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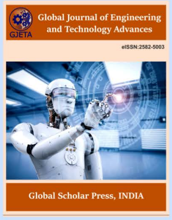

(Research Article)

Field implementation and technical evaluation of hot tapping on active gas pipelines

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Abstract

Hot tapping has become an essential technique for pipeline modification in situations where shutdown is impractical or economically undesirable. This study presents a comprehensive field evaluation of a hot tapping operation performed on an active API 5L Grade B natural gas pipeline within a regional distribution network. The objective was to document the technical execution, assess weld quality through non-destructive testing (NDT), evaluate pneumatic leak testing, and analyze the performance of the drilling process, including coupon retrieval. A split tee and trunnion-mounted ball valve assembly were installed following controlled welding procedures, and weld integrity was verified using PT, MPI, and UT examinations, all of which indicated defect-free joints. Pneumatic testing using staged nitrogen pressurization confirmed full sealing performance without pressure loss or leakage indications. The hot tapping machine operated smoothly, producing a cleanly cut coupon successfully retrieved by the safety wire. The operation also incorporated risk mitigation controls such as gas monitoring, tool verification, and procedural discipline, resulting in zero incidents. The findings align with established literature regarding the effectiveness and safety of modern hot tapping methods. Overall, this case study provides practical insights into field implementation, supporting the broader adoption of hot tapping for maintaining service continuity in active gas pipeline networks.

Keywords: Hot Tapping; Active Gas Pipeline; Weld Integrity; Non-Destructive Testing (NDT); Pneumatic Leak Test

1. Introduction

Natural gas distribution networks play a vital role in supporting industrial activities, transportation, and household energy needs. The growing reliance on natural gas has increased the demand for pipeline networks with high reliability and minimal interruption. Several previous studies have emphasized that unplanned shutdowns during pipeline maintenance can cause significant operational and financial losses, particularly in high-demand regions [1]. Conventional maintenance methods that require halting gas flow are often impractical and pose additional challenges in terms of safety, logistics, and supply continuity. For this reason, industries began to shift toward on-line maintenance techniques as a solution to ensure uninterrupted gas distribution [2].

Hot tapping has been widely recognized as an effective on-line pipeline modification technique, allowing operators to install new branches or perform repairs without shutting down the pipeline. Numerous publications describe hot tapping as a safe and efficient approach when executed with proper engineering controls, especially in gas transmission and distribution systems [3]. In several studies, hot tapping is reported to significantly reduce downtime and operational disruptions compared to traditional cut-and-connect methods [4]. Furthermore, advancements in tapping machine technology, welding practices, and safety protocols have expanded the applicability of hot tapping to higher-pressure and larger-diameter pipelines [5], making it an essential method for modern gas infrastructure management.

Despite its advantages, hot tapping is a complex procedure that involves risks such as welding defects, leakage, drill failure, and the potential for the coupon to fall into the pipeline. Previous researchers highlight that welding quality is

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the most critical determinant of success because poor weld fusion can compromise pipeline integrity when exposed to internal pressure [6]. Studies also show that operational hazards such as uncontrolled gas escape, equipment malfunction, and ignition risk must be carefully addressed through systematic risk assessment and adherence to industrial standards [7]. Additionally, the presence of pressurized gas within the pipeline introduces thermal and mechanical challenges that demand high operator competency and reliable monitoring systems [8].

Although hot tapping has been implemented in many energy and petrochemical industries, academic documentation covering practical field execution, especially in Southeast Asia, remains limited. Many existing publications focus on numerical modeling, weld metallurgy, or safety simulations, while detailed case studies of actual field operations are still scarce [9, 10, 11]. The lack of region-specific documentation poses challenges for engineers who require benchmarking data relevant to local operating conditions, pipeline materials, and regulatory environments. In Indonesia, where the natural gas distribution network continues to expand rapidly, systematic reporting of technical performance, testing outcomes, and risk mitigation strategies during hot tapping activities is essential to support knowledge development and workforce training [12].

This study aims to present a comprehensive technical evaluation of a hot tapping operation performed on an active carbon steel gas pipeline within a regional distribution network. The objectives are to document the materials and equipment used, describe the sequential execution of field activities, evaluate welding and joint integrity through non-destructive tests, analyze pneumatic leak testing results, and assess the performance of the drilling process. In addition, the study seeks to identify key operational risks encountered during field execution and examine the effectiveness of the mitigation measures applied. Through this case study, the article intends to contribute practical insights to the engineering community and enhance the limited regional literature on hot tapping practices.

2. Materials and Methods

The hot tapping operation examined in this study was carried out on an active carbon steel gas pipeline classified as API 5L Grade B. The selected pipeline segment had a nominal diameter of 8 inches and was located within an operating distribution network where shutdown was not feasible due to the need to maintain continuous gas supply. Prior to the installation of fittings, controlled excavation was performed to expose the pipeline safely. The excavation zone was reinforced using shoring systems and enclosed with safety barriers to ensure worker protection and maintain structural stability throughout the operation.

The primary materials employed in the installation included an 8” × 8” × 4” Class 150 RF split tee, which served as the main structural fitting for attaching the tapping valve. A 4” Class 150 RF trunnion-mounted ball valve compliant with API 6D was installed on the outlet of the split tee to regulate flow during and after drilling. Spiral wound gaskets were used to provide sealing reliability at the flange interfaces, while ASTM A193-B7 bolts and A194-2H nuts ensured adequate mechanical strength under pressurized conditions. Welding work utilized low-hydrogen E7018 electrodes in various diameters, selected for their proven ability to minimize hydrogen-induced cracking, which is a critical concern when welding on live pipelines.

The equipment used during the operation included standard shielded metal arc welding (SMAW) machines, electrode ovens to maintain electrode dryness, and alignment clamps to secure the split tee during fit-up. For drilling, a TDW T-760B hot tapping machine was employed, equipped with a hydraulic power unit, boring bar, pilot drill, and hole saw designed to cut through the pipe wall while preserving the integrity of the system. Non-destructive testing (NDT) equipment comprised dye penetrant (PT) kits for surface examination, magnetic particle inspection (MPI) devices for detecting subsurface defects, and ultrasonic testing (UT) instruments for verifying weld penetration and internal soundness. Leak tests were conducted using nitrogen cylinders, calibrated pressure gauges, and high-pressure hoses.

The procedure began with surface cleaning to remove rust, coating residues, and contaminants from the exposed pipeline. The split tee was then installed and aligned with clamps before welding commenced. The welding sequence involved root, hot, filler, and capping passes, all performed in accordance with API 1104 requirements. Upon completion, visual inspection was conducted, followed by PT, MPI, and UT to ensure that the welds were free from cracks, porosity, lack of fusion, or other discontinuities that could compromise safety.

Following the verification of weld integrity, the assembly underwent a pneumatic leak test. Nitrogen gas was introduced in several pressure stages to evaluate sealing performance. The test confirmed the absence of air leakage at the gasket interfaces, weld joints, and valve connections. After ensuring leak-free conditions, the hot tapping machine was mounted onto the valve, and the valve’s functionality was checked. Drilling was performed hydraulically until the pipe wall was fully penetrated. The successful retrieval of the coupon demonstrated that the cutting operation proceeded smoothly and without obstruction.

Throughout the operation, risk mitigation measures were strictly enforced. These included continuous gas monitoring to detect any abnormal concentration levels, repeated verification of the safety wire used to secure the coupon, inspection of valve movement during installation, and rigorous adherence to permit-to-work procedures. These precautions were essential to prevent hazards such as gas leakage, tool malfunction, or accidental release of the coupon into the pipeline. Collectively, the procedures and controls applied ensured that the hot tapping operation could be executed safely and effectively under live pipeline conditions.

3. Results and Discussion

3.1. Weld Integrity and NDT Evaluation

Field observations showed that all welds on the split tee both longitudinal and circumferential were completed following the specified welding sequence (root, hot, filler, and capping passes). Visual inspection confirmed uniform bead appearance and acceptable reinforcement. Subsequent non-destructive testing validated these observations. The PT examination revealed no surface cracks or porosity on the completed welds. MPI testing also indicated the absence of subsurface discontinuities, particularly in high-stress zones such as the toe of the weld and root area. In addition, UT scanning confirmed that internal bonding was free of lack-of-fusion defects and exhibited adequate penetration, meeting the acceptance criteria for hot tap fittings.

These results are consistent with previous studies that emphasize the importance of low-hydrogen electrodes and controlled heat input to prevent hydrogen-induced cracking during welding on pressurized pipelines [13]. Research on live-pipeline welding also reports that proper preheat and interposes temperature control significantly reduce residual stresses and distortion, thereby improving weld soundness [14]. In comparison, the weld quality obtained in this field operation demonstrates adherence to best practices and validates the suitability of the applied welding procedures.

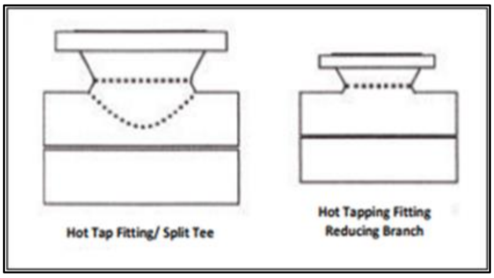

Figure 1 Structural Configuration of Split Tee and Reducing Branch Hot Tap Fittings

Figure 1 illustrates two common configurations of hot tapping fittings: the standard split tee (left) and the reducing branch fitting (right). In the context of this study, the split tee configuration is directly relevant because it represents the exact type of fitting installed on the pipeline during welding and subsequent NDT inspection. The split tee consists of two half-shell components that are welded circumferentially and longitudinally around the carrier pipe, creating a structurally reinforced housing for the tapping valve. The dashed lines shown in the illustration indicate the critical weld zones where proper fusion and defect-free weld metal are essential to maintain structural integrity under pressurized gas conditions

Figure 2 Split Tee Welding Process and Post-Weld Visual Inspection

Figure 2 show two key stages in the installation of the split tee during the hot tapping process. The right-side image captures the circumferential welding performed to secure the split tee onto the live pipeline. The left-side image shows the completed weld with visual inspection markings, indicating that the joint has passed the initial assessment and is ready for subsequent NDT procedures such as PT, MPI, and UT.

3.2. Pneumatic Leak Test Performance

Pneumatic testing using nitrogen gas was carried out at staged pressures of 80 psi, 200 psi, and 210 psi. Throughout the testing period, no pressure drops or bubble indications were detected at the gasket, weld joints, or valve connections. The stability of the pressure readings confirmed the sealing integrity of both the split tee and the ball valve.

These results align with findings from earlier studies which state that multi-stage pneumatic testing is an effective method for detecting micro-leaks prior to tapping, especially in fittings subject to cyclic pressure loads [15]. Other researchers have also highlighted that pneumatic testing at pressures slightly above operating levels provides an additional confidence margin for ensuring long-term integrity of tapping installations [16]. The consistency between field results and literature supports the conclusion that the installation met the required sealing performance before proceeding to drilling.

Figure 3 Leakage test

Figure 3 illustrate the field execution of the pneumatic leak test conducted after welding and assembly of the split tee. The left image shows the nitrogen pressurization setup, where the gauge reading is monitored while soap solution is applied to critical joints to detect any micro-leaks. The right image provides a wider view of the test environment, showing the tapping assembly pressurized and technicians observing the gauge stability during the staged pressure hold. These visual results confirm that no bubble formation or pressure drop occurred, which is consistent with the recorded findings indicating that the split tee, gasket interfaces, and valve connections maintained full sealing integrity prior to drilling.

3.3. Drilling Process and Coupon Retrieval

The drilling operation using the TDW T-760B machine proceeded smoothly, with the boring bar advancing uniformly into the pipe wall. Operator feedback and tool movement indicated no unusual vibration or resistance. After penetration, the coupon was successfully retrieved using the safety wire system, as documented in the field records. A clean coupon face suggested effective hole saw sharpness and appropriate feed rate.

Comparative studies have noted that the retrieval of the coupon is one of the most critical indicators of a successful hot tapping operation, as loss of the coupon can obstruct downstream flow or damage internal surfaces [17]. Other research demonstrates that controlled hydraulic feeding reduces tool chatter and improves coupon capture reliability [18]. The field results are consistent with these findings, indicating that the drilling operation was well controlled and compliant with established procedural standards.

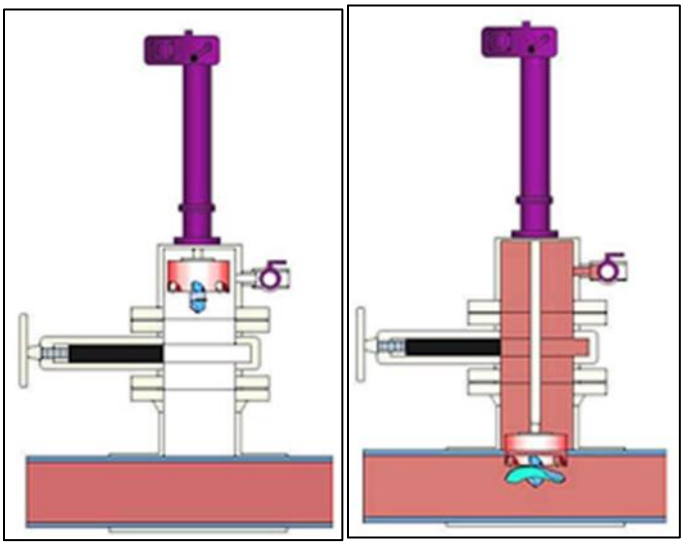

Figure 4 Hot Tapping Machine Setup and Completion of the Drilling Process

Figure 4 depicts two sequential stages of the hot tapping operation. In Figure 4A, the tapping machine is fully mounted onto the valve and split tee assembly, indicating the setup phase prior to drilling. This configuration ensures proper alignment between the boring bar, the hole saw, and the pipeline wall. In Figure 4B, the drilling process has been completed, and the coupon has been fully cut and secured by the safety wire inside the tapping equipment. This condition confirms a successful penetration of the pipe wall and proper retrieval of the coupon, both of which are essential indicators of a controlled and well-executed drilling operation. The two diagrams visually reinforce the field results reported earlier, showing that the tapping machine functioned as expected and that no obstruction or tool malfunction occurred during the cutting process.

3.4. Operational Risks and Mitigation Effectiveness

Several major risks were identified during the field operation, including gas leakage, weld failure, drill bit breakage, and safety wire malfunction. Risk mitigation strategies documented in the project file included repetitive checking of the safety wire, continuous presence of a gas detector, verification of valve operability, and adherence to permit-to-work procedures. No abnormal events or near-miss incidents were recorded.

Published literature affirms that risk mitigation during hot tapping must focus on controlling ignition sources, verifying tool integrity, and ensuring weld qualification before drilling [7]. Studies also emphasize the importance of procedural discipline, as human factors are a major contributor to hot tapping failures globally [8]. The absence of incidents in this project indicates that the applied mitigation strategies were effective and aligned with international best practices.

3.5. Comparison with Conventional Pipeline Modification Methods

Compared to the traditional cut-and-connect method, the hot tapping procedure demonstrated significant operational advantages. Field records from the operation indicate that hot tapping was selected to avoid shutdown and maintain gas supply continuity, a condition that would not have been achievable through conventional pipeline replacement methods. This conclusion is comparable to literature reporting that hot tapping reduces service interruption, minimizes excavation scope, and lowers operational downtime [9]. However, other studies note that hot tapping carries added complexity related to welding on live pipelines and requires highly skilled personnel [10].

In this case study, the combination of controlled welding, validated NDT results, successful pneumatic testing, and effective coupon retrieval confirms that the hot tapping operation delivered reliable performance without compromising safety. The findings reinforce the suitability of hot tapping as a preferred modification method when continuity of service is critical.

4. Conclusion

This study has demonstrated that hot tapping can be performed safely and effectively on active natural gas pipelines when supported by proper engineering controls, qualified welding practices, and structured risk mitigation. The weld integrity assessment using PT, MPI, and UT confirmed that all joints met the applicable acceptance criteria, indicating that the welding procedures and heat input management were adequately controlled. The multi-stage pneumatic leak test successfully validated the sealing performance of both the split tee and valve assembly, ensuring that the system was fully prepared for drilling. The drilling operation itself proceeded without abnormal resistance, vibration, or tool malfunction, and the successful retrieval of the coupon further confirmed procedural compliance and equipment reliability.

Operational risks including gas leakage, weld failure, and potential coupon drop were effectively mitigated through continuous monitoring, verification of tool readiness, and adherence to permit-to-work protocols. No incidents or near misses occurred throughout the activity. When compared to conventional cut-and-connect methods, the hot tapping approach provided significant advantages, especially by maintaining uninterrupted gas supply and minimizing operational downtime.

The overall results affirm that hot tapping remains a highly reliable and efficient technique for pipeline modification in live systems. The documented field experience contributes valuable practical knowledge to the limited regional literature and may serve as a reference for engineers and practitioners planning similar operations in active distribution networks.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper. No financial, personal, or professional relationships with individuals or organizations have influenced the outcome or content of this manuscript.

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