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Comparative Analysis of Natural Gas Pipeline Interconnections

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Abstract. The paper shows a comparison between two intervention methods for interconnecting two gas transmission pipelines within a natural gas transmission system. One intervention implies shutdown of pipelines, while the other one in-service pipelines. Each method is described in detail along with the main technological issues, as well as the related advantages and disadvantages. The technological procedures imply special working techniques such as welding or hot tapping in service pipelines.

1 Introduction

The natural gas transmission activity often requires pipeline interconnections for different purposes, such as: transfer of certain gas volumes to other consumption routes, enhanced safety of pipeline operation, enhanced safety of customer supply etc.

Interconnection of steel transmission pipelines may employ usage of different work procedures, depending on the decision on whether or not to keep the pipelines in service during interconnecting works. Many of the activities related to the interconnection of pipelines, just like the activities related to operating them, can be optimized using computer-aided techniques [1].

Figure 1 shows a simplified interconnection schematic of two main natural gas transmission pipelines of DN 500 mm (20”) outside diameter, X 52 steel grade, 7.1 mm wall thickness, manufactured in compliance with SR EN 1383/2017, *Petroleum and natural gas industries — Steel pipe for pipeline transportation systems*.

The shown case is particularized by analyzing the intervention operations required for the interconnection of the two pipelines in two scenarios:

- interconnect in-service pipelines

and

- interconnect shutdown pipelines.

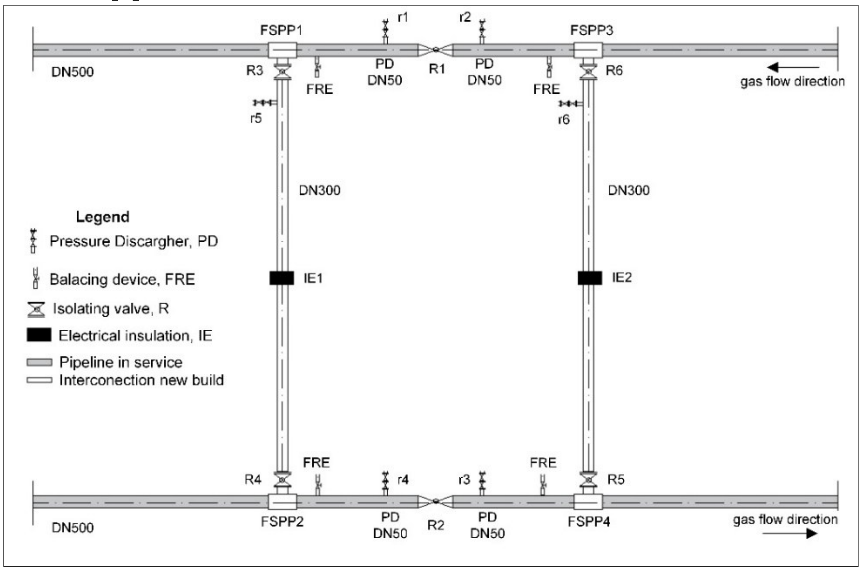

Fig. 1. Schematic of interconnecting two natural gas transmission steel main pipelines

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The interconnection is obtained by making a pipe that ensures connection between the two main pipelines. Equipping with new pipes implies a thorough analysis of consumption demand in the impacted area, as well as a comparative technical - economic analysis of the work procedures that could be applied.

Furthermore, all interventions on the pipelines are made after detailed analysis of risks implied by both scenarios.

2 Interconnection of in-service pipelines

In case of interconnecting pipelines while remaining in service, an important issue is to establish what technological processes are to be used for connecting the new pipes (as part of the interconnection) to the existent ones.

One of the analyzed methods is hot taping in all points requiring a direct connection with the in-service pipelines [2].

Figure 1 shows a simplified constructive scenario of an interconnection by DN 300 mm pipeline segments, set on opposite sides of the R1 and R2 isolation valves installed on the two DN 500 mm pipelines. The purpose of making such interconnection is to ensure a continuous gas supply while performing different maintenance works on several segments of the main pipelines by transmitting the gas volumes from one pipeline to another [2].

The hot tapping technological process is used for connecting the DN 300 mm: R3, R4, R5 and R6 valves (Figure 2).

The main steps of hot tapping (as shown in Figure 3) are the following:

- inspection of pipeline wall by using ultrasound equipment to check the minimum allowed wall thickness and the integrity of pipeline material with the aim of avoiding the burn-through caused by electric arc produced in welding [3];
- examination of the flow regime while hot tapping (by setting a maximum allowed flow speed of gas through the pipe, and a maximum allowed pressure) [4];
- special designed tee-pieces, equipped with multifunctional flanges and weldable body (FSPP) joined by welding to the outer part of pipelines, employing homologated welding procedures and certificated in accordance with SR EN 12732 - 2014;
- drilling into the pressurized system by complying with certain work procedures (set up on in accordance with API Recommended Practice 2201-2010) [5].

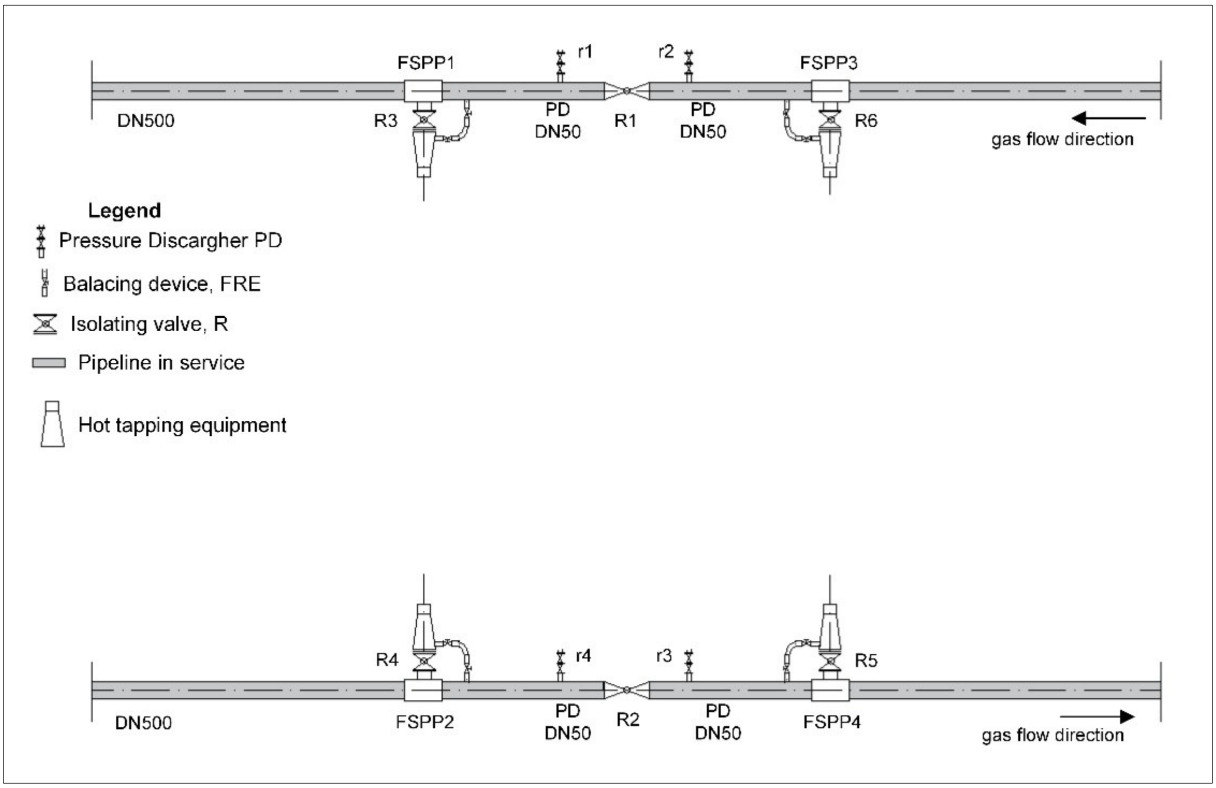

Fig. 2. Layout of DN 300 mm valves for hot tapping

Then, construction and installation works, specific for interconnecting DN 300 mm pipes, are performed by classical methods implying installation of the DN 300 mm connection pipes, the r5 and r6 pressure dischargers, and the IE1 and IE2 electric insulating connections (see Figure 1).

The special designed FSPP 1, FSPP 2, FSPP 3 and FSPP 4 tee-pieces used for connecting the valves on the under-pressure pipeline allow for maintenance operations in the area of the newly constructed pipe while the DN 500 mm main pipeline remains in service.

Thus, after the installation is in place and put into service, maintenance operations may be performed on the connection piping, as follows:

- defects occurred in the pipeline segments between R3 and R4 valves or R5 and R6 valves may be remedied by classical intervention methods where the pipeline segment between the two valves is removed from service and depressurized by the r5 or r6 pressure dischargers;
- for repairs/ replacements of any of the R3, R4, R5 or R6 valves a special designed equipment for intervention on the under-pressure pipeline may be used, by which a plug is installed into a special designed seating in the inner part of the FSPP multifunctional flange; thus, the valve may be removed under pressure, dismantled, repaired or replaced under safety conditions, and then pressurized by removal of the plug through the valve [2].

a. *b.* *c.* *d.*

Fig. 3. Illustration of the technological process stages of under pressure drilling into a natural gas transmission pipeline.

a - tubing inspection; b - examination of the pipeline operating regime; c - installation of the multifunctional flange with weldable hot tapping tee body; d – realize the hot tape operations.

It should be specified that intervention on the under-pressure pipeline implies additional safety measures as compared to the shutdown pipeline scenario, as follows:

a. Checking the pipeline technical condition and the best operating conditions by:
   - documentation - study of the pipeline technical data sheet, made available by the pipeline operator (outside nominal diameter, pipeline material, wall thickness, applied anticorrosion insulation, active anticorrosion protection system, if such is in place, depth of pipeline trench etc.)
   - examination of the pipeline operating regime by calculating and field verification of the gas flow speed in the intervention area, the maximum pipeline operating pressure, and, if the case may be, the possibilities to modify the pipeline operating parameters in determined stages, depending on the requirements of each intervention stage.

The maximum allowed pressure inside the pipeline tubing during under-pressure welding may be calculated as follows [7]:

$$OP \leq \frac{2\sigma_a(S - p_{cus})}{De} \tag{1}$$

where:

OP - pipeline operating pressure while under-pressure connecting [MPa];

S - effective wall thickness of pipe where the special fitting is installed on [mm];
p_{cus} - penetration of the electrode into the base material while forming the welding seam directly onto the pressurized pipeline [mm];
De - pipeline outside diameter [mm];
σ_a - allowable tension [N/mm^2].

b. Ensuring the requirements imposed by the intervention procedures to be employed for interconnecting of in-service pipelines, as follows:

- During hot tapping of fittings to pipes, the following specific issues should be considered:
  - compliance with the minimum safety conditions imposed under API 1104/2005 referring to the minimum allowable pipe wall thickness [3];
  - performing and qualifying the welding procedures in accordance with SR EN 12732/2014 or API 1104/2005, bearing in mind that safety of next interventions is ensured by the welding qualification in situ [6, 3];
  - training of personnel involved in such interventions by employing experienced trainers;
  - qualification of welders for the specific welding procedures: trainees should be provided adequate practice in similar works to achieve a good work pace;
  - supervision and monitoring of interventions.
- During hot tapping, the following requirements should be complied with:
  - operating personnel should be trained to carry such interventions;
  - employment of equipment designed for hot tapping, selected according to the pipeline maximum operating pressure;
  - employment of work procedures in compliance with the requirements of the API RP 2201/2010 [5].
- Construction - installation works in compliance with the quality requirements of the technical projects

Table 1 shows a comparison between the advantages and disadvantages of interconnecting under - pressure pipelines.

Table 1. Advantages and disadvantages of interconnecting under-pressure pipeline

Advantages	Disadvantages
• Pipelines remain in service during the full duration of works. • Avoids interventions in potentially explosive environments and exposing personnel to the risks specific to such interventions. • Limits the working areas on the operating pipes through interventions limited to the interconnection area. • Efficient intervention by carrying out works requiring minimum efforts to pressurize the newly interconnections and make them operational. • Possibility to carry out maintenance on valve R3, R4, R5, R6, without disrupting operation of DN 500 mm main lines and without affecting customers relying on these pipes. • Avoids loss of significant quantities of natural gas during taking out of service or while pressurizing the pipes, and thus, preventing environmental pollution. • Interventions may be planned without having to consider the pipeline shutdown schedule.	• Requires a thorough analysis of several technical factors such as pipeline operating regime so that interventions can be performed while pipe is in operation. • Requires setting and use of a maximum allowable working pressure during welding of pipes under pressure. • Requires special equipment designed for interventions on pipes under pressure. • Requires specialized equipment designed to intervene in such situations.

3 Interconnecting shutdown pipelines

The classical interconnecting method (see Figure 4), by taking the pipelines out of service implies installing pipes and specific pipe elements (split-tee, valves, electric insulating connections, pressure dischargers etc.) after each pipeline segment is successively taken out of service.

Previous to installing the interconnecting elements the intervention areas have to be secured by pneumatic obstructing and controlled venting of remaining gas.

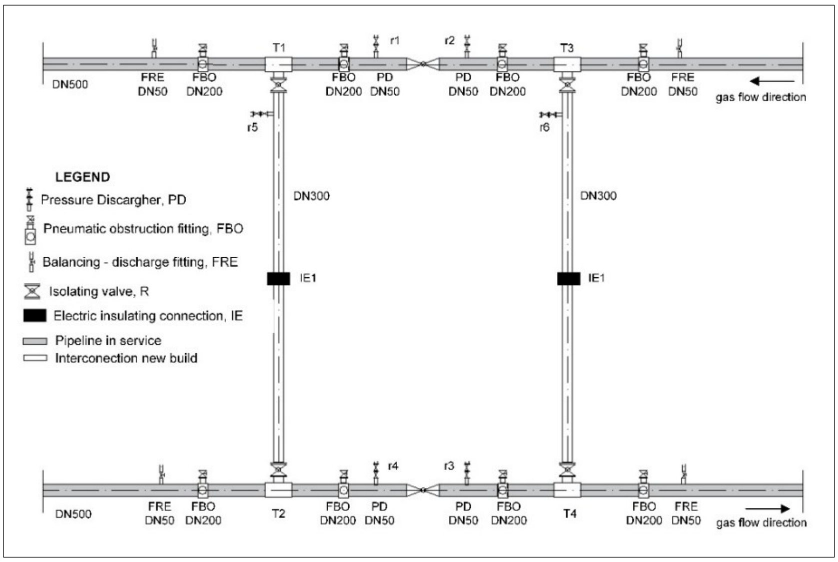

Fig. 4. Schematic of interconnecting two shutdown gas transmission pipelines, ensuring safety by pneumatic plugs

The method involves ensuring safety areas around the pipelines where specific fittings DN 200 mm are to be installed to allow insertion of pneumatic plugs and vents through special fittings (FRE DN 50 mm) to vent remaining gas. Such fittings are installed so as to isolate the potentially explosive areas from the open-air fire intervention areas [7].

The FBO DN 200 mm fitting is obtained by using two welding seam types, one butt weld with full penetration and fillet weld seams for connecting the fitting to the piping. Welding of FRE DN 50 mm fittings to the DN 500 mm pipeline involves fillet welding. Both fittings may be welded in both scenarios: pipeline in service or shutdown [4].

Safety of pipelines is ensured by installing pneumatic plugs in 8 points, as shown in Figure 4. The stages of the process are shown in Figure 5. After isolating the potentially explosive areas from the intervention area, the fitting can be installed as shown in Figure 4 [8].

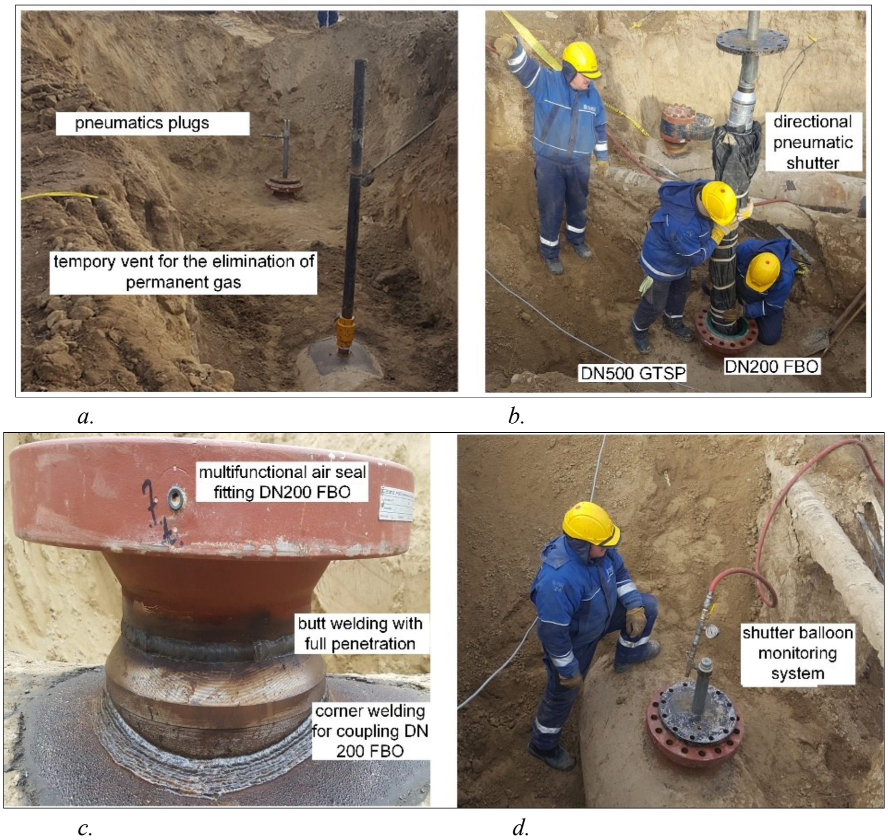

Fig. 5. Stages of ensuring safety of shutdown pipeline

a. - installing the safety equipment on the pipe; b. - installing a directional piece through a fitting FBO made on the pipe; c. - DN200 FBO - types of welding used for fittings; d. - FBO monitoring after pipeline is put into service.

An important step in making the connection is the cutting of shutdown pipelines with specialized cutting/ chamfering equipment designed to work in potentially explosive areas. This practice ensures the intervention area with pneumatic plugs and adequate venting of pipes before interventions with open-air fire.

Table 2 shows the advantages compared to the disadvantages of shutdown pipeline interconnection.

Table 2. Advantages compared to the disadvantages of shutdown pipeline interconnection

Advantages	Disadvantages
• Planned works can be performed after pipelines are taken out of service, thus eliminating the risk of performing interventions near to under-pressure pipes. • Simple fittings T1, T2, T3, T4, not requiring a special construction can be used, thus allowing for a shorter procurement time. • Several types of valves can be used to operate the interconnection area; total pass-through valves are not required.	• Works require shutdown of pipelines during construction of the new designed elements, resulting in loss of gas quantities during venting and pressurizing, as well as gas service interruptions to customers. • Ensuring pipe safety requires works in advance. • Environmental pollution (increase in methane emissions) by venting. • It is necessary to set a well-defined time period for pipeline shutdown. • For pipelines need to be taken out of service, the timeframe for works is restricted by the need to return the pipelines to operation in the shortest time.

4 Conclusions

Two or more gas transmission pipelines can be interconnected by shutdown or in-service interconnect.

In-service interconnect, although involving advanced technologies, specialized teams and detailed analyses of intervention conditions is preferable to the shutdown interconnect.

Hot tapping has lots of advantages such as environmental protection, intervention without disrupting service to customers, and may be performed during a scheduled period or immediately, depending on the availability of teams.

Hot tapping correlated with use of special designed fittings provides a fresh opportunity for maintenance work of pipelines and related components.

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