Corrosion Mitigation in Gas Facilities Piping through the Use of Fusion Bond Epoxy Coated Pipes and Corrosion Resistant Alloy Girth Welds

Saad Alkhaldi, Fadi Ghammas, Tariq Alghamdi, Stefano Alexandirs

Abstract**—**The operating conditions and corrosive nature of the process fluid in the Haradh and Hawiyah areas are subjecting facility piping to undesirable corrosion phenomena. Therefore, production headers inside remote headers have been internally cladded with high alloy material to mitigate the corrosion damage mechanism. Corrosion mitigation in the jump-over lines, constructed between the existing flowlines and the newly constructed facilities to provide operational flexibility, is proposed. This corrosion mitigation system includes the application of fusion bond epoxy (FBE) coating on the internal surface of the pipe and depositing corrosion-resistant alloy (CRA) weld layers at pipe and fittings ends to protect the carbon steel material. In addition, high alloy CRA weld material is used to deposit the girth weld between the 90-degree elbows and mating internally coated segments. A rigorous testing and qualification protocol was established prior to actual adoption at the Haradh and Hawiyah Field Gas Compression Program, currently being executed by Saudi Aramco. The proposed mitigation system, aimed at applying the cladding at the ends of the internally FBE coated pipes/elbows, will resolve field joint coating challenges, eliminate the use of approximately 1700 breakout flanges, and prevent the potential hydrocarbon leaks.

Keywords**—**Corrosion, FBE coated sour service, cost savings**.**

I. Introduction

THE purpose of this article is to highlight the installation solutions for internally coated pipelines, overcoming field joints coating challenges at the Haradh & Hawiyah South Gas Compression Pipeline project. The application of an innovative dual coating and CRA cladding as corrosion mitigation methodology is considered a remarkable achievement, which would not be achieved without the diligent joint efforts of the Saudi Aramco Project Management Team, Consulting Services Department, and the construction company, SAIPEM. The affected segments are the jumpover lines, to be installed on flowlines inside remote headers, transmitting high-pressure sour gas from existing Haradh wells. This paper provides an overview of the piping installation and laboratory qualification tests to support the application of internal coating and cladding approaches to avoid construction complexity associated with the field joint coating challenges between internally coated mating pipe and fittings.

Due to the operating conditions and corrosive nature of the fluid, facility piping, namely the production headers and the jumpover lines, is susceptible to undesirable internal corrosion damages. To mitigate these corrosion failures, production headers inside remote headers have been designed with internally CRA cladded material. Jumpover lines constitute a larger and more involved scope of work, which demands the development of a new construction approach that is cost effective and offers enough flexibility to support the construction effort in the field.

II. Design Evolution

Initially, the jumpover lines were designed with internal CRA cladding to evade the corrosion problems. The cladded items are long lead and contribute to the delay of the overall project schedule considering the number of cladded pipes required for all the facilities under the Gas Compression program. An in-depth analysis was conducted to reduce the overall project cost without affecting the project completion schedule and compromising the integrity and quality of the installed pipes. As a result, it was decided to utilize the internally FBE coated carbon steel pipe in lieu of CRA cladded carbon steel pipe. The idea had been proposed keeping in view the post-compression scenario of the Haradh & Hawiyah Field Gas Compression Project, wherein downstream pressure will be reduced from 900 psig to 300 psig to increase the life of reservoirs. This reduction in pressure will reduce the impact of abrasion, which is potentially associated with sand particles present in the fluid stream on FBE coated lines. The proposal of providing internal FBE coating is applicable for jumpover lines with size 8 inch and above.

The proposal identifying the internally cladded and internally FBE coated portions of the jumpover lines, is depicted in Fig. 1. The initial proposal of installing the jumpover lines at the production header areas was reviewed considering the details pertaining to sand particle size, hardness, velocity and quantity to evaluate the proposed arrangement owing to the limited abrasion resistance of FBE coating.

Saudi Aramco operations team assisted in providing the data surrounding the quality and quantity of the sand particles. It was determined that sand quantity is usually high at the initial start of wells and it reduces with the passage of time.

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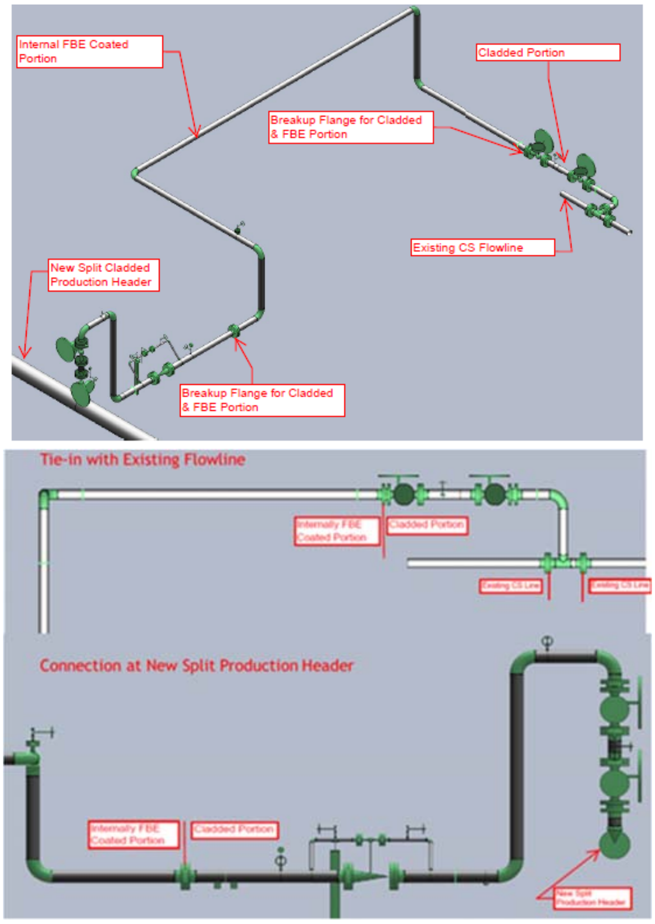

Fig. 1 Depiction of internally coated vs. cladded portions of the Jumpover lines in the original design

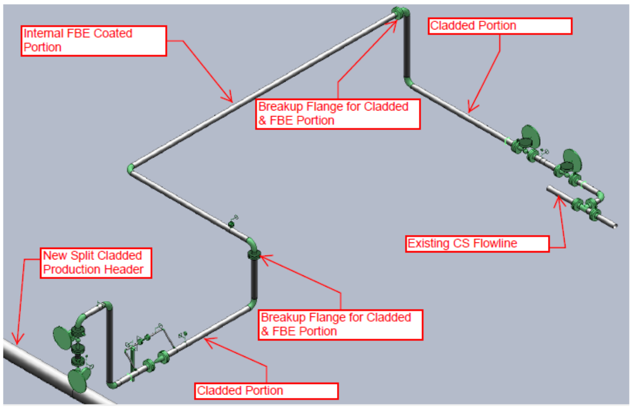

Fig. 2 Modified design with FBE coating limited to the pipe rack

The operational data showed that the maximum quantity of sand expected during the initial start-up of the wells is 0.2 LB/MMscf. In addition, filters with a mesh size of 50 microns are installed at the wells, which will prohibit the sand particles exceeding the mesh size from traveling downstream the piping system, which will ultimately protect the internal pipe coating layer.

Considering all this information, the boundary limits between the internal cladding and FBE coating were redefined by the design team to avoid internal corrosion damages and base metal thinning on the jumpover lines and elbows. In the revised arrangement, FBE coated pipes were limited to the pipe rack only, while the riser portion of the jumpover lines were kept cladded as this is more prone to corrosion and the materials can be availed without impacting the project schedule. Cladding the low point spool and the riser as shown in Fig. 2 will ensure the protection against any potential corrosion due to stagnation.

The cost saving of approx. SAR330 million was achieved due to the implementation of a combination of Alloy 825 pipes at riser spool and internally FBE coating on the pipe racks.

III. Construction Challenges of Internal FBE Coated Pipes

Automatic/robotic crawlers are used to restore the internal FBE coating after completing the field girth welds. These crawlers can be used to apply internal FBE coating on straight runs of pipes but cannot cover the change in direction associated with the pipe configuration encountered at 90-degree elbows. To overcome this problem, breakout flanged connections can be added as a valid construction approach to allow the usage of custom shop coated spools, without girth weld crawlers application. Flanged connections are not recommended for sour wet gas service applications to eliminate potential sour hydrocarbon leak in accordance with Saudi Aramco standard requirement, SAES-L-110 [1].

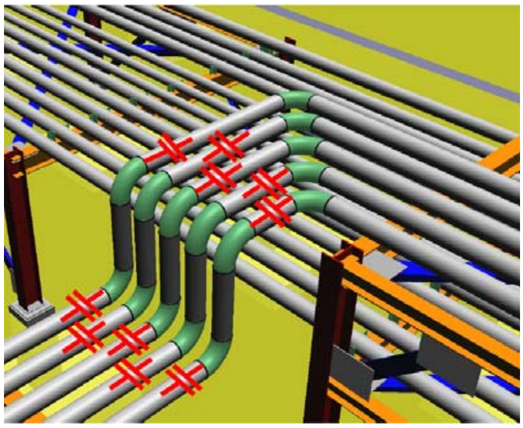

Fig. 3 Construction challenge at 90-degree elbows

Due to the leakage concern, a construction idea was developed by Consulting Services Department to eliminate the need for flange installation and overcome the field coating complexity. The technical solution pertains to the application of CRA weld overlay cladding at the ends of the Internally FBE coated pipes/elbows, which can be further welded together with high alloy 625 welding consumable in the field. This idea turned up to be further cost effective by reducing the number of breakout flanges as well as negating the challenges imposed by field joint coating between the pipe and elbows.

As illustrated in Fig. 4, internal CRA weld overlay with tensile strength of 120 ksi is applied as cladding material [2], to one end of the straight pipe and to the mating elbow respectively, prior to applying the factory internal coat. The coating is then applied over the entire length of carbon steel pipeline and extended over the weld overlay for approximately 50 mm (2 inch) length (i.e., overlap of FBE coating on the weld overlay ends) leaving uncoated areas adjacent to the ends of pipes and fittings of no less than 100 mm wide. The total length of the weld overlay layer shall not be less than 150 mm (6 inch) wide. The uncoated area at the pipe and elbow ends will be subjected to high heat of field welding. Since the weld overlay materials at pipe ends are corrosion resistant in nature, no further field reworks are deemed necessary after the construction work. To ensure adequate corrosion protection, two layers as minimum are applied to ensure a minimum weld thickness of 2.5 mm in line with API 5LD requirements [3]. The CRA weld overlaid ends, of pipe and elbow, will then be welded in the field using high alloy weld filler utilizing an approved welding procedure. Therefore, the resulting field girth weld and the uncoated corrosion resistant weld overlay at pipe ends will not require blasting, cleaning, coating and weld root inspection activities after the completion of the field welding.

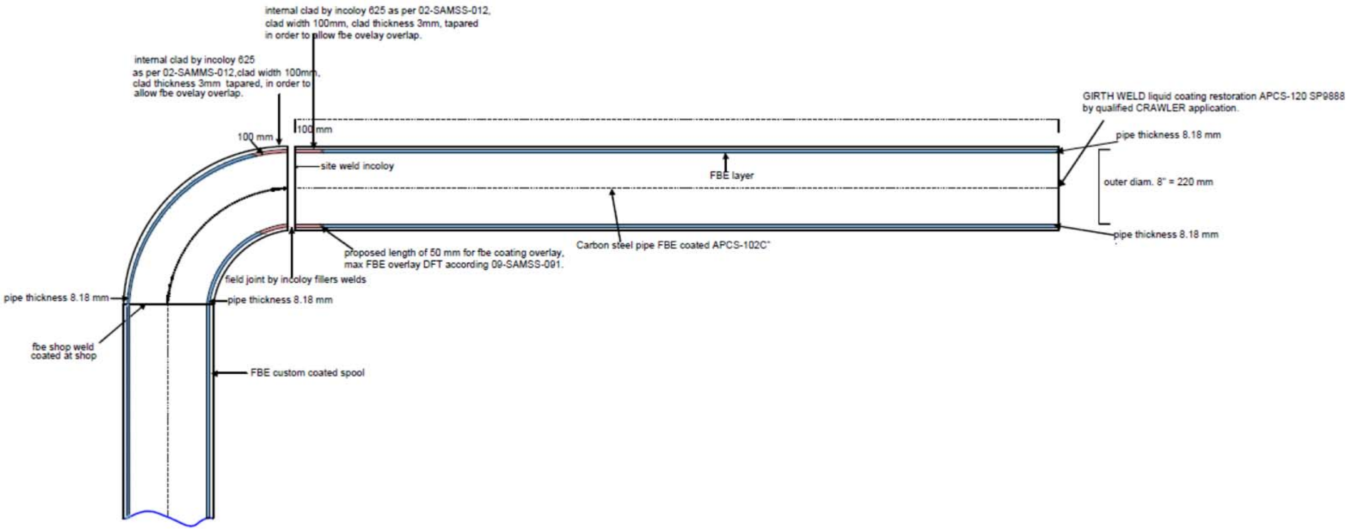

Fig. 4 Internal cladding applied at the pipe and elbow ends

To ensure high quality CRA weld deposit at the ends of pipes and elbows, additional CSD guidelines were established and strictly followed during field execution. These technical requirements are addressed below:

a) The weld overlay layer should be blended very smooth, along a 1:3 slope, to adjacent carbon steel ID surface to ensure high quality factory coating application.
b) The coating adhesion and soundness within 1 meter away of each pipe weld overlaid ends shall be 100% visually inspected as coating discontinuities near to weld overlay deposit may expedite the corrosion activities associated with galvanic reaction.
c) The application of weld overlay at pipe ends may affect the initially specified pipe roundness due to induced heat input. The roundness of pipe ends shall be validated to eliminate any high-low mismatch which will jeopardize the field welding quality, especially if field welding is conducted automatically.
d) The weld overlay application shall meet Saudi Aramco Material Specification requirements, 01-SAMSS-048 and 02-SAMSS-012 [4], [5] and shall be conducted by an approved vendor. The weld overlay shall be applied using controlled heat input. Manual welding is not permitted.
e) The field girth welds between the weld overlaid fitting and pipes ends shall meet Saudi Aramco Welding Standard requirements, SAES-W-019 [6]. The weld is carried out using nickel-based welding electrode, 625 alloy.

IV. Mockup and Testing

To ensure the requirements given in Section III were met, mockups of pipe and elbows were constructed. The applications of CRA weld overlay and FBE coating were verified and witnessed by the assigned Saudi Aramco Vendor Inspection Department (VID) representative. The coating qualification report was then reviewed and approved by CSD. The construction and testing procedure adopted by the project is outlined as:

Fig. 5 Elbow straight cladding

a) Performed weld overlays on two pipe ends of a minimum length of 4 inches (2 inches to be overlapped with FBE and 2 inches to remain uncoated at the girth weld). Weld deposit thickness is not less than 2.5 mm.
b) At the shop, blasting activities were performed in line with the procedure developed to be used at site. Anchor profile

and cleanliness of the cladded and carbon steel sections were verified by the vendor and in line with the coating factory procedure.

c) Heating and coating were applied on the mockup pipe and elbow sections. Upon completion, visual DFT adhesion (pull-off and X-cut) and MEK cure tests was done immediately.
d) Test rings were cut for the lab test. Hot water soak and DSC tests were then conducted on the samples.
e) The field trial results and lab tests were witnessed, signed and reported by the Saudi Aramco VID for final evaluation.

Fig. 6 Elbow transition cladding

Fig. 7 Pipe straight edge cladding

Fig. 8 Pipe transition cladding

V. FIELD TRIALS AND RESULTS

Upon the application of factory coating over the inside surfaces of the pipe and elbows, extended over the CRA weld overlay layer, field girth welding trail was carried out using high alloy nickel-based welding consumable.

All piping surface preparation coating materials selection and application were verified. The coating quality tests including, but not limited to, adhesion, thickness, moisture content, and holiday test were conducted, closely monitored and validated by the assigned SA inspection authority. All test results were found acceptable and in line with the industry practices as well as in compliance with the applicable internationals and Saudi Aramco standards requirements.

VI. CONCLUSION

Following successful rigorous qualification testing, the proposed corrosion mitigations resolution consisting of applying the cladding at the ends of the Internally FBE coated pipes/elbows resolves construction constraints that are inherent with girth weld coating at 90 degree elbows. The joint and complementary effort by the multidisciplinary team has successfully eliminated the use of approximately (1700) high pressure breakout flanges and prevented the potential hydrocarbon leaks. This construction approach ensures a very significant cost savings associated with the cladding of the entire piping system, the procurement of high pressure rating flanges and the elimination of field joint coating activities. This construction solution will be adopted by the Haradh and Hawiyah Field Gas Compression Program currently being executed by Saudi Aramco.

REFERENCES

[1] Saudi Aramco Engineering Standard SAES-L-110, Limitations on Pipe Joints and Components, July 10, 2019 at Dhahran, Saudi Arabia.
[2] American Society of Mechanical Engineers ASME B31.3 for Process Piping B31.3, 2018.
[3] American Petroleum Institute, API 5LD CRA Clad or Lined Steel Pipe, March 2015
[4] Saudi Aramco Material System Specification 01-SAMSS-048, CRA Clad or Lined Steel Pipe, October 03, 2018 at Dhahran, Saudi Arabia.
[5] Saudi Aramco Material System Specification 02-SAMSS-012, Weld Overlayed Fittings, Flanges and Spool Pieces, November 03, 2018 at Dhahran, Saudi Arabia.
[6] Saudi Aramco Engineering Standard SAES-W-019, Girth Welding Requirements for Clad Pipelines, May 12, 2019 at Dhahran, Saudi Arabia.