Latest ILI technology enables the utilisation of existing infrastructure to accelerate a CCS project

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ABSTRACT

TECMA and Baker Hughes have been actively involved in supporting ENI in the development of the “Carbon Capture & Sequestration (CCS) pilot project”.

In order to re-use the existing infrastructure for CO2 transportation in CCS Demo project in Ravenna (Italy), the feasibility to insert a new 4” X65 pipeline into an existing 20” X52 pipeline was evaluated. The existing pipeline acts as casing and thus minimizes environmental impact, facilitates permits request, and provides an external extra-protection.

The initial request was to get accurate geometrical data from the existing 20” pipeline in order to reuse it as a conductor for the new pipeline pulling project, with particular focus on pipeline routing and bends geometry with the objective to confirm the fit for purpose and to plan the pulling process of the new 4’’ pipeline. TECMA and Baker Hughes were tasked to engineer and provide an “intelligent pig system” as compact and smart as possible capable to characterize the pipeline bends, in terms of minimum bend radius, angle and position, along the overall pipeline route (onshore and offshore).

Using the latest ILI technology, TECMA proposed to employ a multi-technology inspection vehicle instead and was able to provide data that helped ENI to re-evaluate the integrity of the existing 20" pipeline and to re-use it as the main CO2 carrier.

INTRODUCTION

The legislation in terms of CO2 emissions (carbon tax), the EU policy lines, as well as the Eni decarbonization strategy itself have highlighted the opportunity to identify an Italian hub suitable for developing a business model that includes sequestration and storage of CO2.
The District of Ravenna has been selected as an ideal as a potential Italian HUB where the Carbon Capture & Sequestration (CCS) model, similar to other European projects currently under development, can be developed.
In detail, Ravenna District has been considered particularly suitable for the following reasons:

- manages mature fields which has, in some cases, economically marginal production.
- is equipped with transport infrastructures serving gas fields that are potentially convertible or synergistic to CO2 reinjection and sequestration activities.
- has specific technical skills and knowledge of the subsoil

CCS Ravenna Hub project aims to analyze the possible plant configurations to capture and sequester the production of CO2 generated by Eni sources located at the Ravenna industrial site as first step, and, subsequently, guarantee access to third parties, once depleted fields (Fig.1) are made available, in order to facilitate the development of a national hub to serve other industrial areas.

Fig 1: Mature fields in north Adriatic Sea

The development strategy provides for a gradual growth of Ravenna Hub aimed at facilitating the decarbonization of industrial emitters, first in Ravenna area and subsequently in other national areas.

COMPANY'S ORIGINAL PROJECT REQUIREMENTS

The CCS pilot project envisages the insertion of a new 4'' X65 pipeline for CO2 transportation into existing pipelines in the CABO-PCW area (Ravenna, Italy).
Although several alternatives are being considered, the basic idea is to maximize the sections where the 4'' is within the existing cases, in order to minimize environmental impact, facilitate permitting request and provide some sort of extra-protection (protective casing) for CO2 transportation.
Existing infrastructures being considered as casing were:

- The 20'' pipeline X52 WT 17.5mm or the 10'' pipeline X52 with thickness ranging from 14.3mm to 15.5mm from CABO to PCWT;
- The 14'' X52 WT or the 14'' X52 WT for the area from PCWT to PCWB, which is connected through platform piping to final designed CO2 injection platform (PCWC).

All these pipelines are currently in service and were part of a High Level Pipeline Inspection management qualification screening program by ENI, that deemed them suitable for more advanced integrity verification to confirm their fit for purpose.
However, considering the many years of service and the intended scope, an accurate inspection of these lines is deemed necessary to confirm that they are fit for the insertion of the 4'' new pipeline.
The overall project layout is presented in Fig.2.
Fig.3 shows the onshore area, which is of particular interest.
In order to estimate the required pulling forces, equipment and worksites for the 4'' PIP insertion activities, it was deemed important to confirm the bends angle, positions, and radius of the existing 20''/10'' pipelines route bends.
Being both pipelines buried in the onshore area, it was not possible to provide this confirmation without carrying out excavating works in the area and this would require interaction with the environment and will be subject to time consuming and complex authorization process.
Consequently, it was expected that this information could be inferred after the Internal Inspection of the pipelines by means of In Line Inspection Pigs.

Further objective of the inspection was the confirmation of the pipelines integrity and the absence of gross section restrictions, dents, etc..

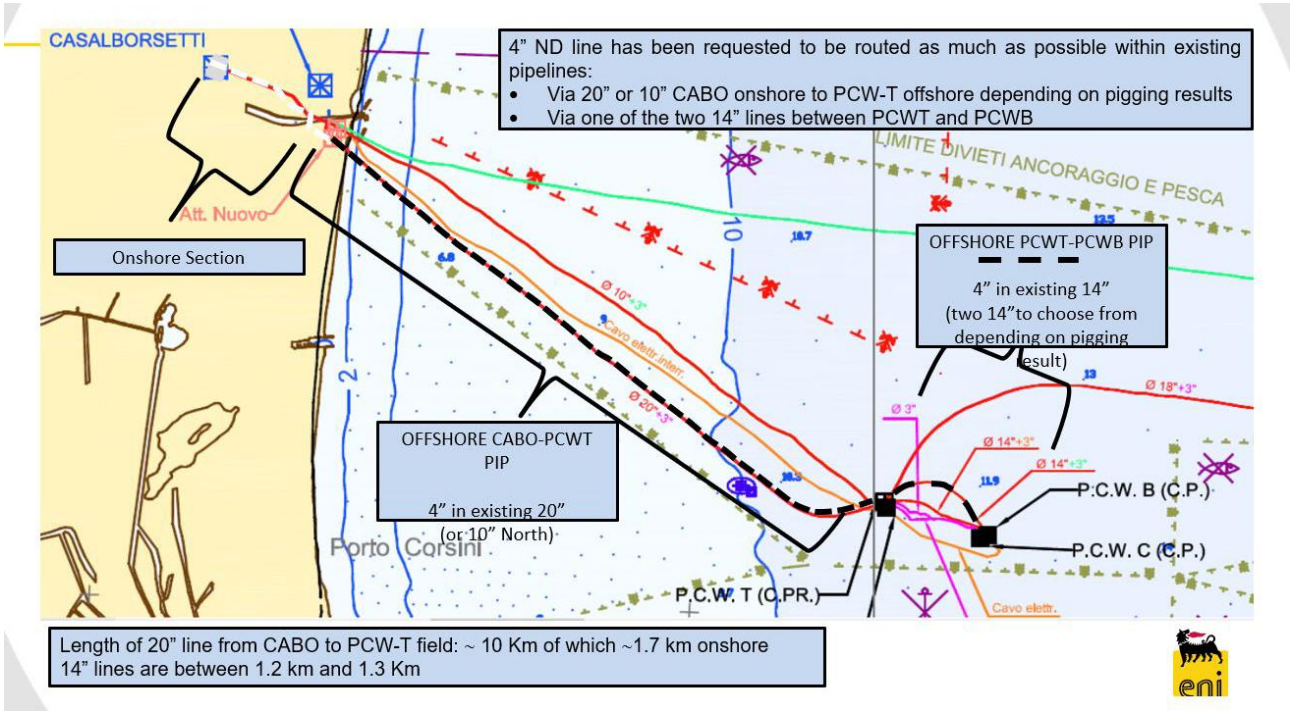
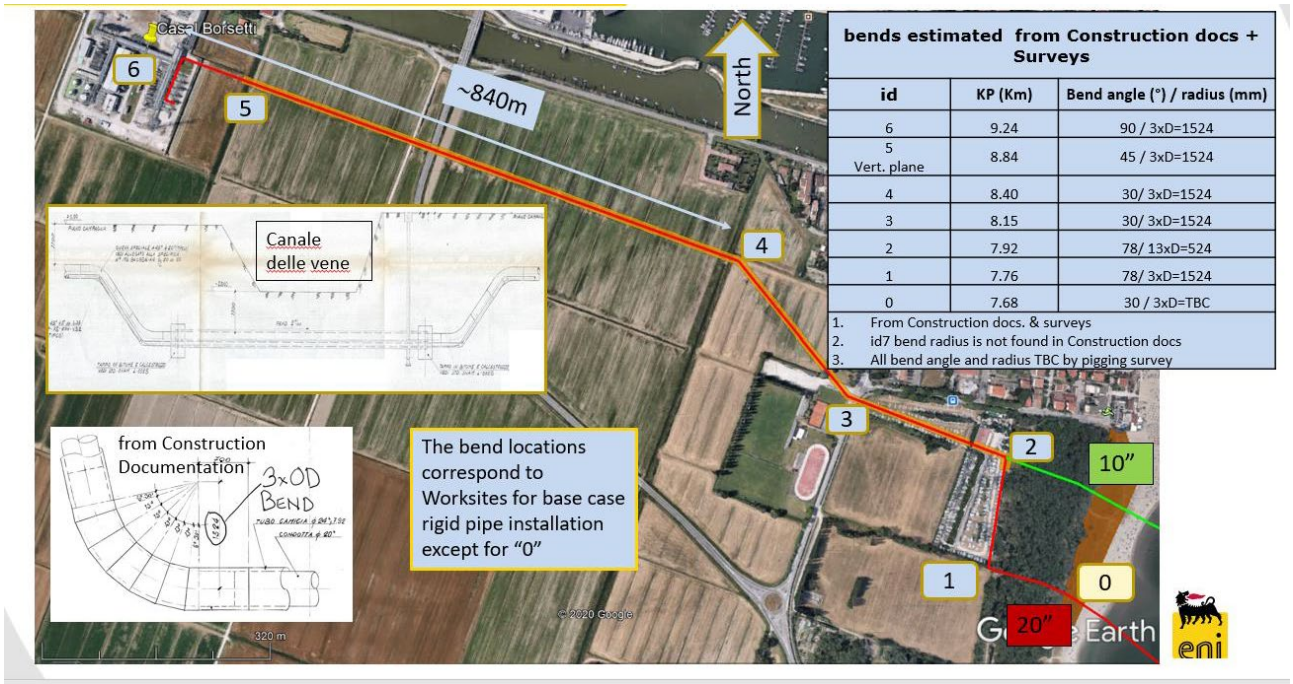


Fig 2: CCS pilot project – Overall layout



bends estimated from Construction docs + Surveys

id	KP (Km)	Bend angle (°) / radius (mm)
6	9.24	90 / 3xD=1524
5 Vert. plane	8.84	45 / 3xD=1524
4	8.40	30/ 3xD=1524
3	8.15	30/ 3xD=1524
2	7.92	78/ 13xD=524
1	7.76	78/ 3xD=1524
0	7.68	30 / 3xD=TBC

1. From Construction docs. & surveys
2. id7 bend radius is not found in Construction docs
3. All bend angle and radius TBC by pigging survey

Fig 3: CCS pilot project – Onshore layout & existing route bends expected configuration

IN LINE INSPECTION INITIAL SCOPE OF WORK

The In Line Inspection (ILI) had the following objectives:

- To confirm that the existing pipelines do not have dents, reduced ovality, wrinkles, obstructions, etc. which could jeopardize the 4'' pipeline insertion operation;
- To assess the Out of Straightness (OOS) of the existing pipelines, presenting a clear correlation chart - route KP versus curvature radius in the horizontal and vertical axis;
- To assess in detail the Angle of bend (expected 30°), the bend radius and the exact position of the bend, and any other onshore/offshore bend for the 20'' pipeline;
- Through the development of an accurate above ground georeferencing system, determine the x,y,z position of each significant pipeline feature (bends, anodes, feature and girth welds.

Considering these objectives, the Intelligent pig had to be equipped with an Inertial Measurement Unit (IMU).
Furthermore, the ILI had to be preceded by an accurate progressive pre-calibration and cleaning of the pipeline to achieve a safe pigging operation and adequate cleanliness level before launching the Intelligent Pig (IP).
In addition, the inspection had to be completed in one single run and provisions had to be made to ensure that the inspection tool will not damage the internal pipeline surface during the pigging process.

IN LINE INSPECTION FINAL SCOPE OF WORK

The initial scope was extended by the requirement of a high-resolution metal loss detection and sizing process. This decision was made considering that the long-term integrity of the available 20" pipeline is critical to the success of the project. As corrosion is a major threat to the integrity of a pipeline, it is imperative to add metal loss inspection to the ILI scope.
Also, the tools with highest accuracy in measuring bend angles, deformations and curvature radius come with a combined high resolution MFL (Magnetic Flux Leakage) to detect and size metal loss. Making all the effort in preparing the pipeline for ILI and not utilizing the full capabilities of the inspection tool would be a waste.

IN LINE INSPECTION PROCESS RESULTS

A full survey of the ENI E&P DICS Platform PCW-T to ENI Casalborsetti Plant (CABO) 20" pipeline and of the ENI E&P DICS Platform PCW-B (BP) to Platform PCW-T 14" pipeline was successfully completed by TECMA. The pipelines survey was performed using Baker Hughes' combined Magnetic Flux Leakage (MFL), Geometry (Calliper), and Mapping (IMU) inspection vehicle.

<u>20" PCWT-CABO FINDINGS</u>
The inspection has confirmed that the pipeline is 9.371km long, predominantly manufactured from Seamless pipe, with a predominant wall thickness of 17.48mm.

Approximately 91% of the total number of pipe spools have metal loss or mill/manufacturing features reported within them.
Most of the metal loss identified within the pipeline are internal and have the appearance of mill/manufacturing features. The majority of these internal mill/manufacturing features have a depth below 20%wt.
External corrosion features have been identified on the riser section of Platform PCW-T.
Additionally, some external features located in the onshore section have been conservatively classified as metal loss (corrosion), however their classification is ambiguous and may be related to mill/manufacturing faults.

The following table summarises the metal loss features identified during the survey.

Tab. 1: Metal loss features identified

Feature Type	Quantity	Deepest Feature	
		Depth (%wt)	Girth Weld Number
External Metal Loss	211	41	120
Internal Metal Loss	0		
External Mill/Manufacturing Features	3	15	250
Internal Mill/Manufacturing Features	9751	35	2950
Total Metal loss	211	41	120
Total Mill/Manufacturing Features	9754	35	2950
Total Features	9965	41	120

Only 1 dent has been identified during the full pipeline analysis, with a sized depth of 1.16% of the outside diameter (OD) and is located in pipe spool number 7050. This is a plain dent, i.e. not considered to be associated with metal loss and / or welds.
No ovalities (out of roundness features) or other geometrical features were identified.
The maximum bore restriction identified within the inspection data is 447.9mm. This is within the launch area at the upstream weld (Girth Weld 100) of the insulated joint at absolute distance 13.62m.

The following table summarises the pipeline geometry anomalies identified during the survey.

Tab. 2: Geometric features identified

Feature Type	Quantity	Comment
Dents (Total)	1	Deepest: 1.16%OD
Plain Dents	1	
Dents with Weld or Metal Loss	0	
Girth Weld Anomalies	0	
Ferrous Metal Objects	1	Touching Pipe: 0
Eccentric Casings	0	
Repair Shells	0	
Patch Repairs	0	
Ovalities ID Reductions ID Expansions Wrinkles	0 0 0 0	

14” PCWT-CABO FINDINGS

The inspection has confirmed that the pipeline is 1.250km long, predominantly manufactured from Seamless pipe, with a predominant wall thickness of 14.27mm.

Approximately 22% of the total number of pipe spools have metal loss or mill/manufacturing features reported within them.
External corrosion features have been identified on the riser sections of both Platform PCW-B and Platform PCW-T.

The following table summarises the metal loss features identified during the survey.

Tab. 3: Metal loss features identified

Feature Type	Quantity	Deepest Feature	
		Depth (%wt)	Girth Weld Number
External Metal Loss	80	53	1120
Internal Metal Loss	0		
External Mill/Manufacturing Features	7	13	590
Internal Mill/Manufacturing Features	9	10	580
Total Metal loss	80	53	1120
Total Mill/Manufacturing Features	16	13	590
Total Features	96	53	1120

No dents above the reporting threshold, ovalities (out of roundness features) or other geometrical features were identified.
The maximum bore restriction identified within the inspection data is 315.82mm. This is within the launch area at the insulated joint (Girth Weld 80) at absolute distance 6.214m.

The following table summarises the pipeline geometry anomalies identified during the survey.

Tab. 4: Geometric features identified

Feature Type	Quantity	Comment
Dents (Total)	0	
Plain Dents	0	
Dents with Weld or Metal Loss	0	
Girth Weld Anomalies	0	
Ferrous Metal Objects	0	
Eccentric Casings	0	
Repair Shells	0	
Patch Repairs	0	
Ovalities ID Reductions ID Expansions Wrinkles	0 0 0 0	

INTEGRITY STUDIES AND FFS ASSESSMENT

With the benefit of the inspection data sets acquired during the inspection of the 20-inch pipeline, integrity evaluations were carried out both to verify the compatibility of the detected features for natural gas service conditions and in the aimed CO2 service, based on the Estimated Repair Factor.

The ERF (Estimated Repair Factor) values have been calculated based on the service cases:

• Case 1 (Natural Gas):
o Design pressure: 123.4 Bar (wt=17.48 mm)
o Design pressure: 157.4 Bar (wt=22.3 mm)
o Design factor: 0.50
o MOP: 117.68 Bar
o ERF evaluation with MOP @117.68 Bar

• Case 2 (CO2):
o Design pressure: 135.7 Bar (wt=17.48 mm)
o Design pressure: 173.1 Bar (wt=22.3 mm)
o Design factor: 0.55
o MOP: 60.0 Bar
o ERF evaluation with MOP @60.0 Bar

Following the pressure sentencing of all metal loss features, with Case 1 - one metal loss feature has been identified with an ERF >1(*). Details of this feature are provided below. With Case 2 - all metal loss features in the pipeline have and ERF <1.

Furthermore, with the aid of the mapping data (x,y,z) a stress-state analysis was performed to verify the deformation (bending strain) to which the pipeline was subjected.
On the basis of the 2021 Inertial Mapping Unit (IMU) data, the strain assessment has not identified any bending strain features.

Supported by the promising results obtained from the analyses conducted on the 20-inch section, it was suggested to ENI to proceed with the similar analysis process on the 14-inch section for both natural gas and CO2 service scenarios.

The ERF (Estimated Repair Factor) values have been calculated based on two cases:

• Case 1 (Natural Gas):
o Design pressure: 143.9 Bar (wt=14.27 mm)
o Design factor: 0.50
o MOP: 60.0 Bar
o ERF evaluation with MOP @60.0 Bar

• Case 2 (CO2):
o Design pressure: 158.3 Bar (wt=14.27 mm)
o Design factor: 0.55
o MOP: 60.0 Bar
o ERF evaluation with MOP @60.0 Bar

Following the pressure sentencing of all metal loss features, for both Case 1 and Case 2 – it was concluded that all metal loss features in the pipeline have and ERF <1.

*This feature has been repaired in 2022.

CONCLUSIONS

To get a comprehensive picture of the 20” pipeline condition, TECMA proposed to run an ILI vehicle that adds to the required scope a high-resolution metal loss inspection.

With the aim to minimize any issue (e.g., lodgment of any pig inside the pipeline) TECMA implemented the operation with their field-proven-progressive-safe calibration & enhanced cleaning process.

Leveraging on the advantage of having collected high resolution metal loss data during the inspection run, it has been possible to verify the absence of any metal loss feature that could affect the safe operation of the pipeline for CO2 transportation in gas phase and consequently allow performing a complete integrity assessment to substantiate the Management decision to re-use the former 20" gas production pipeline as the main CO2 carrier, thus avoiding the very expensive and time consuming pull-in-pipe of the dedicated 4” process pipeline.

Being able to avoid the pull-in-pipe project of a new dedicated process pipeline, greatly contributed to reduce the environmental impact of the numerous phases associated to construction and pre-commissioning, such as water consumption, chemical treatment and exhausts emissions from the compressor spread.

Given the satisfactory result of this inspection, the same activity was performed also on the intrafield 14” pipeline. The outcome of this further operation confirmed the fit for service change for CO2 transportation for this pipeline too.

REFERENCES

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Baker Hughes 451732_20A_Strain_Report – 20inch PCWT-CABO Bending Strain Report

Baker Hughes 452599_14A Inspection Report – 14inch PCWB-PCWT

TECMA per ENI E&P_DICS Riassunto Esecutivo_20" PCWT-CABO

TECMA per ENI E&P_DICS Riassunto Esecutivo_14"BBP PCWB-PCWT