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The Study of Residual Chemical Carryover in Gas Well Production Facilities: A Case Problem

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ABSTRACT - The PT JM Field is capable of producing approximately 133 MMSCFD of gas and 5,600 BCPD of condensate with fluid behavior characterized by retrograde condensation such as mercury-bearing gas systems. These conditions show the importance of filtration in ensuring safe and reliable downstream operations. However, an operational issue was identified in 2024 in the form of an unusually high differential pressure which reached 30 psid across the Condensate Mercury Pre-Filter. The condition was a reflection of partial blockage at the filter outlet and led to a reduction in the system performance. Therefore, this study aimed to identify the root cause through the laboratory analysis of sludge collected during pipeline pigging between the PG and the KCR Gas Plants. The results showed that the GEOPIC sample consisted of 12.03 wt.% solid and 21.52 wt.% liquid fractions while the BIDI2 had 5.70 wt.% and 42.86 wt.% respectively. Elemental analysis also confirmed the presence of C, H, N, S, and Na while FTIR spectroscopy showed characteristic C=N, N–H, and S=O functional groups which were the reflection of a strong similarity to imidazolinamide-based corrosion inhibitors. Ionic analysis further detected Cl^-, PO_4^{3-}, and NH_4^+ ions in the pigging fluid which were commonly associated with the corrosion inhibitors applied in the system. The results led to the implementation of several mitigation measures such as filter replacement, pipeline pigging optimization, and equipment inspection during the Turnaround (TAR). These actions successfully mitigated sludge accumulation and restored normal filtration performance.

Keywords: solid carryover, residual chemical carryover, corrosion inhibitor, condensate mercury pre filter.

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INTRODUCTION

The Delta-XYZ Field, located in the South Sumatra Basin, Indonesia, is a gas field that began production in 2011 and is classified as a retrograde gas-condensate reservoir. When reservoir pressure declines below the dew point, liquid hydrocarbons begin to condense within the reservoir rock, a phenomenon known as retrograde condensation. This behavior leads to the loss of valuable liquid hydrocarbons because part of the condensate becomes trapped within the pore spaces and remains immobile, thereby creating challenges for production under surface operating conditions Alshammari 2025. Consequently, surface facilities in retrograde gas fields require careful design and operation to manage multiphase production streams and minimize operational disruptions.

The production from the Delta-XYZ Field originates from nine wells and consists of natural gas mixed with condensate, produced water, and trace impurities (Shaliha 2015). Therefore, an integrated separation and processing system is required to ensure the gas meets sales specifications and for the condensate to be safely handled and transported. The overall gas processing sequence is in several stages which include the production from wells, primary separation, impurity removal through adsorption and absorption processes, fractionation, the IT-Effect process, and the delivery of sales gas to consumers.

Operational issues were experienced at the Delta-XYZ Field in 2024 which were characterized by a significantly high differential pressure of up to 30 psig across the Condensate Mercury Pre-Filter and an increased frequency of filter replacement.

The level control valve unit at the Gas Knockout Drum was also found to be jammed. Subsequent inspections showed the accumulation of solids and sludge on the filter media as a reflection of solid carryover within the condensate handling system. The problem could not be resolved through routine operational adjustments because the foundational cause was not immediately evident. The conditions showed the need for detailed analysis to provide appropriate recommendations. Therefore, this study aims to identify the root causes of solid carryover through laboratory characterization of sludge samples obtained from pipeline pigging operations combined with an evaluation of production process parameters. The outcomes are expected to support effective mitigation measures and enhance the reliability and integrity of condensate processing operations at the Delta-XYZ Field.

This study contributes to the existing body of knowledge by providing an integrated field-based diagnostic method that combines operational data evaluation, laboratory chemical characterization, and process flow tracing to identify corrosion inhibitor-related solid carryover. The integrated perspective bridges the gap between corrosion chemistry, multiphase hydrocarbon processing, and operational filtration performance in gas–condensate production systems. It also addresses the gap by integrating laboratory characterization of pigging sludge including elemental, functional group, and ionic analyses with an evaluation of actual production and processing conditions at the Delta-XYZ Field. The contribution is related to the provision of a field-based diagnostic method to identify corrosion inhibitor-related solid carryover and in proposing practical mitigation measures to improve condensate filtration reliability and overall process integrity in gas–condensate production facilities.

METHODOLOGY

This study adopted a comprehensive field-based diagnostic method to investigate the occurrence of solid carryover within the condensate handling system at the DELTA-XYZ Field. The method combined hypothesis-driven analysis, operational data evaluation, laboratory characterization, and process flow verification to identify the root causes of abnormal differential pressure and filter blockage. The investigation was initiated after repeated operational anomalies such as the persistent increase in differential pressure across the Condensate Mercury Pre-Filter and frequent filter replacement events. Therefore, operational data were collected from critical units associated with condensate separation, stabilization, and filtration with a focus on the pressure and temperature measurements, flow conditions, and operating histories. Historical operating data were also reviewed to identify deviations from normal operating envelopes and to correlate pressure fluctuations with process events such as pigging, chemical injection adjustments, or equipment maintenance activities. Furthermore, maintenance logs, inspection reports, and TAR schedules were examined to identify any operational interventions that could have influenced the solid carryover observed. There was a specific focus on equipment opening, cleaning activities, filter replacements, and valve malfunctions that occurred before or during the onset of the problem. This review enabled the connection of physical observations with operational timelines. Moreover, laboratory investigations were conducted on sludge and pigging samples collected from the pipeline and PG Knockout Drum. The focus was on the determination of solid and liquid fractions, elemental composition analysis, functional group identification using FTIR spectroscopy, and ionic composition evaluation for the pigging solution.

The analyses were aimed at identifying and comparing the chemical signature of the sludge with known compositions of corrosion inhibitors and other chemicals injected into the system. Hot oil property analysis and hot oil–condensate interaction tests were also conducted to evaluate the possibility of thermal degradation, incompatibility, or precipitation that could contribute to solid formation. A detailed process flow tracing was performed to assess potential solid transport pathways within the condensate handling system. Furthermore, pressure–temperature trends, laboratory results, and equipment configuration were correlated to assess the possibility of each proposed hypothesis. This step enabled the identification of the most probable source and mechanism of solid carryover based on converging lines of evidence. The identified root

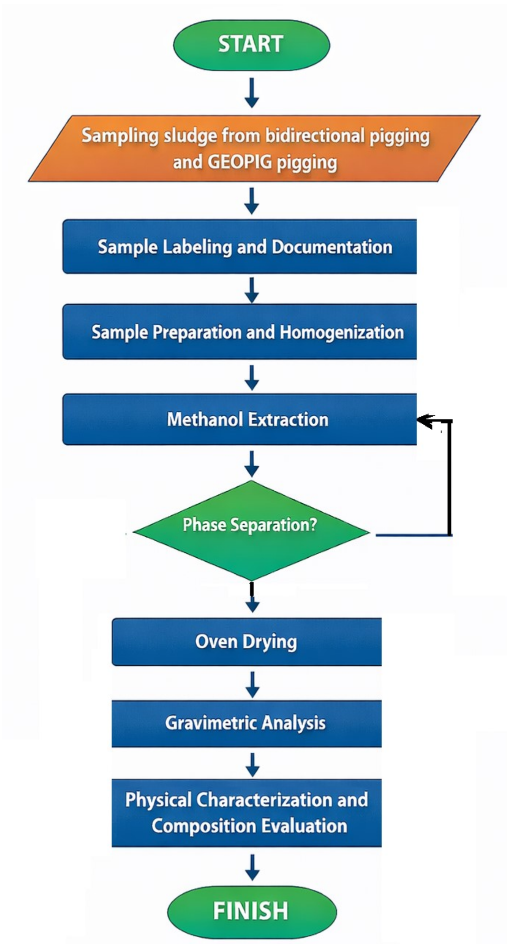


Figure 1. Methodological flowchart for sludge sampling in the DELTA-XYZ field

causes were used to formulate and implement mitigation measures such as filter replacement strategies, optimization of pigging operations, and inspection of critical equipment during TAR. The effectiveness of these measures was subsequently evaluated through post-mitigation operational monitoring.

Methodological flowchart for sludge sampling, phase separation, oven drying, gravimetric analysis, and physical characterization of samples obtained from bidirectional pigging and geopig pigging activities in the DELTA-XYZ Field, is depicted at Figure 1.

RESULT AND DISCUSSION

Solid pigging test

The sludge samples collected from bidirectional and geopig pigging operations in the DELTA-XYZ Field were subjected to phase separation and gravimetric analysis to evaluate their physical characteristics and composition. During sample preparation, methanol extraction was applied to separate the black sticky fraction containing sand particles from the clear liquid phase, followed by oven drying. A significant reduction in sample mass was observed during the drying process, indicating the presence of volatile components.

The mass loss was attributed to the evaporation of residual hydrocarbon compounds that remained trapped within the sludge matrix. The condition suggested that the sludge was not purely inorganic in nature. Gravimetric analysis further showed that the liquid phase constituted 21.52 wt.% of the total sludge mass for sample 175/25 (Sludge Pigging GEOPIG) and 42.86 wt.% for sample 176/25 (Sludge Pigging BIDI2). These results reflected that a substantial fraction of the sludge consisted of liquid hydrocarbons particularly in the BIDI sample where the liquid content was approximately half of the total mass. The high liquid fraction showed that the sludge formation was closely associated with hydrocarbon condensation and chemical residues rather than only corrosion products or mineral solids.

Figure 2. The visual of sludge pigging Delta-XYZ field (LEMIGAS 2025)

Visual inspection of the separated liquid phase in Figure 1 shows a strong resemblance to field condensate in terms of color and clarity. This observation supported the hypothesis that the liquid fraction was dominated by condensate components entrained and retained within the sludge structure. The assumption was further confirmed by collecting and using the fresh condensate samples from the field as reference fluids. These samples were compared with the clear liquid phase extracted from the sludge through gas chromatographic analysis.

The comparative chromatographic results provided a basis for assessing compositional similarities between the sludge-derived liquid phase and fresh condensate. This comparison is very important for understanding the mechanism of sludge formation by showing that the sludge accumulation is related to solid deposition and also requires the trapping and agglomeration of condensate components. The behavior can enhance sludge cohesiveness and contribute to the progressive blockage observed in filtration systems particularly under conditions of limited pigging and prolonged chemical injection.

The samples presented in Figure 3 were analyzed using the Gas Chromatography–Flame Ionization Detector (GC–FID) method to characterize the hydrocarbon composition of the liquid phase extracted from the sludge. The analytical method was selected due to its sensitivity toward hydrocarbon compounds and suitability for comparing compositional differences between field samples and reference fluids. The GC–FID analysis was performed on the BIDI2 sludge pigging sample (#176) in the liquid phase and compared directly with a fresh condensate (#181) collected from the production system.

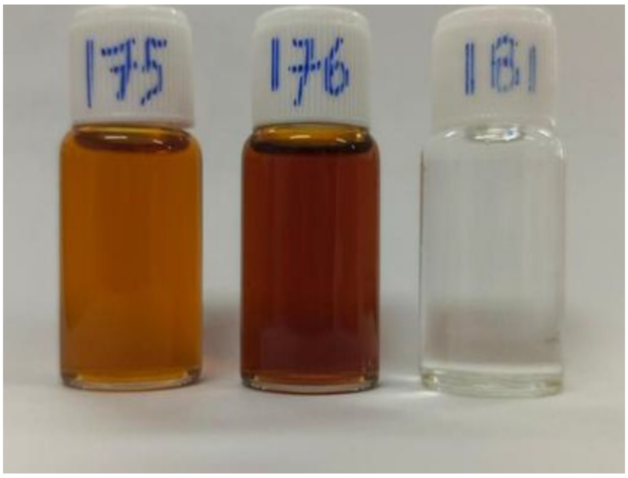


Figure 3. The visual of liquid sludge pigging GEOPIG (#175) , BIDI2 (#176) and condensate (#181) (LEMIGAS 2025)

The chromatograms produced and presented in Figure 4 reflected a detectable difference in hydrocarbon distribution patterns between the sludge-derived liquid phase and the fresh condensate. It was observed that the fresh condensate exhibited a more defined chromatographic profile with relatively higher peak intensities often identified with nonpolar hydrocarbon components commonly present in condensate fluids. Meanwhile, the chromatogram obtained from the BIDI2 sludge liquid phase showed a broader and less distinct distribution of peaks accompanied by generally lower signal intensities.

The observed differences in chromatogram intensity suggested that nonpolar hydrocarbon compounds did not dominate the liquid phase of the sludge sample. The reduced signal intensity was a sign that a significant portion of the liquid phase could consist of compounds with lower FID response or non-hydrocarbon constituents because the flame ionization detector primarily responded to hydrocarbons. The behavior implied that the liquid phase of the sludge was not simply entrained condensate but rather a complex mixture possibly containing chemical additives and degradation or interaction products formed during production and processing.

The results were consistent with earlier observations from gravimetric analysis and visual inspection that the sludge contained a substantial liquid fraction with different properties compared to the fresh condensate. The altered hydrocarbon distribution observed in the GC–FID analysis supported the hypothesis that chemical interactions between condensate and injected chemicals such as corrosion inhibitors contributed to the formation of sludge with distinct compositional characteristics. This compositional alteration enhanced the cohesiveness of the sludge and promoted solid agglomeration which subsequently increased the possibility of solid carryover and filtration blockage in the condensate handling system.

Sandy sticky black sludge analysis

The assumption that the black sludge contained solid particles such as sand led to the implementation of a separation procedure to allow independent analysis of the solid fraction and the sticky viscous components. All sludge samples exhibiting sticky and sandy characteristics were initially dissolved in methanol because organic corrosion inhibitor compounds particularly those based on imidazolinamide were known to be soluble in this solvent. The assumption was further supported by the physical appearance of the viscous and sticky fractions which closely resembled the rheological characteristics of corrosion inhibitors commonly applied in field operations.

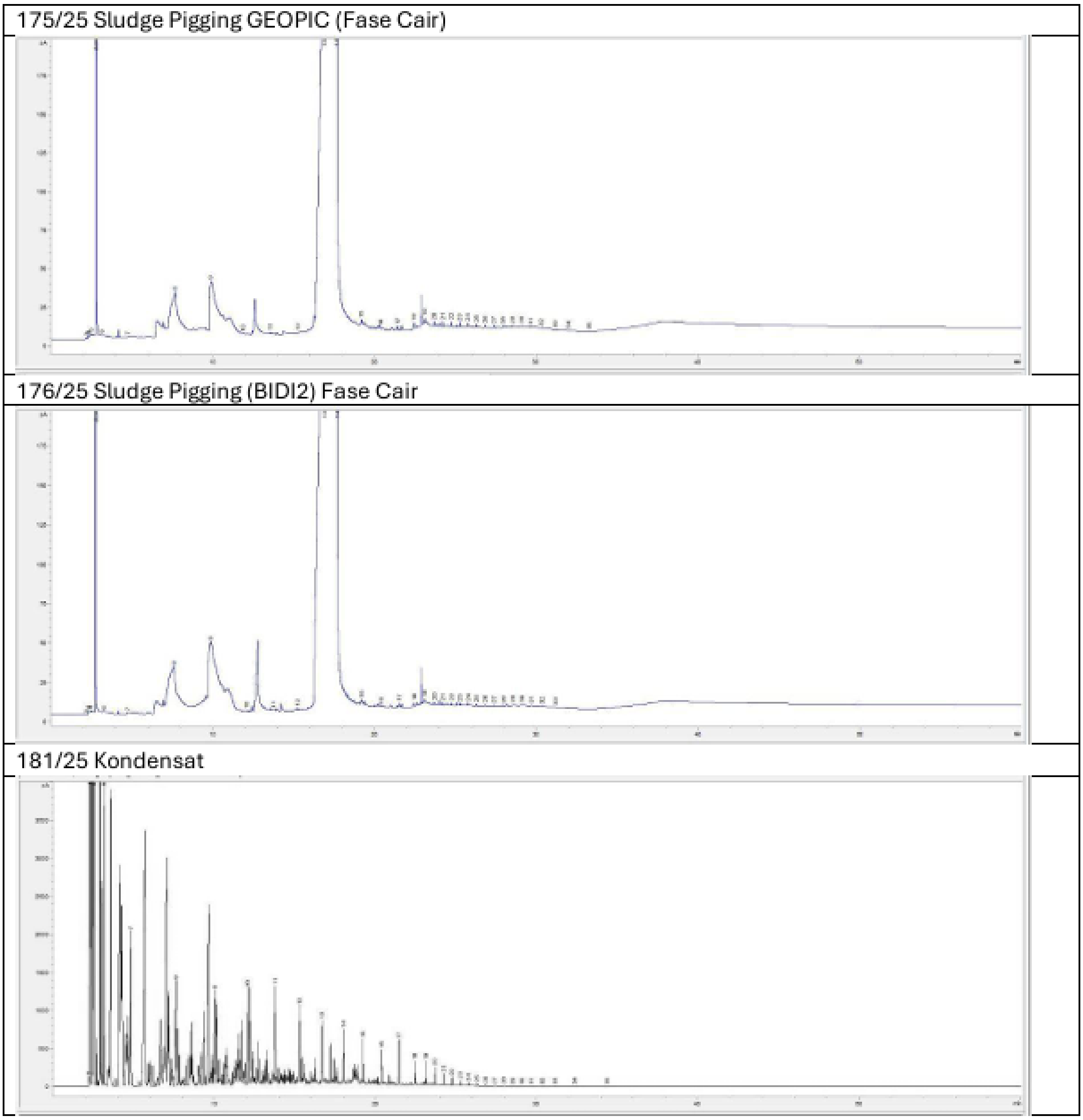


Figure 4. Chromatograms of liquid-phase sludge and condensate samples Delta-XYZ Field

The dissolution was followed by the filtration of the mixture to separate the insoluble solid fraction from the methanol-soluble components. The retained solid material was subsequently dried in an oven to remove residual solvent and volatile compounds. This was necessary to ensure the remaining solids represented non-volatile constituents such as sand particles, corrosion products, or precipitated inorganic matter. The methanol-soluble fraction which represented the viscous organic phase was preserved for further chemical characterization.

The separation results presented in Figure 5 clearly showed the distinction between the solid fraction and the viscous organic fraction. The solid fraction consisted mainly of granular material with sand-like characteristics while the viscous fraction exhibited a dark color and adhesive properties to signal the presence of organic compounds rather than purely mineral solids. This physical distinction provided an initial sign that the sludge formation mechanism included both inorganic solids and organic residues.

The separation results presented in Figure 5 clearly showed the distinction between the solid fraction and the viscous organic fraction. The solid fraction consisted mainly of granular material with sand-like characteristics while the viscous fraction exhibited a dark color and adhesive properties to signal the presence of organic compounds rather than purely mineral solids. This physical distinction provided an initial sign that the sludge formation mechanism included both inorganic solids and organic residues.

Subsequent FTIR analysis of the viscous fraction showed the presence of characteristic functional groups including C=N, N–H, and S=O which were commonly associated with imidazolinamide-based corrosion inhibitors. The results confirmed that a significant portion of the sticky sludge was composed of organic inhibitor residues or their degradation products. The presence of these functional groups suggested that chemical transformation or incompatibility could have occurred during prolonged exposure to process conditions such as temperature, pressure, and interaction with hydrocarbons.

The results of GC–FID analysis further supported this interpretation because the chromatographic profile of the viscous fraction showed a relatively low response compared to fresh condensate. This was a sign that nonpolar hydrocarbons did not dominate the composition of the organic phase. The behavior was consistent with the presence of polar or semi-polar organic compounds such as corrosion inhibitors which typically exhibited lower FID sensitivity than hydrocarbon condensate components. Moreover, the difference in hydrocarbon distribution between the sludge-derived liquid phase and fresh condensate confirmed that the viscous fraction was not simply entrained condensate but rather a chemically altered phase .

Ionic analysis of the pigging solution detected the presence of Cl^-, PO_4^{3-}, and NH_4^+ ions which corresponded to the primary ionic constituents of corrosion inhibitor formulations used in the system. The detection of these ions provided further evidence that corrosion inhibitor residues had a central role in sludge formation. The interaction with inorganic solids and process fluids possibly

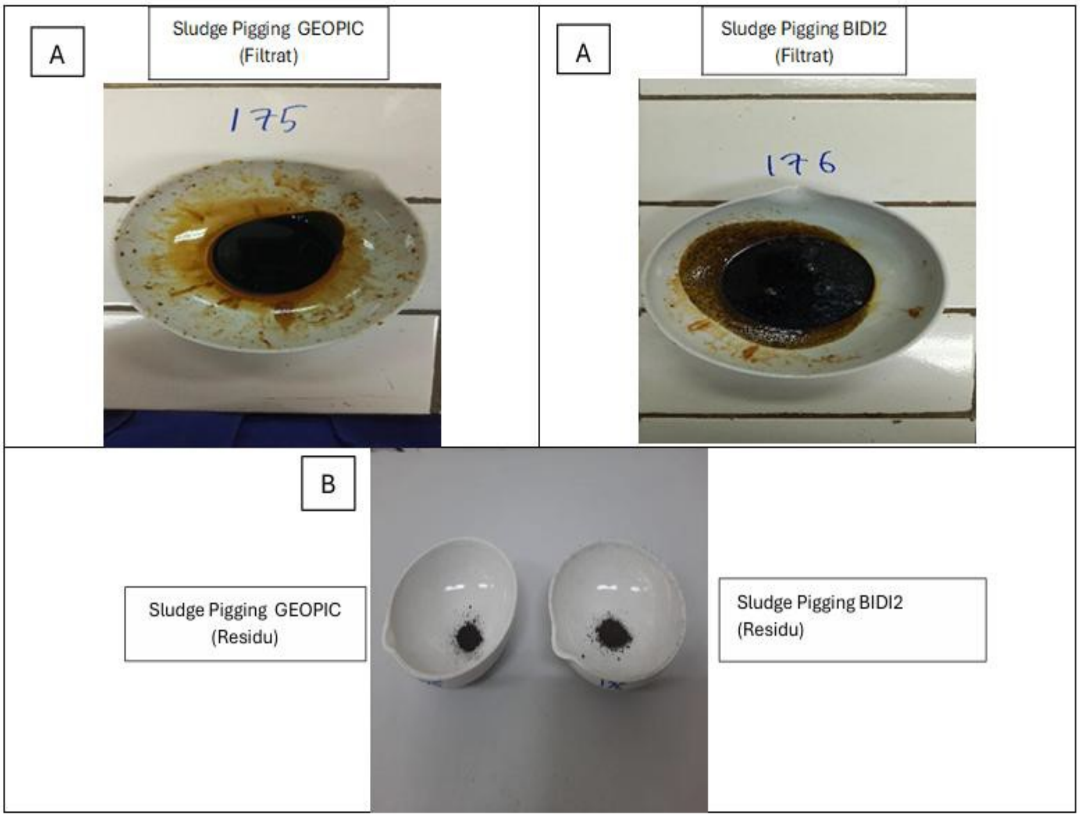


Figure 5. The results of the separation between the solid and viscous parts of Sludge pigging BIDI2 (LEMIGAS 2025)

promoted agglomeration which increased the cohesiveness of the sludge and facilitated its transport as solid carryover. The results from the separation procedure, FTIR spectroscopy, GC–FID analysis, and ionic characterization consistently showed that the sludge was composed of a combination of inorganic solids such as sand particles and organic residues derived from corrosion inhibitors. The mixed composition explained the strong adhesive nature of the sludge and its tendency to accumulate on filtration media which subsequently led to increased differential pressure and filtration blockage observed in the condensate handling system.

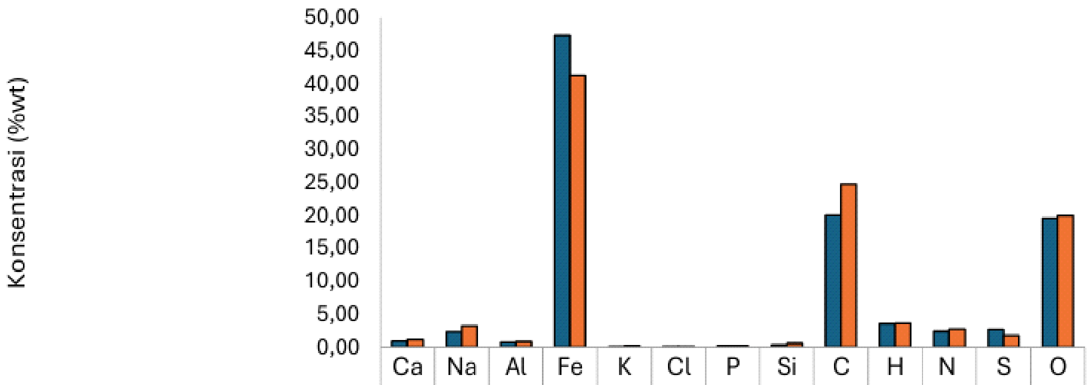
Solid particle analysis

The results of the gravimetric measurements showed that the solid fraction accounted for approximately 12.03 wt.% of the total sticky and sandy sludge in the GEOPIG and 5.70 wt.% in the BIDI2. These values suggested that solids represented a smaller portion of the total sludge mass, but their presence was very important in initiating agglomeration processes and providing nucleation sites for organic residues to accelerate sludge accumulation and filtration blockage.

The chemical nature of the solids was determined through a detailed characterization AAS, XRF, and Elemental CHN Analyzer methods. The normalized elemental composition presented in Figure 6 showed that the dominant elements in the solid fraction were iron (Fe), carbon (C), oxygen (O), hydrogen (H), sulfur (S), nitrogen (N), and sodium (Na). This elemental distribution was a sign that the solids were not purely inorganic mineral particles but rather a complex mixture of corrosion-related products, organic residues, and entrained salts.

The relatively high carbon content detected in the solid fraction suggested contributions from heavy hydrocarbon components that crystallized from condensate and remained insoluble in methanol. Furthermore, carbon-rich solids could also originate from the active ingredients of corrosion inhibitors which could experience chemical degradation, polymerization, or partial carbonization when exposed to elevated temperatures, prolonged residence times, and interactions with other process fluids. These transformed compounds are capable of losing their solubility and precipitating as solid or semi-solid residues. The interpretation was consistent with earlier GC–FID and FTIR results which showed the presence of chemically altered organic compounds within the sludge matrix.

The simultaneous detection of Fe and S strongly reflected the occurrence of corrosion processes within the production and processing system. This is because iron sulfide compounds can form on steel surfaces under the acidic conditions



	Ca	Na	Al	Fe	K	Cl	P	Si	C	H	N	S	O
175/25 Sludge Pigging GEOPIC (Residu)	0,91	2,31	0,76	47,25	0,12	0,04	0,15	0,32	20,04	3,55	2,40	2,67	19,49
176/25 Sludge Pigging BIDI2 (Residu)	1,13	3,20	0,81	41,22	0,14	0,02	0,18	0,60	24,71	3,65	2,73	1,70	19,92

Element

Figure 6. AAS, XRF, and elemental CHN solid sample analyses (LEMIGAS 2025)

Table 1. Functional clusters in the spectrum of FTIR fresh corrosion inhibitor (LEMIGAS 2025)

Functional Group	N-H	CH2	CH2	C=N	S=O	C-N	C-N	C=C
Wavenumber (cm−1)	3328	2926	2855	1636	1399	1111	1044	699

commonly experienced in gas–condensate facilities. However, the corrosion products can detach from the metal surface and be transported downstream as suspended solids when a stable and adherent protective layer is not established. The particles entrained in the condensate flow can interact with sticky organic residues to promote further agglomeration and increase the overall cohesiveness of the sludge.

The other elements identified in the solid fraction such as Na, calcium (Ca), chloring (Cl), and phosphorous (P) were attributed to the salts present in produced water carried along with the hydrocarbon stream. The contribution of these salts became more pronounced when the desalter unit was not operating or when its performance was not optimal. The conditions can allow saline components to pass through the system and interact with organic residues and corrosion products to cause precipitation or co-deposition within the sludge.

Further evidence supporting the role of corrosion inhibitors in the formation process was obtained from the physical behavior of the methanol-treated sludge. The remaining solid after dissolution, filtration, and oven drying exhibited resin-like and adhesive properties such as polyamide-based materials which were commonly used in corrosion inhibitor formulations. This observation suggested that the organic fraction of the sludge experienced transformation from a soluble chemical additive into an insoluble resinous material under prolonged operational exposure.

The observation led to the collection of fresh corrosion inhibitor samples subjected to controlled heating at approximately 30 °C which represented field conditions to simulate solvent evaporation and loss of volatile components. The residues produced had physical characteristics comparable to those observed in the sludge-derived solids to further confirm that corrosion inhibitor degradation and transformation were significant to sludge formation.

The results generally showed that the sludge formation mechanism at the DELTA-XYZ Field included a synergistic interaction between inorganic solids such as sand and corrosion products, organic residues derived from corrosion inhibitors, and saline components from produced water. The presence of solid particles provided nucleation sites while sticky organic residues acted as binding agents to form cohesive sludge deposits. The deposits formed were readily transported as solid carryovers and tended to accumulate on the filtration media. This subsequently increased the differential pressure and frequent filter blockage observed in the condensate handling system.

The data presented in Table 1 showed that the absorption band at 1636 cm^{-1} was characteristic of the C=N stretching vibration associated with the imidazoline ring structure identified as a key functional group commonly found in imidazolinamide-based corrosion inhibitors. The absorption observed at 3328 cm^{-1} corresponded to the N–H stretching vibration to signal the presence of amide functional groups that represented the active components of the corrosion inhibitor formulation.

The other transmittance bands observed in the region of 1111 cm^{-1} and 1044 cm^{-1} were attributed to C–N stretching vibrations which further supported the presence of nitrogen-containing organic compounds typical of corrosion inhibitor molecules. The absorptions at 2926 cm^{-1} and 2855 cm^{-1} were also assigned to the stretching vibrations of CH_2 groups which served as a sign of aliphatic hydrocarbon chains. Meanwhile, the absorption at 1399 cm^{-1} was associated with unconjugated S=O functional groups and suggested the presence of sulfur-containing compounds. These functional groups are known to enhance corrosion inhibition performance by donating free electron pairs that can interact with vacant d-orbitals on the iron surface to strengthen the adsorption and bonding of inhibitor molecules onto the metal surface. The FTIR spectral analysis showed a high degree of similarity in absorbance patterns between the GEOPIG and the BIDI2 when compared with both the fresh corrosion inhibitor and the heated corrosion inhibitor samples (Figure 6). This similarity reflected that the organic components present in the sludge were chemically related to the corrosion inhibitors used in the field.

Significant differences were observed in the absorption intensity at 2926 cm^{-1} and 2855 cm^{-1} with the sludge samples exhibiting higher intensities compared to the reference inhibitors . This increase was possibly associated with the presence of additional hydrocarbon compounds co-extracted and dissolved during methanol treatment which contributed to stronger CH_2-related absorbance. Furthermore, the absorption band at 3328 cm^{-1} in the sludge samples appeared more pronounced probably due to higher heating exposure during sample preparation aimed at removing methanol solvent. The heating process can alter hydrogen bonding interactions to cause an increase in N–H stretching intensity within the FTIR spectrum.

The FTIR results generally provided strong evidence that the organic fraction of the sludge was closely related to corrosion inhibitor compounds. The thermal treatment and solvent interactions during both field operation and laboratory preparation also influenced the spectral characteristics observed.

Another stage of the investigation into the solid carryover issue was conducted by tracing the production and condensate flow paths. The analysis focused on identifying potential sources of solids entering the condensate handling system. In this configuration, the inlet of the Condensate Stabilizer Column was supplied by the Condensate Surge Vessel and one of the streams originated from the Knockout (KO) Drum.

The occurrence of solid carryover motivated DELTA-XYZ field to implement corrective actions which were coincidentally in line with a scheduled TAR activity when a comprehensive inspection and equipment maintenance program was conducted. A significant number of impurities and deposits were found inside the Gas Knockout Drum during the inspection. An important observation was that the physical appearance of the materials was identical to the deposits previously observed on the Condensate Mercury Pre-Filter to signal a common source and transport mechanism.

The nature of the deposits was verified by collecting samples from the Gas Knockout Drum during the TAR for laboratory analysis. The test parameters and corresponding results are summarized in Figure 7. The initial concerns regarding the presence of corrosive solid materials were addressed through the analytical results which showed low Fe content. The trend suggested that the deposits were not predominantly composed of corrosion products.

The laboratory analysis further showed that the parameter with the highest value was LOI at approximately 92.96%. The high value reflected that the sludge was dominated by organic matter primarily consisting of hydrocarbons and water rather than inorganic or metallic solids. This observation was consistent with previous analytical results and supported the inference that the solid carryover was largely associated with organic residues possibly originating from chemical additives and hydrocarbon-related processes (Soltani, 2020).

The production flow tracing and laboratory results collectively confirmed that the Gas Knockout Drum represented a critical upstream source of solid and organic carryover subsequently transported into the Condensate Stabilizer Column and downstream filtration units. This understanding provided a clear basis for implementing targeted mitigation measures at upstream separation stages to prevent recurrence of similar operational issues.

The residual solid carryover at PT DELTA-XYZ field represented a significant operational challenge that negatively affected production quality and overall operational efficiency. The efforts to address the issue require the

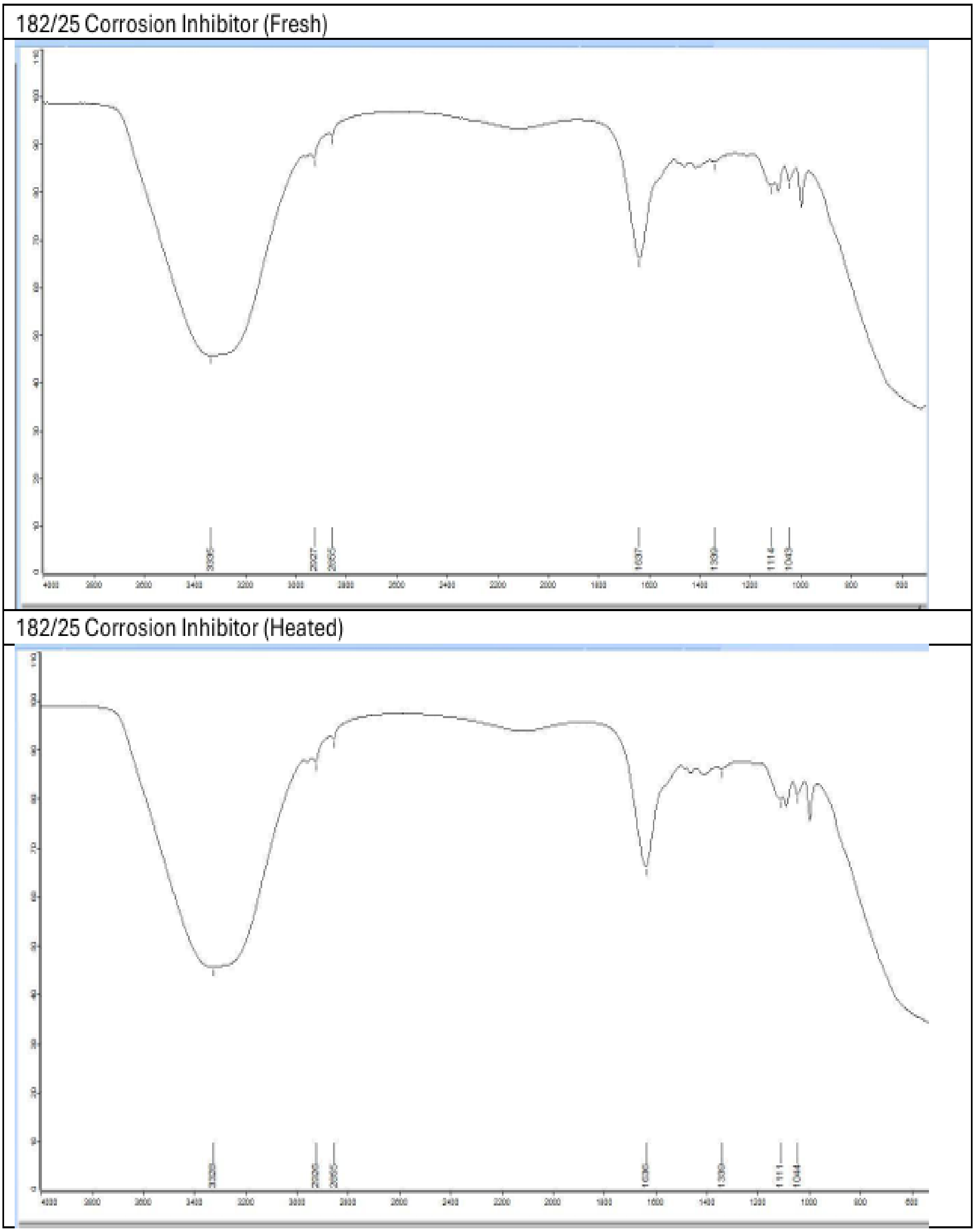


Figure 7. FTIR spectrum for the sludge and corrosion inhibitor samples (LEMIGAS 2025)

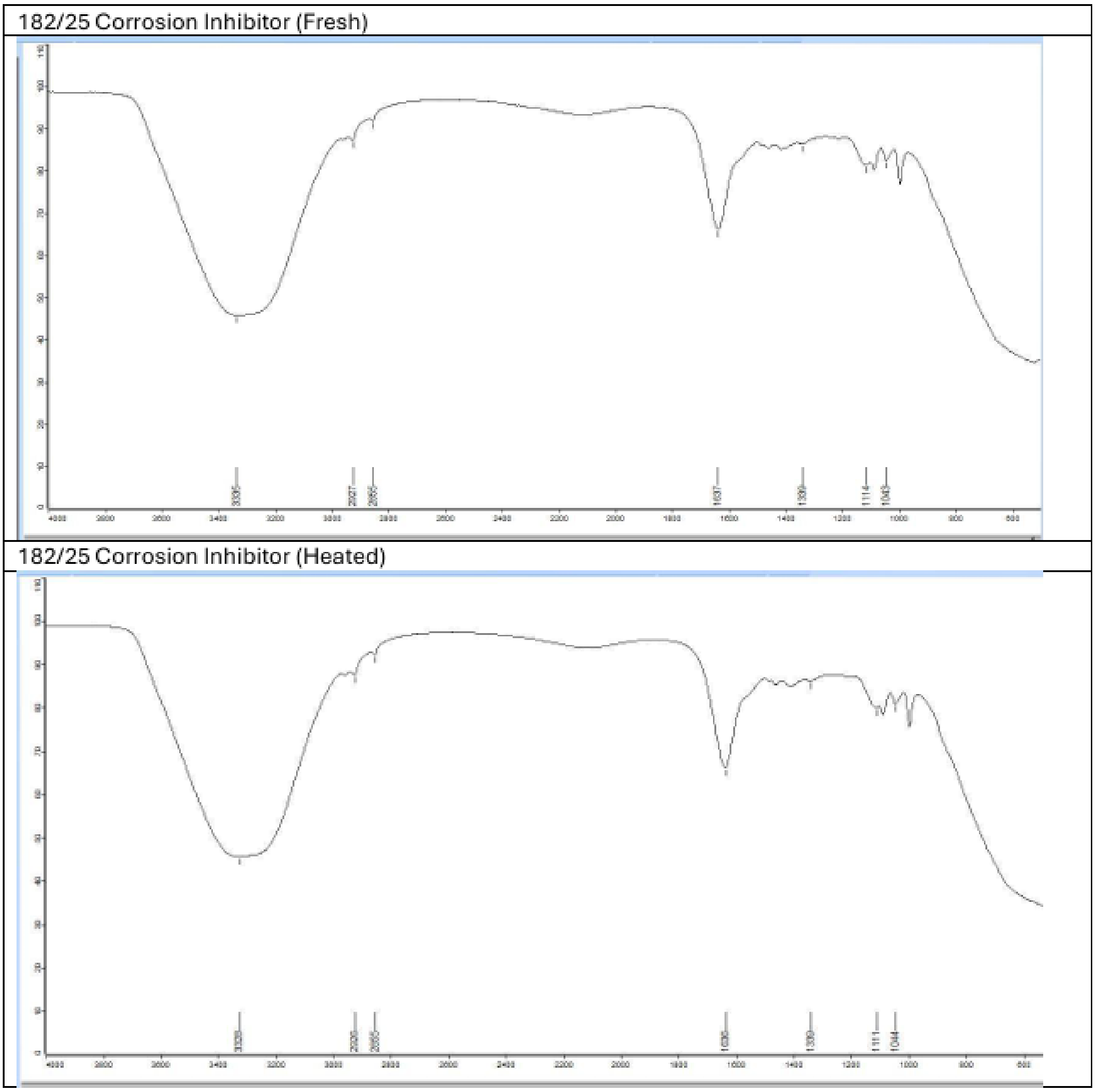


Figure 7. FTIR spectrum for the sludge and corrosion inhibitor samples (LEMIGAS 2025)

implementation of well-planned mitigation strategies to ensure production activities can be conducted safely, reliably, and in a sustainable manner. The results show that both immediate operational improvements and long-term preventive measures are necessary to effectively manage solid carryover within the condensate processing system.

The application of a multi-stage filtration system is considered a critical mitigation measure from an operational perspective. This system consists of sequential filtration stages which start from a coarse filter with a large pore size such as a metal filter followed by medium- and fine-pore filters. The process flow analysis of the condensate processing facilities shows that the most suitable location for implementation is between the Condensate Stabilizer and the Mercury Removal Unit to function as a pre-filter to capture solid residues associated with corrosion inhibitors. The implementation of this filtration stage is expected to significantly extend the service life of the Condensate Mercury Pre-Filter.

Additional installations can be considered in the upstream of the Condensate Stabilizer to remove solid–water emulsions formed during chemical injection as well as the downstream of the Mercury Removal Unit with the aim of providing polish before condensate delivery to storage tanks.

Operational reliability can be further improved by adopting a filtration configuration with dual tray units working alternately. The configuration allows one tray to remain in operation while the other experiences cleaning or maintenance to minimize the risk of unplanned shutdowns and ensure continuity of condensate processing operations. Moreover, the selection of reusable metal filter elements, particularly stainless-steel filters provides both economic and environmental benefits. These filters can be washed and reused multiple times to reduce long-term operating costs and minimize waste generation compared to disposable filter media. Preventive strategies are recommended for long-term and sustainable control of solid carryover. A key requirement is the identification and evaluation of the types of scale and deposits formed which can only be achieved through comprehensive laboratory analysis. The understanding of the composition and formation mechanisms of the deposits provides the foundation for selecting appropriate chemical treatment programs. Compatibility evaluations also need to be conducted between corrosion inhibitors and scale inhibitors before application. This is necessary because incompatible chemical combinations can lead to adverse reactions that accelerate scale formation and reduce the effectiveness of equipment protection. Furthermore, the concentration of corrosion inhibitors needs to be optimized in line with formation fluid characteristics with a focus on the chemical composition, pH, temperature, and water content. Proper adjustment of inhibitor dosage is also very important to maintaining effective corrosion protection while preventing excessive residual accumulation that can subsequently contribute to solid carryover.

The integration of the operational and preventive measures can allow PT DELTA-XYZ field to significantly reduce the occurrence of residual solid carryover, improve filtration performance, lower differential pressure across critical equipment, and enhance overall production reliability.

The integrated analysis of sludge characteristics, production flow tracing, laboratory investigations, and operational history showed that residual solid carryover at DELTA-XYZ Field was a chemically and operationally motivated phenomenon rather than an isolated equipment failure. The combined evidence confirmed that corrosion inhibitor residues interacting with condensate, produced water, and corrosion products under prolonged pipeline residence time and in the absence of routine pigging had a dominant role in sludge formation and downstream filtration blockage. Therefore, the mitigation strategies proposed in this study include pipeline pigging, optimization of corrosion inhibitor selection and dosage, implementation of multi-stage and reusable filtration systems, and compatibility evaluation of injected chemicals serve as corrective actions and constitute a preventive operational framework. The measures are directly connected to the identified root causes and provide measurable improvements which include reduced solid carryover, lower differential pressure across filters, extended filter service life and improved operational reliability.

CONCLUSION

In conclusion, the results of the investigation and detailed analysis conducted showed that the main operational issue at DELTA-XYZ Field was the significant increase in differential pressure across the Condensate Mercury Pre-Filter. This abnormal condition was primarily caused by the gradual accumulation of solid carryover and sludge which originated from residues of corrosion inhibitors transported by the gas and condensate stream from Gas Plant Field to the Central Gas Plant.

The accumulation of the deposits did not occur instantaneously but developed progressively over time. An example of the key contributing factors was the absence of routine pigging operations since the pipeline was first put into service in 2011. This allowed solid residues to build up along the pipeline and downstream equipment. Moreover, the use of corrosion inhibitors from multiple suppliers with different chemical formulations had a significant role in speeding up the formation of unstable compounds. The inconsistency in inhibitor chemistry reduced the stability of the injected chemicals in the process stream which led to precipitation and the formation of solid residues that subsequently clogged the filtration system.

Several corrective actions and operational improvements were implemented which included regular replacement of filter elements, the initiation and optimization of pipeline pigging programs, as well as a comprehensive evaluation of the type and dosage of corrosion inhibitors used in the system. Furthermore, recommendations were developed for the application of multi-stage filtration systems and the use of reusable filter elements as long-term solutions to improve filtration performance and operational reliability.

Economic evaluation also showed the possibility of these alternative strategies to deliver significant cost efficiency while enhancing system reliability and reducing the risk of recurrence of similar filtration and solid carryover problems in future operations.

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GLOSSARY OF TERMS AND SYMBOLS

Terms & Symbols	Definition	Unit
CHN	Carbon (c), hydrogen (h), nitrogen (n)	
XRF	X-ray fluorescence spectrometry	
TAR	Turnaround/planned shutdown	
SCFD	Standard cubic feet/day	
BCPD	Barrel condensate/day	
FTIR	Fourier transform infrared spectroscopy	
GC-FID	Gas chromatography–flame ionization detection	
LOI	Loss on Ignition	
AAS	Atomic absorption spectrometry	
CHN	Carbon, Hydrogen, and Nitrogen	
GEOPIG	Geopig sample	
BIDI2	Bidirectional pig sample	

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