28/09/2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Tensile Test

TEST METHOD: AWS B4.0

Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division		
Instrument utilized:	TCRADV E-2		
*Customer's Reference:	Letter Dated : 06.09.2017		
Sample received on:	12/09/2017		
*Condition of sample:	Welded Plate Sample - 700 mm L X 300 mm W X 25 mm Thk		
*Nature of sample:	Welded Plate Sample - 25 mm Thk		
*Specification:	-		
Date of completion of test:	28/09/2017	Sample Drawn by	**Witness By Client**

***SAMPLE ID: Coupon ID - E2209(10Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat, All weld tensile**

TEST	RESULT
Gauge Dia. (mm)	12.46
Area (mm^2)	121.93
Gauge Length (mm)	50.00
Final Length (mm)	62.66
Final Dia. (mm)	8.96
0.2% Proof Load (N)	83359
Ultimate Load (N)	104920
0.2% Proof Stress (N/mm^2)	684
U.T.S. (N/mm^2)	860
% Reduction in area	48.28
% Elongation	25.32
Fracture	W.G.L

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Karan

Authorised Signatory
K. S. RANA (T.M.)

Advanced Engineering P. Ltd.

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-27944.1 | Page 1 of 1 | Date: 28.09.2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Chemical Analysis by Optical Emission Spectrometer Method

TEST METHOD: ASTM E-1086-08, IS 9879-98

Test performed at: TCR Advanced Engineering Pvt. Ltd., Testing Division

Instrument utilized:	Optical Emission Spectrometer, SpectromaxX, TCRADV/E-1
*Customer's Reference:	Letter Dated : 06.09.2017
Sample received on:	12.09.2017
*Condition of sample:	Welded Plate Sample - (500 mm +200 mm L) X 300 mm W X 25 mm Thk
*Nature of sample:	Welded Plate Sample - 25 mm Thk
*Specification:	-
Date of completion of test:	28.09.2017 Sample Drawn by **Witness By Client**

***SAMPLE ID: Coupon ID - E2209(11Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat , Location - T/2**

ELEMENT	RESULT
Carbon (%)	0.022
Sulfur (%)	0.004
Phosphorous (%)	0.024
Manganese (%)	1.120
Silicon (%)	0.580
Chromium (%)	23.340
Nickel (%)	9.730
Molybdenum (%)	3.110
Copper (%)	0.076
Nitrogen (%)	0.150

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Chaitanya

Authorised Signatory
K. S. RANA (T.M.)

1. The results relate only to the sample tested. 2. Test certificate shall not be re-produced except in full without the written approval of laboratory. 3. TCR Advanced has made their best endeavours to provide accurate and reliable information, TCR Advanced is not responsible for any financial liability due to any act of omission or error made. 4. Samples are preserved for 15 days, Any ambiguity in test results should be brought forward to the lab management within this period. 5. * Information provided by customer.

TCR Advanced Engineering P. Ltd.

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Research Center & Testing Division:
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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-27944.2	Page 1 of 1	Date: 28.09.2017

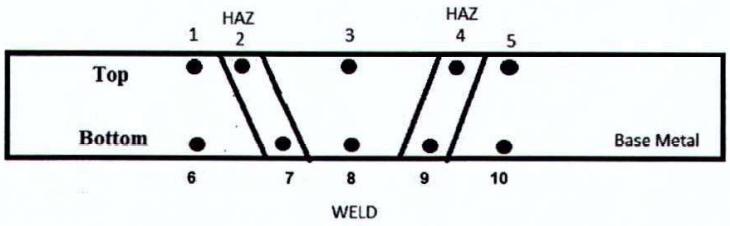
To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Welded Coupon Hardness Test

TEST METHOD: ASTM E 384 - 11

Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division		
Instrument utilized:	Vickers cum Brinnel Hardness tester		
*Customer's Reference:	Letter Dated : 06.09.2017		
Sample received on:	12.09.2017		
*Condition of sample:	Welded Plate Sample - (500 mm +200 mm L) X 300 mm W X 25 mm Thk		
*Nature of sample:	Welded Plate Sample - 25 mm Thk		
*Specification:	-		
Date of completion of test:	28/9/2017	Sample Drawn by	**Witness By Client**

***SAMPLE ID: Coupon ID - E2209(11Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**



LOCATION	Hardness in 'HV' at 10kg load	LOCATION	Hardness in 'HV' at 10kg load
Loc-1	279, 279, 276	Loc-6	279, 281, 281
Loc-2	297, 294, 297	Loc-7	299, 299, 297
Loc-3	306, 306, 304	Loc-8	317, 317, 314
Loc-4	292, 292, 294	Loc-9	294, 294, 297
Loc-5	272, 274, 272	Loc-10	285, 285, 283

Checked By: Karan

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Authorised Signatory
K. S. RANA (T.M.)

TCR Advanced Engineering P. Ltd.

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

Managing Director
Paresh U. Haribhakti
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TEST REPORT

Report No: P-27944.3 Page 1 of 1 Date: 28.09.2017

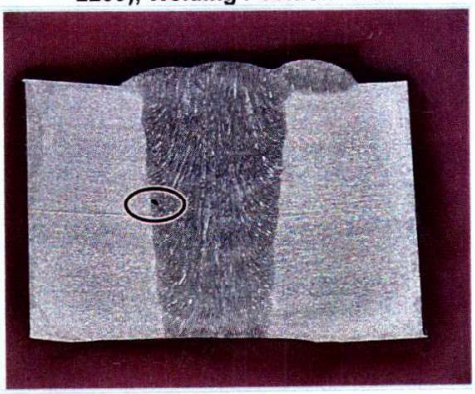
To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Macrostructure Examination

TEST METHOD: ASTM-E-381-01,E-340-13

Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division
Instrument utilized:	Digital Camera/Stereo Microscope
*Customer's Reference:	Letter Dated : 06.09.2017
Sample received on:	12/9/2017
*Condition of sample:	Welded Plate Sample - (500 mm +200 mm L) X 300 mm W X 25 mm Thk
*Nature of sample:	Welded Plate Sample - 25 mm Thk
*Specification:	-
Date of completion of test:	28.09.2017 Sample Drawn by **Witness By Client**

***SAMPLE ID: Coupon ID - E2209(11Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**



Sample Photograph

Observation: Macrostructure shows good fusion however inclusion is observed.

Etchant: 50% HCL

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Abhishek

Authorised Signatory
K. S. RANA (T.M.)

1. The results relate only to the sample tested. 2. Test certificate shall not be re-produced except in full without the written approval of laboratory. 3. TCR Advanced has made their best endeavours to provide accurate and reliable information, TCR Advanced is not responsible for any financial liability due to any act of omission or error made. 4. Samples are preserved for 15 days, Any ambiguity in test results should be brought forward to the lab management within this period. 5.* Information provided by customer.

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

Managing Director
Paresh U. Haribhakti
BE. (Met.), M.E. (Mat. Tech.) MIE, LMIIM,LMIIW, **Chartered Engineer**

TEST REPORT

Report No: P-27944.4 Page 1 of 1 Date: 28.09.2017

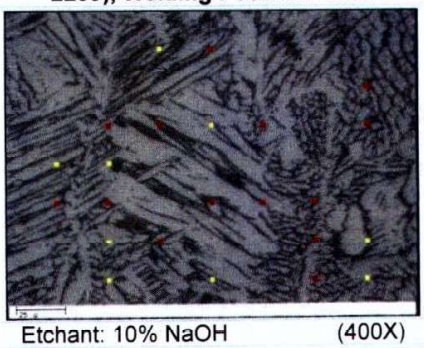
To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Volume Fraction Measurement
Test Method: ASTM E 562-2011

Test performed at: TCR Advanced Engineering Pvt. Ltd., Testing Division

Instrument utilized:	Optical Microscope, TCRADV/E-20
*Customer's Reference:	Letter Dated : 06.09.2017
Sample received on:	12.09.2017
*Condition of sample:	Welded Plate Sample - (500 mm +200 mm L) X 300 mm W X 25 mm Thk
*Nature of sample:	Welded Plate Sample - 25 mm Thk
*Specification:	-
Date of completion of test:	28/09/2017 Sample Drawn by **Witness By Client**

***SAMPLE ID: Coupon ID - E2209(11Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**



Etchant: 10% NaOH (400X)

Frames	% Ferrite	Frames	% Ferrite	Frames	% Ferrite
1	45.9	11	38.8	21	40.8
2	40.8	12	43.9	22	39.8
3	35.7	13	40.8	23	39.8
4	40.8	14	39.8	24	40.8
5	38.8	15	42.9	25	36.7
6	38.8	16	40.8	26	38.8
7	40.8	17	38.8	27	34.7
8	35.7	18	33.7	28	35.7
9	26.0	19	40.8	29	35.7
10	33.7	20	35.7	30	37.8

Average of 30 Frames: 38.45 % Requirement:

Remarks: ,

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Abhishek

Authorised Signatory
K. S. RANA (T.M.)

TCR Advanced Engineering P. Ltd.

TCR ADVANCED ENGINEERING PVT. LTD.

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-27944.5	Page 1 of 1	Date: 28/09/2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Tensile Test

TEST METHOD: AWS B4.0

Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division		
Instrument utilized:	TCRADV E-2		
*Customer's Reference:	Letter Dated : 06.09.2017		
Sample received on:	12/09/2017		
*Condition of sample:	Welded Plate Sample - (500 mm +200 mm L) X 300 mm W X 25 mm Thk		
*Nature of sample:	Welded Plate Sample - 25 mm Thk		
*Specification:	-		
Date of completion of test:	28/09/2017	Sample Drawn by	**Witness By Client**

***SAMPLE ID: Coupon ID - E2209(11Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**

TEST	RESULT
Gauge Dia. (mm)	12.42
Area (mm^2)	121.15
Gauge Length (mm)	50.00
Final Length (mm)	62.96
Final Dia. (mm)	8.71
0.2% Proof Load (N)	82099
Ultimate Load (N)	103959
0.2% Proof Stress (N/mm^2)	678
U.T.S. (N/mm^2)	858
% Reduction in area	50.81
% Elongation	25.92
Fracture	W.G.L

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Karan

Authorised Signatory
K. S. RANA (T.M.)

TCR Advanced Engineering P. Ltd.

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-27944.7 | Page 1 of 1 | Date: 28.09.2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

Test	**Ferrite Measuremenet**
Test Method	**TCR ADV/TM-62**
Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division
*Customer's Reference:	Letter Dated : 06.09.2017
Sample received on:	12.09.2017
*Condition of sample:	Welded Plate Sample - (500 mm +200 mm L) X 300 mm W X 25 mm Thk
*Nature of sample:	Welded Plate Sample - 25 mm Thk
*Specification:	-
Date of completion of test:	28/09/2017 Sample Drawn by **Witness By Client**

***SAMPLE ID: Coupon ID - E2209(11Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**

Sr. No.	Description	Result
1	Equipment/Make:	Fisher ferritoscope
2	Ferrite(%):	26.8,25.6,26.6
3	Average value (%):	26.33

Remarks:

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Vishal

Authorised Signatory
K. S. RANA (T.M.)

TCR Advanced Engineering P. Ltd.

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-27945.1	Page 1 of 1	Date: 28/09/2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Tensile Test

TEST METHOD: AWS B4.0

Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division		
Instrument utilized:	TCRADV E-2		
*Customer's Reference:	Letter Dated : 06.09.2017		
Sample received on:	12/09/2017		
*Condition of sample:	Welded Plate Sample - (500 mm +200 mm L) X 300 mm W X 25 mm Thk		
*Nature of sample:	Welded Plate Sample - 25 mm Thk		
*Specification:	-		
Date of completion of test:	28/09/2017	Sample Drawn by	**Witness By Client**

***SAMPLE ID: Coupon ID - E2209(11Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat, All weld tensile**

TEST	RESULT
Gauge Dia. (mm)	12.52
Area (mm^2)	123.11
Gauge Length (mm)	50.00
Final Length (mm)	62.03
Final Dia. (mm)	8.97
0.2% Proof Load (N)	84043
Ultimate Load (N)	104919
0.2% Proof Stress (N/mm^2)	683
U.T.S. (N/mm^2)	852
% Reduction in area	48.66
% Elongation	24.06
Fracture	W.G.L

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Karan

Authorised Signatory
K. S. RANA (T.M.)

TCR Advanced Engineering P. Ltd.

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Managing Director
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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: Q-00792.1	Page 1 of 1	Date: 13/01/2018

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

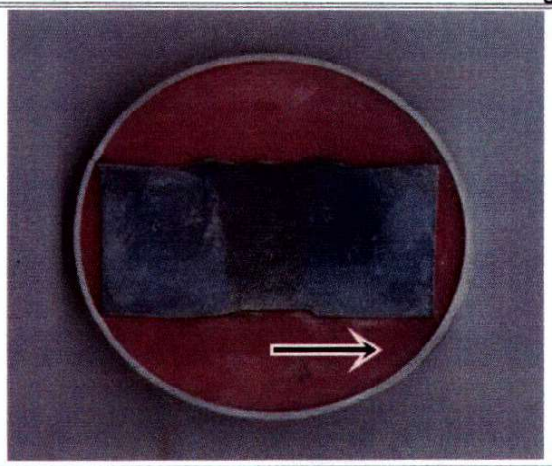
TEST: Micro Hardness Profile

TEST METHOD: ASTM-E - 384

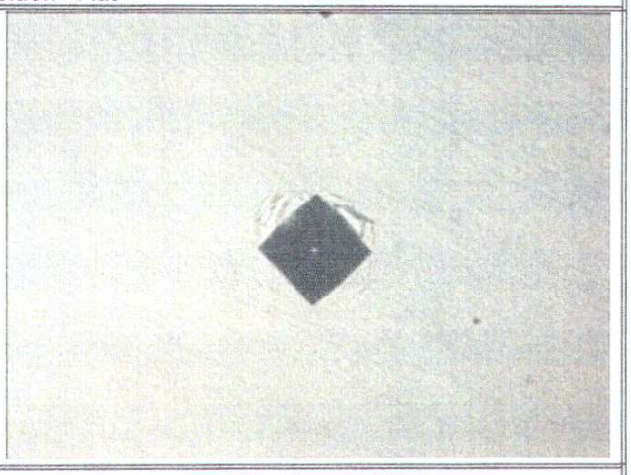
Test Performed at: TCR Advanced Engineering Pvt. Ltd.

Test Equipment / Range:	TCRADV/E-70		
*Customer's Reference:	Email Dated : 10.01.2018		
Sample received on:	10/01/2018		
*Condition of sample:	Welded Plate Sample - 100 mm x 15 mm X 25 mm Thk		
*Specification:	-		
Date of completion of test:	13/01/2018	Sample Drawn by:	**Party**

***SAMPLE ID: Coupon ID - E2209(10Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**

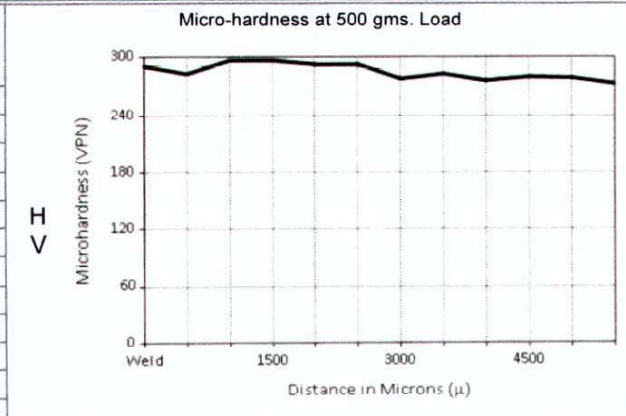


Sample Photograph



Magnification 400X

Distance from Surface (Microns)	Micro-hardness at 500 gms. Load
Weld	291
500	283
1000	297
1500	297
2000	293
2500 HAZ	293
3000	278
3500	283
4000	276
4500	280
5000	279
5500	273



End of report.

Checked By:abhishek

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Authorised Signatory
K. S. RANA (T.M.)

TCR Advanced Engineering P. Ltd.

TCR ADVANCED ENGINEERING PVT. LTD.

Research Center & Testing Division:
Regd. Off. : 250-252/9, GIDC Estate, Makarpura, Vadodara – 390010

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Email : testing@tcradvanced.com Website : www.tcradvanced.com

ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

Managing Director
Paresh U. Haribhakti
BE. (Met.), M.E. (Mat. Tech.) MIE, LMIIM,LMIIW, **Chartered Engineer**

TEST REPORT

Report No: Q-00793.1	Page 1 of 1	Date: 13/01/2018

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

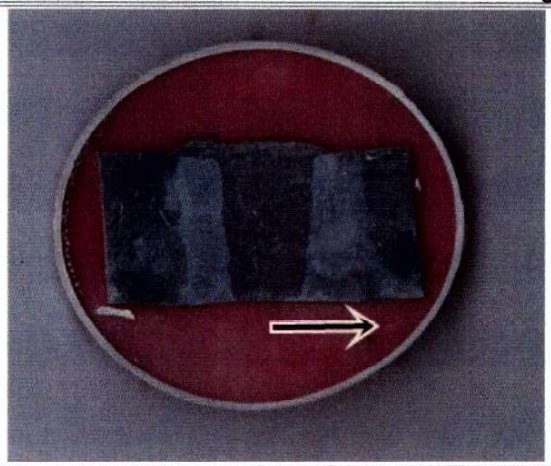
TEST: Micro Hardness Profile

TEST METHOD: ASTM-E - 384

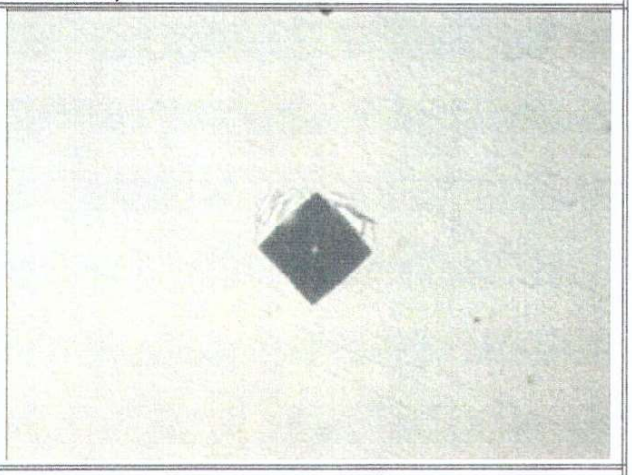
Test Performed at: TCR Advanced Engineering Pvt. Ltd.

Test Equipment / Range:	TCRADV/E-70	
*Customer's Reference:	Email Dated : 10.01.2018	
Sample received on:	10/01/2018	
*Condition of sample:	Welded Plate Sample - 100 mm x 15 mm X 25 mm Thk	
*Specification:	-	
Date of completion of test:	13/01/2018	Sample Drawn by: **Party**

***SAMPLE ID: Coupon ID - E2209(11Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat,**

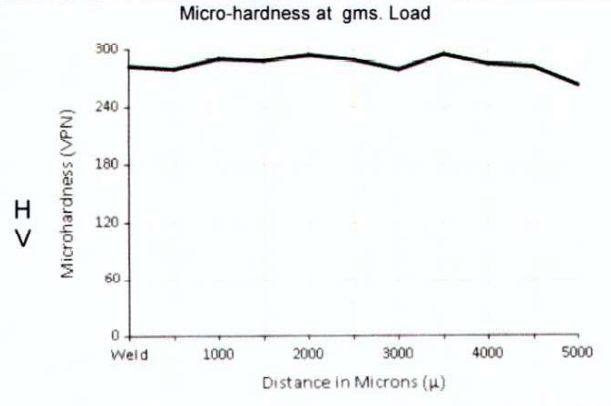


Sample Photograph



Magnification 400X

Distance from Surface (Microns)	Micro-hardness at gms. Load
Weld	283
500	280
1000	291
1500	289
2000	295
2500	290
3000	280
3500	296
4000	286
4500	283
5000	264



End of report.

Checked By:abhishek

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Authorised Signatory
K. S. RANA (T.M.)

TCR Advanced Engineering P. Ltd.

TCR ADVANCED ENGINEERING PVT. LTD.

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Managing Director
Paresh U. Haribhakti
BE. (Met.), M.E. (Mat. Tech.) MIE, LMIIM,LMIIW, **Chartered Engineer**

ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: Q-00794.1	Page 1 of 1	Date: 13/01/2018

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

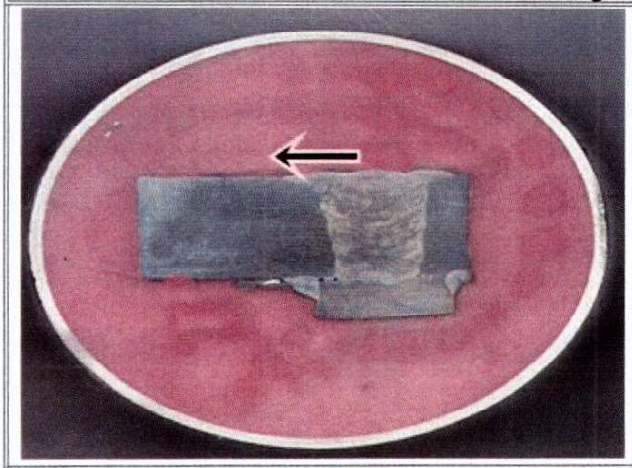
TEST: Micro Hardness Profile

TEST METHOD: ASTM-E - 384

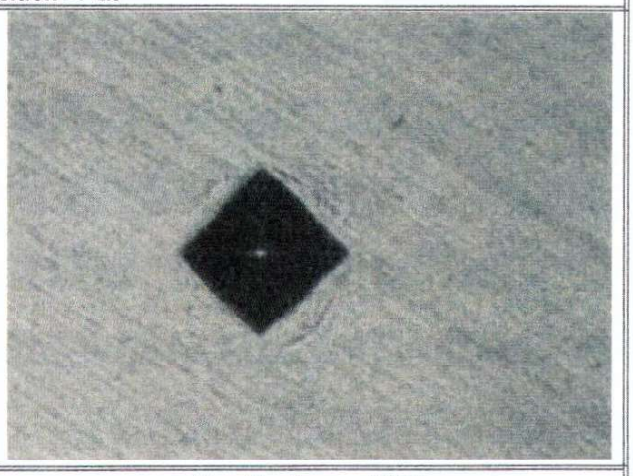
Test Performed at: TCR Advanced Engineering Pvt. Ltd.

Test Equipment / Range:	TCRADV/E-70		
*Customer's Reference:	Email Dated : 10.01.2018		
Sample received on:	10/01/2018		
*Condition of sample:	Welded Plate Sample - 500mmL X 300W X 25mm Thk		
*Specification:	-		
Date of completion of test:	13/01/2018	Sample Drawn by:	**Party**

***SAMPLE ID: Coupon ID - E2209(12Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**

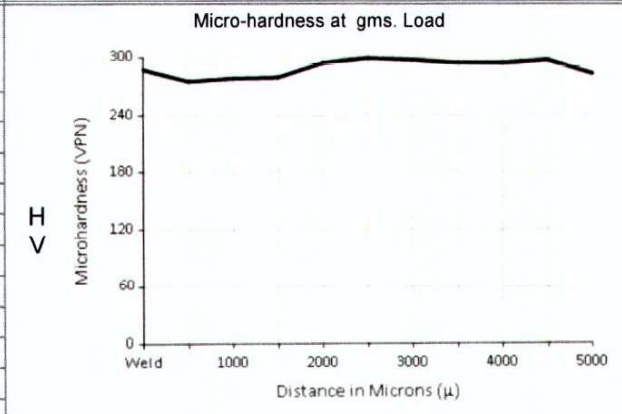


Sample Photograph



Magnification 400X

Distance from Surface (Microns)	Micro-hardness at gms. Load
Weld	288
500	276
1000	279
1500	280
2000	295
2500	300
3000	298
3500	295
4000	295
4500	298
5000	284



End of report.

Checked By:abhishek

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Authorised Signatory
K. S. RANA (T.M.)

TCR Advanced Engineering P. Ltd.

TCR ADVANCED ENGINEERING PVT. LTD.

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Managing Director
Paresh U. Haribhakti
BE. (Met.), M.E. (Mat. Tech.) MIE, LMIIM,LMIIW, Chartered Engineer

ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No:P-34349.1	Page 1 of 1	Date: 20.11.2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Sodium Hydroxide Test

TEST METHOD: Method A as per ASTM A 923-14

TEST PERFORMED AT:	TCR ADVANCED ENGINEERING PVT. LTD., TESTING DIVISION		
Instrument utilized:	Optical Microscope		
*Customer's Reference:	Letter Dated : 11.09.2017		
Sample received on:	15.11.2017		
*Condition of sample:	Welded Plate Sample - 700 mm L X 300 mm W X 25 mm Thk		
*Nature of sample:	Welded Plate Sample - 25 mm Thk		
*Specification:	-		
Date of completion of test:	18/11/2017	Sample Drawn by	**Witness By Client**

***SAMPLE ID: Coupon ID - E2209(10Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**

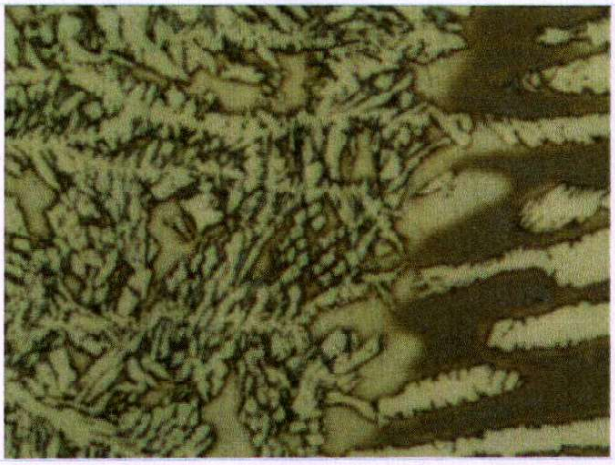

Plate 1: At HAZ 400 X

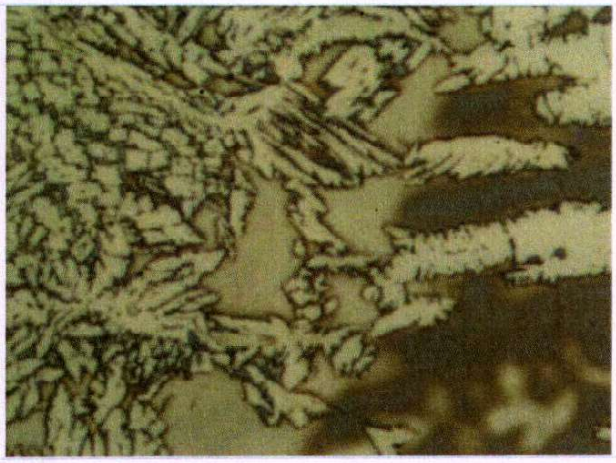

Plate 2: At HAZ 400 X

Observation:	Microstructure shows a typical duplex microstructure of ferrite and austenite. No significant presence of inter-metallic phases and precipitates are observed in the microstructure.
Observed at:	400 X
Etchant:	40 Gms NaOH in 100 ml distilled Water for 5 Sec
Remarks:	The ferrite has been etched without revelation of inter-metallic phase. Interphase boundaries are smooth (Unaffected Structure).

Checked By: Abhishek

Authorised Signatory
G. R. PATEL (Q.M.)

TCR Advanced Engineering P. Ltd.

TCR ADVANCED ENGINEERING PVT. LTD.

Research Center & Testing Division:
Regd. Off. : 250-252/9, GIDC Estate, Makarpura, Vadodara – 390010

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Email : testing@tcradvanced.com Website : www.tcradvanced.com

ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

Managing Director
Paresh U. Haribhakti
BE. (Met.), M.E. (Mat. Tech.) MIE, LMIIM,LMIIW, Chartered Engineer

TEST REPORT

Report No:P-34350.1	Page 1 of 1	Date: 20.11.2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Sodium Hydroxide Test

TEST METHOD: Method A as per ASTM A 923-14

TEST PERFORMED AT:	TCR ADVANCED ENGINEERING PVT. LTD., TESTING DIVISION		
Instrument utilized:	Optical Microscope		
*Customer's Reference:	Letter Dated : 11.09.2017		
Sample received on:	15.11.2017		
*Condition of sample:	Welded Plate Sample - (500 mm +200 mm L) X 300 mm W X 25 mm Thk		
*Nature of sample:	Welded Plate Sample - 25 mm Thk		
*Specification:	-		
Date of completion of test:	18/11/2017	Sample Drawn by	**Witness By Client**

***SAMPLE ID: Coupon ID - E2209(11Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**

Plate 1: At HAZ 400 X

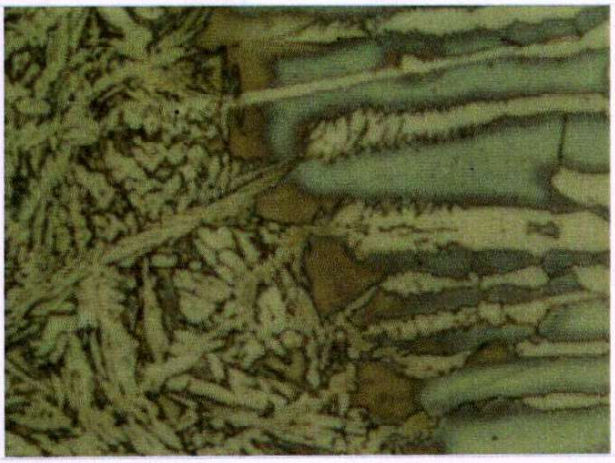

Plate 2: At HAZ 400 X

Observation:	Microstructure shows a typical duplex microstructure of ferrite and austenite. No significant presence of inter-metallic phases and precipitates are observed in the microstructure.
Observed at:	400 X
Etchant:	40 Gms NaOH in 100 ml distilled Water for 5 Sec
Remarks:	The ferrite has been etched without revelation of inter-metallic phase. Interphase boundaries are smooth (Unaffected Structure).

Checked By: Abhishek

ADVANCED ENGINEERING PVT. VADODARA

Authorised Signatory
G. R. PATEL (Q.M.)

TCR Advanced Engineering P. Ltd.

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Research Center & Testing Division:
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Managing Director
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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No:P-34348.1	Page 1 of 1	Date: 20.11.2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Sodium Hydroxide Test

TEST METHOD: Method A as per ASTM A 923-14

TEST PERFORMED AT:	TCR ADVANCED ENGINEERING PVT. LTD., TESTING DIVISION		
Instrument utilized:	Optical Microscope		
*Customer's Reference:	Letter Dated : 11.09.2017		
Sample received on:	15.11.2017		
*Condition of sample:	Welded Plate Sample - 500mmL X 300W X 25mm Thk		
*Nature of sample:	Welded Plate Sample - 25 mm Thk		
*Specification:	DSS		
Date of completion of test:	18/11/2017	Sample Drawn by	**Witness By Client**

***SAMPLE ID: Coupon ID - E2209(12Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**

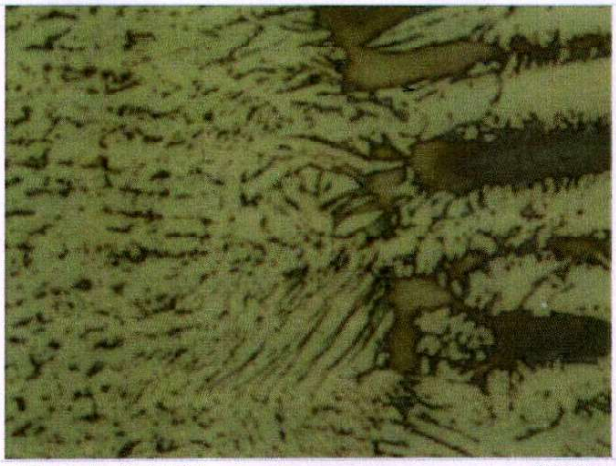

Plate 1: At HAZ 400 X

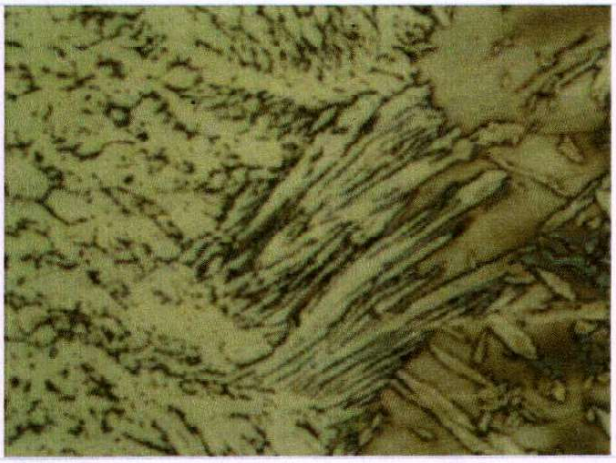

Plate 2: At HAZ 400 X

Observation:	Microstructure shows a typical duplex microstructure of ferrite and austenite. No significant presence of inter-metallic phases and precipitates are observed in the microstructure.
Observed at:	400 X
Etchant:	40 Gms NaOH in 100 ml distilled Water for 5 Sec
Remarks:	The ferrite has been etched without revelation of inter-metallic phase. Interphase boundaries are smooth (Unaffected Structure).

Checked By: Abhishek

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Authorised Signatory
G. R. PATEL (Q.M.)

TCR Advanced Engineering P. Ltd.

Managing Director
Paresh U. Haribhakti
BE. (Met.), M.E. (Mat.Tech) MIE, LMIIM,LMIIW, Chartered Engineer

TCR ADVANCED ENGINEERING PVT. LTD.

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ON APPROVED LIST OF VERIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P08252.7	Page 1 of 1	Date: 29.03.2017

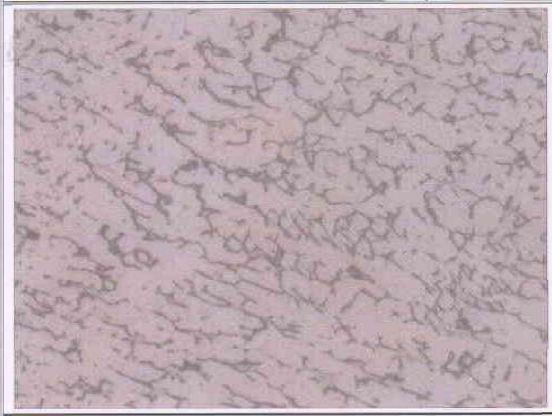
To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar.

Test: Volume Fraction of Ferrite/Austenite

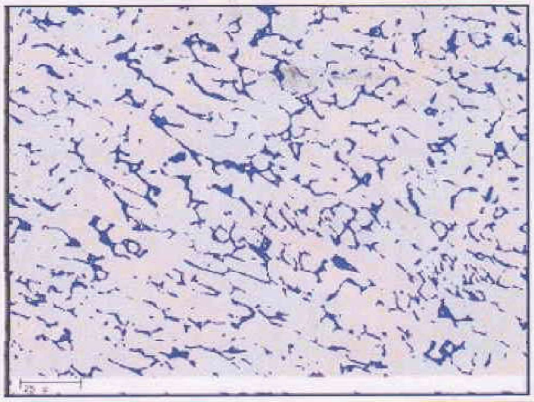
Test Method: TCRADV/TM-20 (As Per ASTM E-562)

Test Performed at	:	TCR Advanced Engineering Pvt. Ltd., Testing Division		
Instrument Utilized:	:	Optical Microscope, TCRADV/E-20		
*Customer's Reference:	:	Letter Dated : 08.03.2017		
Sample received on	:	11.08.2015		
*Condition of Sample	:	Welded Plate Sample		
*Nature of Sample	:	Welded Plate Sample - 500mmL X 300W X 25mm Thk		
*Specification	:	DSS		
Date of completion of test	:	29.03.2017	Witness: By	**Client**

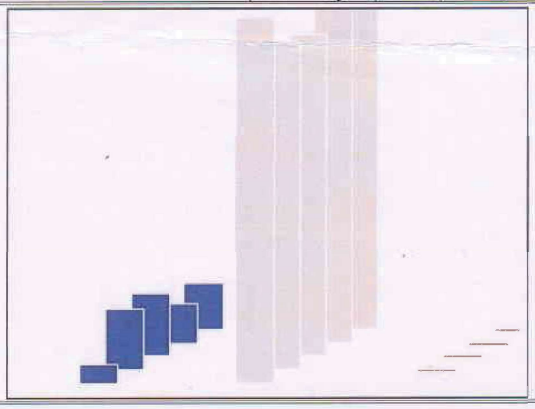
***SAMPLE ID:- Coupon ID - E2209(12Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**



Etchant: 20% NaOH (Electrolytic) (400X)



Solarized image (400X)



Frames	% Ferrite	% Austenite
1.	08.33	91.67
2.	12.04	87.96
3.	16.61	83.39
4.	10.92	89.08
5.	12.86	87.14
Average of 5 Frames	**12.15**	**87.85**

Note: Volume fraction is carried out from worst fields of the sample.

Checked by: Abhishek

Authorized Signatory
K. S. RANA (T.M.)

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

TCR Advanced Engineering P. Ltd.

TCR ADVANCED ENGINEERING PVT. LTD.

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Email : testing@tcradvanced.com Website : www.tcradvanced.com

Managing Director
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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-27942.4 Page 1 of 1 Date: 28.09.2017

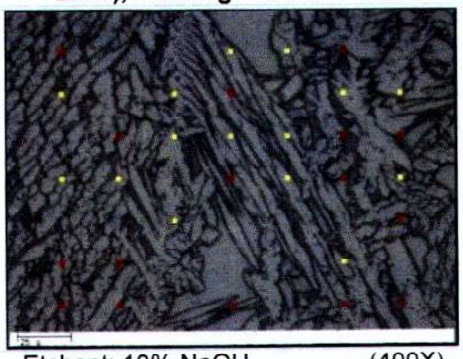
To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Volume Fraction Measurement
Test Method: ASTM E 562-2011

Test performed at: TCR Advanced Engineering Pvt. Ltd., Testing Division

Instrument utilized:	Optical Microscope, TCRADV/E-20
*Customer's Reference:	Letter Dated : 06.09.2017
Sample received on:	12.09.2017
*Condition of sample:	Welded Plate Sample - 700 mm L X 300 mm W X 25 mm Thk
*Nature of sample:	Welded Plate Sample - 25 mm Thk
*Specification:	-
Date of completion of test:	28/09/2017 Sample Drawn by **Witness By Client**

***SAMPLE ID: Coupon ID - E2209(10Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**



Etchant: 10% NaOH (400X)

Frames	% Ferrite	Frames	% Ferrite	Frames	% Ferrite
1	45.9	11	37.8	21	40.8
2	40.8	12	43.9	22	34.7
3	35.7	13	43.9	23	39.8
4	40.8	14	38.8	24	42.9
5	39.8	15	40.8	25	44.9
6	42.9	16	38.8	26	40.8
7	42.9	17	39.8	27	41.8
8	44.9	18	45.9	28	26.0
9	48.0	19	42.9	29	40.8
10	45.9	20	37.8	30	37.8

Average of 30 Frames: 40.94 % Requirement:

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Abhishek

Authorised Signatory
K. S. RANA (T.M.)

TCR Advanced Engineering P. Ltd.

TCR ADVANCED ENGINEERING PVT. LTD.

Research Center & Testing Division:
Regd. Off. : 250-252/9, GIDC Estate, Makarpura, Vadodara – 390010

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Managing Director
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BE. (Met.), M.E. (Mat. Tech.) MIE, LMIIM,LMIIW, Chartered Engineer

ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-27944.4 Page 1 of 1 Date: 28.09.2017

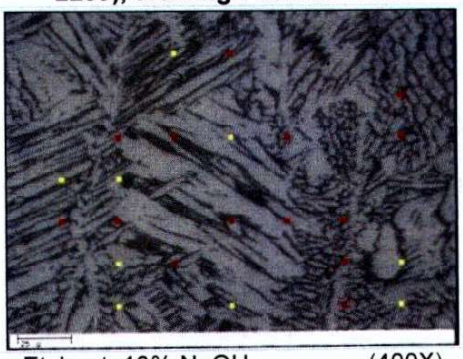
To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Volume Fraction Measurement
Test Method: ASTM E 562-2011

Test performed at: TCR Advanced Engineering Pvt. Ltd., Testing Division

Instrument utilized:	Optical Microscope, TCRADV/E-20
*Customer's Reference:	Letter Dated : 06.09.2017
Sample received on:	12.09.2017
*Condition of sample:	Welded Plate Sample - (500 mm +200 mm L) X 300 mm W X 25 mm Thk
*Nature of sample:	Welded Plate Sample - 25 mm Thk
*Specification:	-
Date of completion of test:	28/09/2017 Sample Drawn by **Witness By Client**

***SAMPLE ID: Coupon ID - E2209(11Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**



Etchant: 10% NaOH (400X)

Frames	% Ferrite	Frames	% Ferrite	Frames	% Ferrite
1	45.9	11	38.8	21	40.8
2	40.8	12	43.9	22	39.8
3	35.7	13	40.8	23	39.8
4	40.8	14	39.8	24	40.8
5	38.8	15	42.9	25	36.7
6	38.8	16	40.8	26	38.8
7	40.8	17	38.8	27	34.7
8	35.7	18	33.7	28	35.7
9	26.0	19	40.8	29	35.7
10	33.7	20	35.7	30	37.8

Average of 30 Frames: 38.45 % Requirement:

Remarks: ,

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Abhishek

Authorised Signatory
K. S. RANA (T.M.)

TCR Advanced Engineering P. Ltd.

TCR ADVANCED ENGINEERING PVT. LTD.

Research Center & Testing Division:
Regd. Off. : 250-252/9, GIDC Estate, Makarpura, Vadodara – 390010

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Managing Director
Paresh U. Haribhakti
BE. (Met.), M.E. (Mat. Tech.) MIE, LMIIM,LMIIW, Chartered Engineer

ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-35735.1	Page 1 of 1	Date: 04.12.2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: V Notch Charpy Impact Test

TEST METHOD: ASTM A370 - 14

Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division		
Test Equipment / Range:	TCRADV/E-17, IT 350 / 0 to 350 Joules		
*Customer's Reference:	Letter Dated : 25.11.2017		
Sample received on:	27/11/2017		
*Condition of sample:	Welded Plate Sample - 25 mm Thk X 57 mm W X 300 mm L		
*Nature of sample:	Welded Plate Sample - 25 mm Thk		
*Specification:	ASTM A 240 Grade 2205		
Date of completion of test:	04.12.2017	Sample Drawn by	**Party**

***SAMPLE ID: 10 Ni 22 Cr, impact Location at weld**

Sample Size (mm)	10 X 10 X 55
Test Temperature °C	-46

Sample No.	**Energy Absorbed (Joules)**
Sample No 1	34
Sample No 2	36
Sample No 3	34
Average	34.66

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Checked By: Karan

Authorised Signatory
K. S. RANA (T.M.)

TCR Advanced Engineering P. Ltd.

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-35736.1	Page 1 of 1	Date: 04.12.2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: V Notch Charpy Impact Test

TEST METHOD: ASTM A370 - 14

Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division		
Test Equipment / Range:	TCRADV/E-17, IT 350 / 0 to 350 Joules		
*Customer's Reference:	Letter Dated : 25.11.2017		
Sample received on:	27/11/2017		
*Condition of sample:	Welded Plate Sample - 25 mm Thk X 72 mm W X 300 mm L		
*Nature of sample:	Welded Plate Sample - 25 mm Thk		
*Specification:	ASTM A 240 Grade 2205		
Date of completion of test:	04.12.2017	Sample Drawn by	**Party**

***SAMPLE ID: 11 Ni 22 Cr, impact Location at weld**

Sample Size (mm)	10 X 10 X 55
Test Temperature °C	-46

Sample No.	**Energy Absorbed (Joules)**
Sample No 1	44
Sample No 2	44
Sample No 3	46
Average	44.66

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Karan

Authorised Signatory
K. S. RANA (T.M.)

TCR Advanced Engineering P. Ltd.

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-35737.1	Page 1 of 1	Date: 04.12.2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: V Notch Charpy Impact Test

TEST METHOD: ASTM A370 - 14

Test performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division		
Test Equipment / Range:	TCRADV/E-17, IT 350 / 0 to 350 Joules		
*Customer's Reference:	Letter Dated : 25.11.2017		
Sample received on:	27/11/2017		
*Condition of sample:	Welded Plate Sample - 25 mm Thk X 57 mm W X 300 mm L		
*Nature of sample:	Welded Plate Sample - 25 mm Thk		
*Specification:	ASTM A 240 Grade 2205		
Date of completion of test:	04.12.2017	Sample Drawn by	**Party**

***SAMPLE ID: 12 Ni 22 Cr, impact Location at weld**

Sample Size (mm)	10 X 10 X 55
Test Temperature ºC	-46

Sample No.	**Energy Absorbed (Joules)**
Sample No 1	28
Sample No 2	30
Sample No 3	28
Average	28.66

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Karan

Authorised Signatory
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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-34348.1	Page 1 of 1	Date:26.11.2017

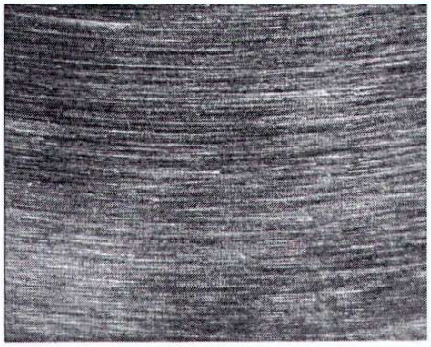
To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

Test: Pitting Corrosion Test

Test Method: ASTM G 48 Method A

Test performed at:	TCR Advanced Engineering Pvt Ltd, Testing Division	
Instrument utilized:	TCRADV/E-33	
*Customer's Reference:	Letter Dated : 11.09.2017	
Sample Received on:	15.11.2017	
*Condition of sample:	Welded Plate Sample - 500mmL X 300W X 25mm Thk	
*Description of sample:	Welded Plate Sample - 25 mm Thk	
*Specification:	DSS	
Date Completion of Test	25.11.2017	Drawn By: Party

***SAMPLE ID: Coupon ID - E2209(12Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**



20X Magnification

-	Result
Specimen Size (mm) (L x W x Thk)	28.20 x 17.78 x 13.10
Area (dm^2)	0.2207
Test Solution	6% $FeCl_3$ of 1.3 pH
Test Temperature (^oC)	22
Test Duration (Hrs.)	24
Initial Weight of Sample (gms)	50.3925
Final Weight of Sample (gms)	50.3918
Loss in Weight (gms)	0.0007
Corrosion Rate (gm/m^2)	0.32
Observation:	No pitting corrosion is observed at 20X magnification.
Remark: -	

Checked by: Faisal

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Authorised Signatory
G. R. PATEL (Q.M.)

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Managing Director
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TEST REPORT

Report No: P-34349.1	Page 1 of 1	Date:26.11.2017

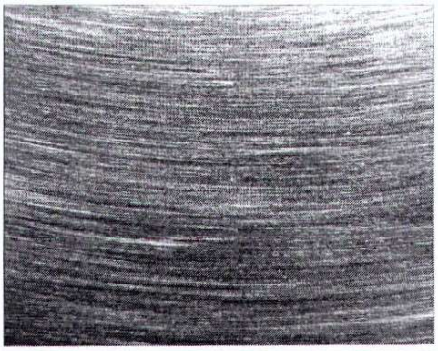
To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

Test: Pitting Corrosion Test

Test Method: ASTM G 48 Method A

Test performed at:	TCR Advanced Engineering Pvt Ltd, Testing Division	
Instrument utilized:	TCRADV/E-33	
*Customer's Reference:	Letter Dated : 11.09.2017	
Sample Received on:	15.11.2017	
*Condition of sample:	Welded Plate Sample - 700 mm L X 300 mm W X 25 mm Thk	
*Description of sample:	Welded Plate Sample - 25 mm Thk	
*Specification:	-	
Date Completion of Test	25.11.2017	Drawn By: Party

***SAMPLE ID: Coupon ID - E2209(10Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**



20X Magnification

-	Result
Specimen Size (mm) (L x W x Thk)	28.83 x 15.67 x 12.50
Area (dm^2)	0.1976
Test Solution	6% $FeCl_3$ of 1.3 pH
Test Temperature (^oC)	22
Test Duration (Hrs.)	24
Initial Weight of Sample (gms)	43.7551
Final Weight of Sample (gms)	43.7548
Loss in Weight (gms)	0.0003
Corrosion Rate (gm/m^2)	0.15
Observation:	No pitting corrosion is observed at 20X magnification.
Remark: -	

Checked by: Faisal

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Authorised Signatory
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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No: P-34350.1	Page 1 of 1	Date:26.11.2017

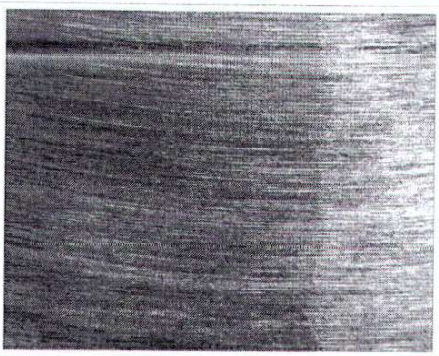
To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

Test: Pitting Corrosion Test

Test Method: ASTM G 48 Method A

Test performed at:	TCR Advanced Engineering Pvt Ltd, Testing Division	
Instrument utilized:	TCRADV/E-33	
*Customer's Reference:	Letter Dated : 11.09.2017	
Sample Received on:	15.11.2017	
*Condition of sample:	Welded Plate Sample - (500 mm +200 mm L) X 300 mm W X 25 mm Thk	
*Description of sample:	Welded Plate Sample - 25 mm Thk	
*Specification:	-	
Date Completion of Test	25.11.2017	Drawn By: Party

***SAMPLE ID: Coupon ID - E2209(11Ni22Cr), Welding Process - SMAW, Filler Wire - E2209-16 (GRINOX-2209), Welding Position - Flat**



20X Magnification

-	Result
Specimen Size (mm) (L x W x Thk)	24.70 x 16.34 x 14.07
Area (dm^2)	0.1962
Test Solution	6% $FeCl_3$ of 1.3 pH
Test Temperature (^oC)	22
Test Duration (Hrs.)	24
Initial Weight of Sample (gms)	43.7583
Final Weight of Sample (gms)	43.7576
Loss in Weight (gms)	0.0007
Corrosion Rate (gm/m^2)	0.36
Observation:	No pitting corrosion is observed at 20X magnification.
Remark: -	

Checked by: Faisal

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Report No:P-38706.1 | Page 1 of 1 | Date: 26.12.2017

To,
Purvesh Nanavati
Government Engg. College ,SEC-28,Gandhinagar

TEST: Microstructure Examination

TEST METHOD: ASTM E407-07

TEST performed at:	TCR Advanced Engineering Pvt. Ltd., Testing Division
Instrument utilized:	Optical Microscope, TCRADV/ E-185
*Customer's Reference:	Letter Dated : 23.12.2017
Sample received on:	25/12/2017
*Condition of sample:	U bend sample
*Nature of sample:	U bend sample
*Specification:	-
Date of completion of test:	26/12/2017 Sample Drawn by **Party**

***SAMPLE ID: Sample Id 1Ni22Cr (15 Gr. A)**

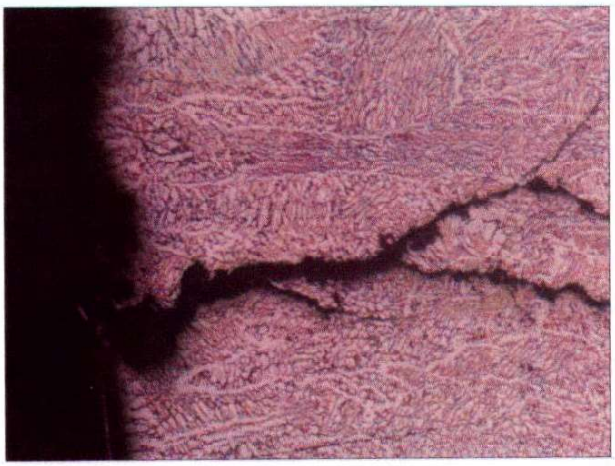

Plate 1: At Od X

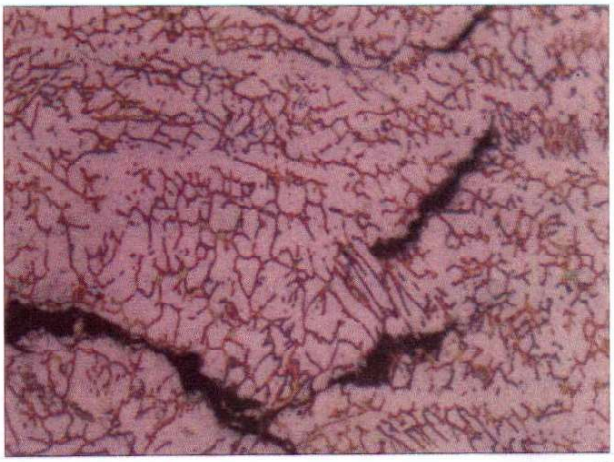

Plate 2: At od X

Observation: Presence of branching nature of inter-dendritic crack is observed on OD edge at the weld region.

Observed at: 100-400 X **Etchant:** 10% Ammonium persulfate (Electrolytic)

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: Abhishek

Authorised Signatory
K. S. RANA (I.M.)

TCR Advanced Engineering P. Ltd.

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LMIIM,LMIIW, **Chartered Engineer**

TEST REPORT

REPORT NO:- P – 38708.1	**Page:-**1 of 1	**DATE :**26/12/2017.
TEST: Ferrite Measurement		
TEST PROCEDURE NO : TCRADV/TM- 76 **REV. :** 0		
CUSTOMER : Purvesh Nanavati (Government College of Gandhinagar)	**SITE :** TCR Advanced Engineering Pvt.ltd ,Vadodara	
COMPONENT : Welded Plate Sample	**SAMPLE ID: -**	
MATERIAL SPECIFICATION : 11 ni 22 cr	**INSPECTED BY :** Mayur Gurjar	
DATE OF EXAMINATION : 26/12/2017	**EQIPMENT USED :** Fischer Ferritoscope	

Sr No	Location	Ferrite Number	Average	Ferrite Percentage (%)	Average
1	Welded Plate Sample (On Weld)	27.6,28.7,28.2	28.16	27.70,27.66,27.44	27.6

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: - samir

Authorised Signatory

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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

REPORT NO:- P – 38709.1	**Page:-**1 of 1	**DATE :**26/12/2017
TEST: Ferrite Measurement		
TEST PROCEDURE NO : TCRADV/TM- 76 **REV. :** 0		
CUSTOMER : Purvesh Nanavati (Government College of Gandhinagar)	**SITE :** Tcr Advanced Engineering Pvt.ltd ,Vadodara	
COMPONENT : Welded Plate Sample	**SAMPLE ID: -**	
MATERIAL SPECIFICATION : 12 ni 22 cr	**INSPECTED BY :** Mayur Gurjar	
DATE OF EXAMINATION : 26/12/2017	**EQIPMENT USED :** Fischer Ferritoscope	

Sr No	Location	Ferrite Number	Average	Ferrite Percentage (%)	Average
1	Welded Plate Sample (On Weld)	1 - 10.8 2 - 16.8 3 - 13.5 4 - 16.1 5 - 12.1 6 - 12.8	13.68	1 - 11.85 2 - 16.52 3 - 14.50 4 - 14.96 5 - 13.49 6 - 12.96	14.04

TCR ADVANCED ENGINEERING PVT. LTD. VADODARA

Checked By: - samir

Authorised Signatory

Table QW-253
Welding Variables Procedure Specifications (WPS) — Shielded Metal-Arc Welding (SMAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.4	– Backing			X
	.10	ϕ Root spacing			X
	.11	± Retainers			X
QW-403 Base Metals	.5	ϕ Group Number		X	
	.6	*T* Limits impact		X	
	.8	ϕ *T* Qualified	X		
	.9	*t* Pass > 1/2 in. (13 mm)	X		
	.11	ϕ P-No. qualified	X		
QW-404 Filler Metals	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.6	ϕ Diameter			X
	.7	ϕ Diameter > 1/4 in. (6 mm)		X	
	.12	ϕ Classification		X	
	.30	ϕ *t*	X		
	.33	ϕ Classification			X
QW-405 Positions	.1	+ Position			X
	.2	ϕ Position		X	
	.3	ϕ ↑↓ Vertical welding			X
QW-406 Preheat	.1	Decrease > 100°F (55°C)	X		
	.2	ϕ Preheat maint.			X
	.3	Increase > 100°F (55°C) (IP)		X	
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T & T range)		X	
	.4	*T* Limits	X		
QW-409 Electrical Characteristics	.1	> Heat input		X	
	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X
QW-410 Technique	.1	ϕ String/weave			X
	.5	ϕ Method cleaning			X
	.6	ϕ Method back gouge			X
	.9	ϕ Multiple to single pass/side		X	X
	.25	ϕ Manual or automatic			X
	.26	± Peening			X
	.64	Use of thermal processes	X		

Legend:
+ Addition – Deletion > Increase/greater than < Decrease/less than ↑ Uphill ↓ Downhill ← Forehand → Backhand ϕ Change

PK Nanavati <pknanavati@gecg28.ac.in>

Confirmation of the recommendation of your paper entitled Effect of Ferrite Content on mechanical properties and Stress Corrosion cracking resistance in 22 Cr 5 Ni Duplex stainless Steels welded joints presented in C-II Document number II-2074-18

1 message

no-reply@sharepointonline.com <no-reply@sharepointonline.com> Mon, Aug 20, 2018 at 12:32 PM
Reply-To: nadege@iiwelding.net
To: pknanavati@gecg28.ac.in

[Submitted by nadege@iiwelding.net]
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Document number II-2074-18

⊙Author document	○Commission document

Title (mandatory): Effect of Ferrite Content on mechanical properties and Stress Corrosion cracking resistance in 22 Cr 5 Ni Duplex stainless Steels welded joints
Notes:
Email address of 1. author was not available - Dr. Kotecki please forward the message to Mr. Nanavati.

Best regards,
Gerhard Posch

Author(s) - Please put the main author (corresponding author in the peer-review system) in first position
P. K. Nanavati, D.J.Kotecki, Sanjay N. Soman
Corresponding author email - this data will be used for the invitation to submit to the peer-review system
pknanavati@gecg28.ac.in

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