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IN THIS ISSUE

PRECISION EQUIPMENTS

PROCEDURE QUALIFICATION OF GRADE 5 WELDS WITH LAS CONSUMABLES (EB6) FOR -15°C IMPACT PERFORMANCE

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In welding engineering, choosing the right consumables is essential to obtaining mechanical qualities that satisfy demanding service specifications. Common welding techniques like Tungsten Inert Gas (TIG), Metal Inert Gas (MIG), Gas Tungsten Arc Welding (GTAW) and Submerged Arc Welding (SAW) each have unique benefits. Because of its deep penetration and high deposition rates, SAW is frequently chosen among these for heavy fabrication. One recent project was the construction of a heat exchanger that would be used in Belgium. The client has specified that the shell must withstand temperatures as low as -15°C and the tubes must withstand temperatures as high as 380°C. The local atmospheric conditions, where temperatures can drop below freezing, are the reason for this low-temperature requirement. As a result, operational and environmental requirements had to be taken into consideration when choosing plate materials and welding consumables. Because SA 387 Gr 5 Cl 2 plate material can function dependably at temperatures as low as -45°C, it was selected. A major obstacle, though, was choosing Low Alloy Steel (LAS) welding consumables. There is not much recorded evidence to support LAS's performance at -15°C, and its use at low temperatures below (0°C) is rare. The issue about weld integrity and operational safety in such low temperatures was brought about by this lack of precedent. This article describes how the welding process is carried out, including the engineering approach, material selection plan, and creative solutions used to get past the related technical obstacles.

INTRODUCTION

When constructing pressure vessels, the SA 387 Grade 5 Class 2 plate provides exceptional efficiency, especially in harsh operating conditions. Because of its high strength-to-weight ratio, this material allows for the use of thinner plates without sacrificing structural integrity, resulting in lower weight and overall material consumption. Additionally, its outstanding notch toughness makes it ideal for usage at low temperatures, such as at temperatures as low as -45°C. This is especially important in low temperature applications or areas with severe climate conditions because it improves fracture resistance and reduces the possibility of brittle failure. Furthermore, when proper procedures like preheating and post-weld heat treatment (PWHT) are followed, SA 387 Gr 5 Cl 2 plate has excellent weldability, which guarantees the production of high-integrity welds necessary for pressure containment. Its mechanical benefits frequently outweigh its higher price and any extra heat treatment it may require, making it worthwhile in important uses. It adheres completely to the ASME Boiler and Pressure Vessel Code (BPVC) standards, especially Sections VIII, Division 1 and 2, which guarantees its approval in regulatory inspections. Additionally, it functions effectively in corrosive conditions with appropriate surface treatments, making it ideal for the chemical, petrochemical, and oil & gas industries.

The combination of SA 387 Gr 5 Cl 2 plate with Low Alloy Steel (LAS) welding consumables has proven to be effective for pressure vessel construction, especially when the use calls for high strength and notch toughness. LAS consumables are designed to either match or somewhat exceed the mechanical characteristics of the underlying material, resulting in welds that are strong, ductile, toughness and resistant to cracking. They offer superior metallurgical compatibility and lessen the chance of hydrogen-induced cracking, which is crucial for pressure-retaining components, when used correctly, with adequate preheating, post heating /intermediate stress reliving and post-weld heat treatment (PWHT). Their effectiveness is most apparent in high-pressure, low-temperature settings, where they preserve weld integrity and toughness even at sub-zero temperatures. Nonetheless, the difficulty is that not all LAS kinds are suitable for temperatures as low as -15°C, so it must be confirmed that the chosen LAS consumables have proven performance at those temperatures.

LAS consumables provide a dependable and effective method for welding SA 387 Gr 5 Cl 2 steel, which contributes to the pressure vessel's mechanical performance and long-term safety, provided that the proper selection and strict adherence to welding procedures are followed. Image 1. Shows the different types of welding consumables.

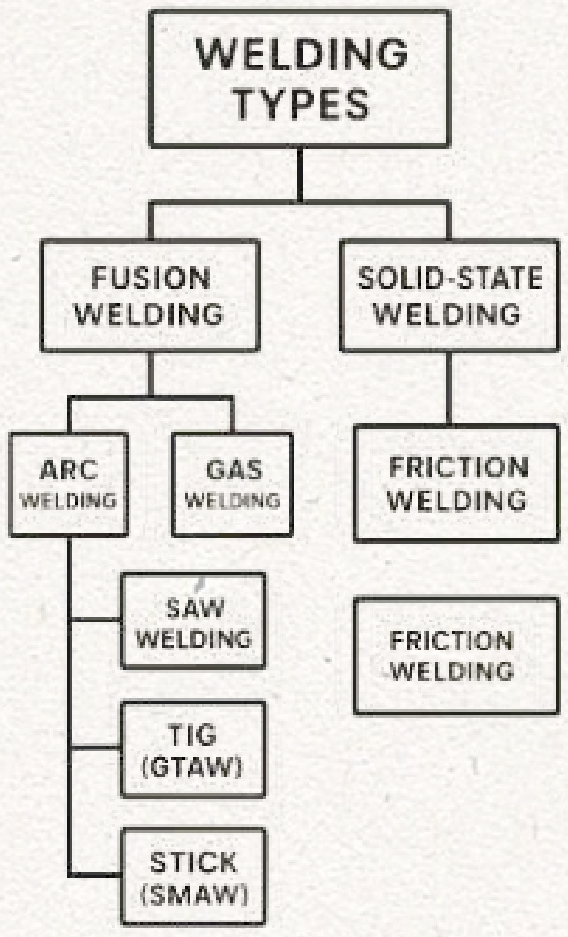

Image 1. Types of welding process.

We have attained a major accomplishment at Precision Equipments Chennai Pvt. Ltd. by effectively certifying Low Alloy Steel (LAS) saw consumables, namely the EB6 grade and suitable flux, for usage with this base materials. It is extremely uncommon to find in terms of use LAS consumables with tested impact toughness at -15°C, especially for vital buildings that demand high toughness in sub-zero conditions. Our team has effectively finished a whole welding procedure qualification utilizing the Submerged Arc Welding (SAW) technique with wire EB6 and suitable flux in a market where even this consumable rated for 0°C impact is hard to get. The method satisfied all mechanical property criteria, including Charpy V-Notch (CVN) impact testing at -15°C, demonstrating a significant improvement in our welding development skills. Precision Equipments Chennai Pvt. Ltd. is now a leader in the usage of specialized this consumable for SA 387 Gr 5 Cl 2 welding, establishing a new standard in the sector, thanks to this accomplishment, which also increases our knowledge in cold-service welding applications.

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Submerged Arc Welding (SAW) is extensively used in various industries for fabrication due to its high reliability, deep weld penetration, smooth surface finish, and increased productivity. In this process, a molten layer of granular flux shields both the welding arc and the weld pool from atmospheric contamination. This protective layer safeguards the molten metal and the remaining flux particles. SAW is commonly employed for butt and fillet welds in the fabrication of structural components such as submarines, pressure vessels, large water pipelines, and bridge beams and columns. It is also effective for cladding applications, where stainless steel can be surfaced onto mild carbon steel, allowing a hard material to be applied over a softer base. In fabrication workshops, SAW continues to be a valuable technique. Key input parameters such as welding current, voltage, and travel speed -directly influence the quality and strength of the weld. Among these, welding current plays a critical role in achieving proper penetration. Table.1 shows the welding method and their reference NO (ISO 4063).

Welding method	Reference number
Metal-arc welding with coated electrode	111
Flux-cored wire metal-arc welding without gas shield	114
Submerged arc welding	12
MIG welding	131
MAG welding	135
MAG welding with flux-cored wire	136
TIC welding	141
Plasma arc welding	15
Oxy-fuel gas welding	31

Table 1. Welding method and their reference NO (ISO 4063).

Heat Input Calculation Formula

The heat input (Q) is a critical factor in determining the rate of cooling of the weld and its overall quality. The formula to calculate the heat input is:

$$\text{Heat Input (kJ/mm)} = \frac{V \times I \times 60}{S \times 1000 \times \eta}$$

Where:

- V = Voltage (volts)
- I = Current (amperes)
- S = Travel speed (mm/min)
- η = Process efficiency factor

METHODOLOGY:

The use of EB6 wire in Submerged Arc Welding (SAW) with suitable flux on Grade 5 base material is discussed in terms of its performance and qualification. The focus of this research is on the welding process, material behavior, and qualification results obtained in accordance with stringent low-temperature impact criteria.

The work was carried out at Precision Equipments Chennai Pvt. Ltd, where a complete Procedure Qualification Record (PQR) was developed and validated. The objective was to demonstrate the feasibility and effectiveness of using (EB6) saw wire consumables with suitable flux to weld SA 387 Gr 5 Cl2 plate, a combination rarely achieved with confirmed -15°C Charpy V-notch (CVN) impact toughness. This investigation covers both the technical performance of the welded joint and the methodologies employed during qualification. The PQR included detailed assessments of:

- Base material condition (including heat treatment status)
- Joint design and preparation
- Visual inspection and Liquid Penetrant Testing (LPT)
- Radiographic Testing (RT) for internal defect evaluation
- Metallographic (microstructure) examination
- Hardness distribution across weld and HAZ
- Chemical analysis of weld and base materials
- Sample dimensions and orientation
- Charpy impact testing at -15°C, with measurements of impact energy (J), lateral expansion, and shear area
- Final assessment of mechanical properties and chemical composition conformity

This successful qualification marks a critical advancement in welding technology, enabling the use of high-performance LAS consumables in demanding service environments requiring both structural integrity and cold-weather toughness.

QUALIFICATION PROCEDURE

This PQR outlines the welding process for SA 387 Grade 5 Class 2 base material. A plate measuring 500x300x45 mm was the coupon used to qualify. The welding process used Gas Tungsten Arc Welding (GTAW), Shielded Metal Arc Welding (SMAW), and Submerged Arc Welding (SAW).

EB6 solid wire with a diameter of 2.4 mm was chosen as the electrode for saw process. The welding parameters were optimized within the ranges listed below:

- Amperage: 250-450 A
- Voltage: 28-30 V
- Travel Speed: 500-550 mm/min
- Heat Input: 1.63 kJ/mm

Argon was utilized as the shielding gas since it creates an inert atmosphere that allows for a clean and steady arc during the welding procedure. With a test coupon size of 45 mm thick, the saw weld metal thickness obtained was 20 mm. The filler material used to weld the specimen is listed in Table.2.

Following welding, visual die penetration test and radiographic were performed. Following the Post Weld Heat Treatment (PWHT), a second radiographic inspection was performed to assess the integrity of the weld after PWHT. Later, in accordance with ASME Section IX, the sample was sent to the lab for chemical and mechanical analysis, under the Third-Party Inspection (TPI) organization witnessed and reviewed the full testing procedure.

This PQR ensures that all critical parameters required for successful welding of SA 387 Grade 5 Class 2 base material are documented and verified, establishing a repeatable and reliable welding procedure for future applications.

FILLER METALS (QW-404)			
Welding Process	**GTAW**	**SMAW**	**SAW**
SFA Specification	5.28	5.5	5.23
AWS Classification	ER 80S-B6	E 8018-B5	EB6
Filler Metal F No	6	4	6
Weld Metal Analysis	5	5	5
Size Of Filler Metal	2	3.15&4.0	2.4
Filler Metal Product Form	Solid	NA	Solid

Table 2. Filler material details.

For this qualification, an average impact energy of saw weld is 147.33 Joules was recorded, with a lateral expansion of 1.39 mm and a shear area percentage of 59%. Image.2 shows the sample location of impact test.

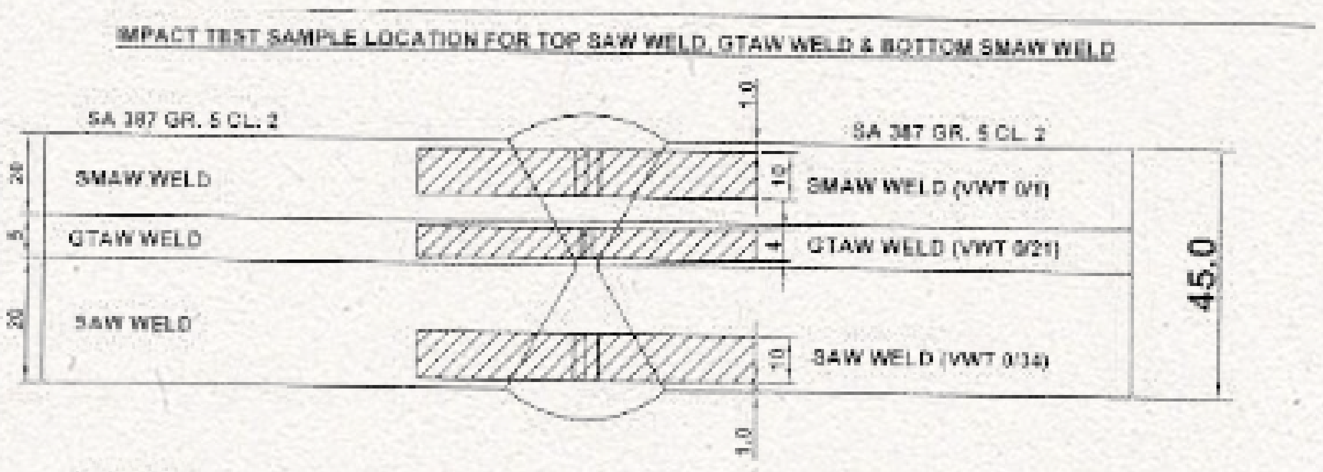

Image 2. impact test sample location.

The welding sample featured a “V” groove joint with a 60-degree angle. The top portion was welded using 20 mm of SAW, the root face consisted of 5 mm GTAW, and the final base was completed with 20 mm of SMAW. All welding was performed using qualified consumables. Image.3 shows the joints of weld.

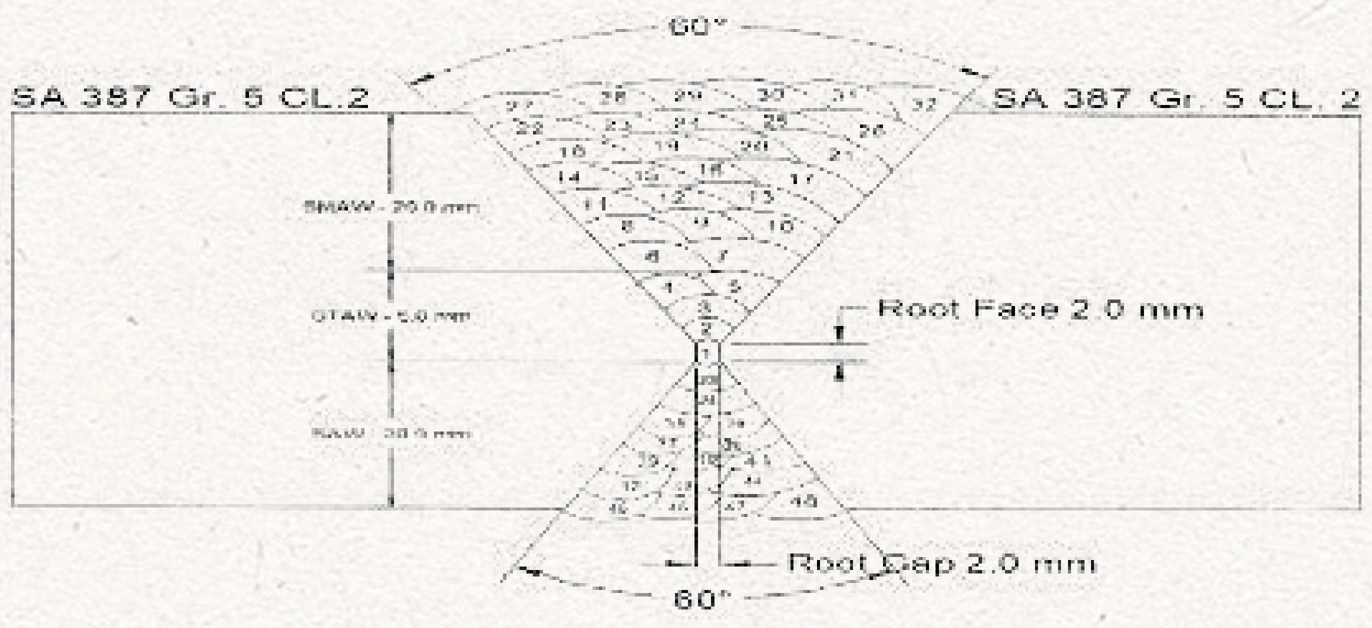

Image 3. Joints

Preheat Temperature Requirements

1. **Minimum Preheat Temperature:** 200°C (applicable for both SMAW and SAW processes)
2. **Maximum Interpass Temperature:** 295°C (applicable for both SMAW and SAW processes)
3. **Preheat Maintenance Temperature:** 200°C (maintained throughout the welding process for both SMAW and SAW)

Post Weld Heat Treatment (PWHT) Requirements

1. **PWHT Temperature Range:** 730°C
2. **Holding Time:** 540 minutes
3. **Post-Heating:** Immediately after welding, post-heating is carried out at **350°C for 120 minutes**, followed by **slow cooling** under insulation using **ceramic glass wool** to prevent rapid temperature drop and reduce the risk of thermal cracking.

RESULTS AND DISCUSSION

The mechanical test results met the specified requirements. The test parameters were as follows:

- **Cross-sectional Area:** 899.11 mm²
- **Tensile Load:** 482.69 kN
- **Tensile Strength**: 536.85 MPa
- **Fracture Position:** Fracture occurred in the base metal
- **Nature of Fracture:** Ductile

All mechanical properties were observed and tested as per the applicable standards.

The chemical analysis was conducted in accordance with ASME Section II, Part C, and all results were within the acceptable limits.

Toughness Test

The average values measured during the toughness test were average 147 joules with -15-degree impact.

Hardness Test

The Vickers hardness test was performed using an FIE VM-50 model hardness tester. The measured hardness values were 189, 188, and 187 HV, which are consistent and within the expected range.

Lateral Expansion Test

During -15 degrees, the lateral expansion was seen to be 1.39 and 1.40 mm, and the observed shear was 58 and 59%.

Tensile test

The tensile test for recorded area 899.11 mm^2 yielded an ultimate load of 482.69 KN and an ultimate unit stress of 536.85 MPa.

Metallographic Examination

Microscopic analysis (Image 4) shows complete fusion between the weld metal and base metal. The macro-etched sample was examined both visually and under a stereo microscope at 10x magnification. The examination confirmed complete fusion without any observable defects.

Image .4 microscopic observation of weld and base metal

The graphical representation of the different hardness testing steps is shown in Image 5. It illustrates the hardness values as per NACE MR0103 (measured in HV10), NACE MR0175 (also in HV10), and ISO 9015-1 standards.

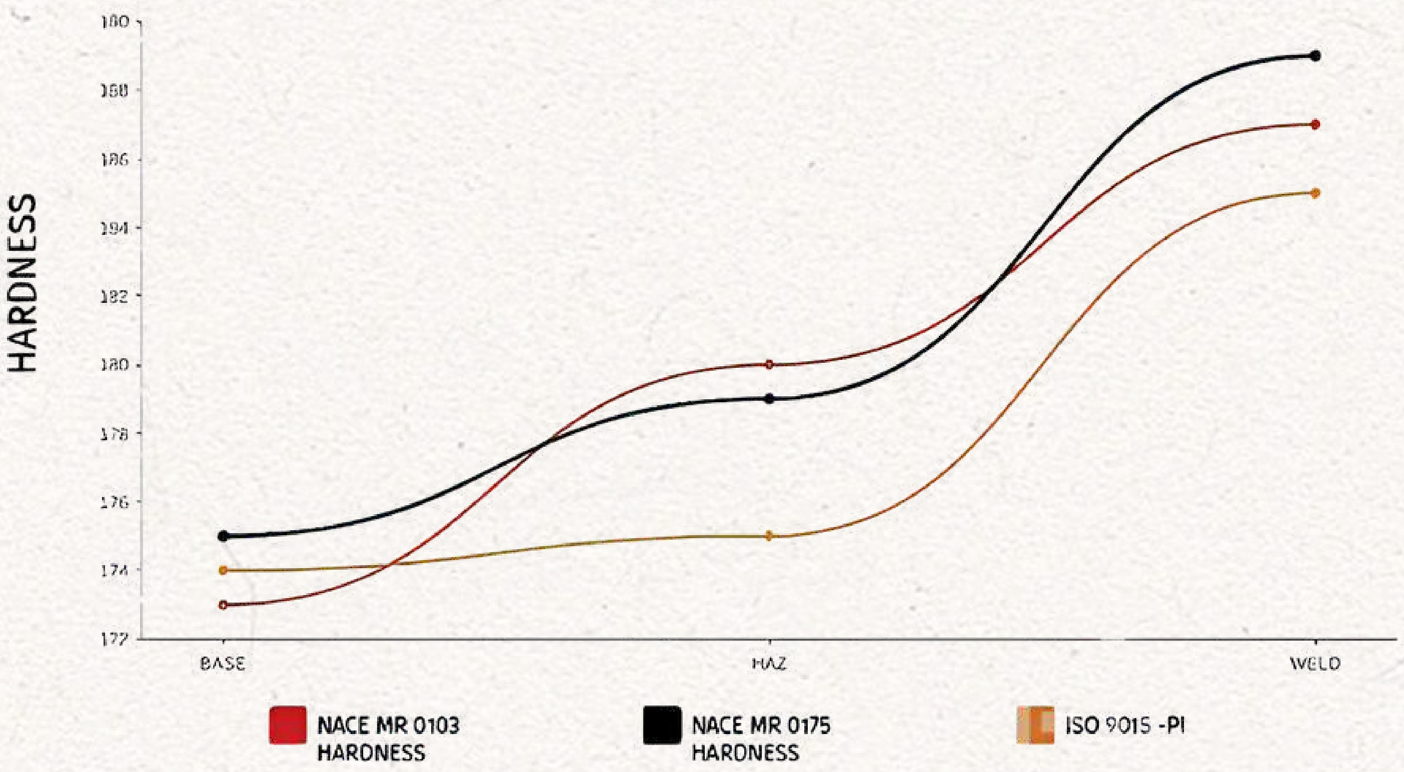

Image.5 shows the graphical representation of the hardness.

The welding procedure for SA 387 Gr 5 Cl 2 using EB6 consumables has been successfully qualified with verified -15°C impact toughness, meeting all mechanical and metallurgical requirements.

CONCLUSION

The successful qualification of the welding procedure for SA 387 Grade 5 Class 2 using EB6 solid wire with suitable flux was verified impact toughness at -15°C marks a major milestone in our welding development initiatives. This accomplishment, achieved through the optimized combination of SAW, GTAW and SMAW processes, carefully controlled welding parameters, and a calculated heat input of 1.63 kJ/mm, confirms our capability to deliver high-integrity welds that meet both mechanical strength and sub-zero toughness requirements. The use of argon shielding gas, direct current (DC), and electrode positive (EP) polarity proved essential in achieving stable arc behaviour, sound fusion, and clean weld metal. This procedure is now validated for critical service applications that demand both high-temperature performance and low-temperature impact resistance, establishing a new standard for welding Grade 5 materials with LAS consumables. It reinforces our position as a leader in advanced welding solutions for challenging environments.

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