

CODES & COGS

WHITEPAPER

Advancing Pressure Control Equipment (PCE) Integrity Testing For Well Intervention Operations

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A. Executive Summary

A-1 Overview

Over the years, in the upstream oil and gas industry, ensuring the integrity and functionality of Pressure Control Equipment (PCE) is critical to the safety of personnel, assets, and the environment during well intervention operations. Despite advancements in PCE technology, many well intervention companies adhere to outdated testing models, such as annual pressure and function tests, leaving critical vulnerabilities undetected.

This white paper introduces **Pressure Control Equipment (PCE) Integrity Testing Services**, a proactive and comprehensive solution designed to inspect, pressure test, and function test PCEs daily, prior to well intervention activities. These services target equipment such as coiled tubing rig-up equipment, slickline blowout preventers (BOPs), lubricators, E-line systems, and wellhead maintenance tools. By leveraging real-time data transmission and advanced monitoring techniques, this service mitigates risks, enhances safety, and optimizes operational efficiency. Through case studies of historical incidents and detailed justifications, this paper demonstrates the urgent need for this innovative service.

A-2 Problem Statement

Pressure Control Equipment (PCE) is fundamental to maintaining well control during intervention services such as coiled tubing operations, slickline and E-line services, and wellhead maintenance. Historically, the industry has relied on periodic testing—often annually—to ensure equipment functionality. This approach fails to address the dynamic risks associated with frequent equipment handling, transportation damage, and operational wear and tear.

B. Case Studies: The Cost of Neglected Testing

B-1 Case Study 1: North Sea Well Intervention Incident (2018)

Incident Summary

An incident in the North Sea highlighted the risks associated with inadequate PCE inspections during well intervention operations. During a slickline operation, a wellhead pressure control assembly (including a BOP and associated lubricator components) failed while retrieving a tool string.

Root Cause

- **Inadequate PCE Inspections**: Regular and thorough inspections were not conducted, leading to undetected wear and tear, and ultimately, equipment failure.
- **Mechanical Stress**: The equipment was subjected to mechanical stress during operations, which exacerbated existing vulnerabilities and led to failure.
- **Lack of Real-Time Monitoring**: The absence of real-time monitoring systems meant that the failure was not detected until it was too late.

Impact

- **Safety Risks**: The failure posed immediate safety risks to personnel on the rig, as well as potential environmental hazards due to the uncontrolled release of well fluids.
- **Operational Downtime**: The incident halted operations for several weeks, leading to financial losses and delays in production.

B-2 Case Study 2: Equinor – Gullfaks C Coiled Tubing Incident in the North Sea (2023)

Incident Summary

On January 25, 2023, during a clean-up operation after a fracturing operation on the Gullfaks C facility in the North Sea, fractures occurred in the coiled tubing (CT) on the surface and down the well. The fractures happened near the reel and injection head, leading to the activation of the blind shear ram on the CT blowout preventer (CT-BOP) to shut in the well and restore the primary barrier.



Figure 1: Gullfaks C

Root Cause

- **Sulphide Stress Corrosion (SSC)**: The investigation identified that the direct cause of the CT fractures was SSC induced by H_2S. H_2S arose from a chemical reaction between the oxygen scavenger and citric acid being pumped through the CT, combined with iron from the tubing.
- **Material Vulnerability**: The material quality selected for the CT was vulnerable to H2S exposure, which, combined with mechanical stresses, led to the incident.
- **Chemical Mixing**: The mixing of chemicals, choice of materials, and compatibility testing were identified as underlying causes.

Impact

- **Health Risks**: Personnel on deck were exposed to H_2S, potentially exceeding the maximum allowable concentration for a 12-hour shift offshore.
- **Financial Losses**: The incident resulted in financial losses due to postponed production, extra work, and damaged equipment.
- **Environmental Safety**: Although there were no direct environmental consequences, the incident highlighted the importance of maintaining well integrity and safety measures.

B-3 Case Study 3: Deepwater Horizon Blowout in the Gulf of Mexico (2010)

Incident Summary

On April 20, 2010, the United States experienced one of the most catastrophic blowouts in history. This disaster occurred during the completion of an exploratory well in the Macondo Prospect in Mississippi Canyon Block 252 of the Gulf of Mexico. The blowout preventer (BOP) failed to prevent the influx due to several factors, including wiring failure and an off-centred drill pipe.



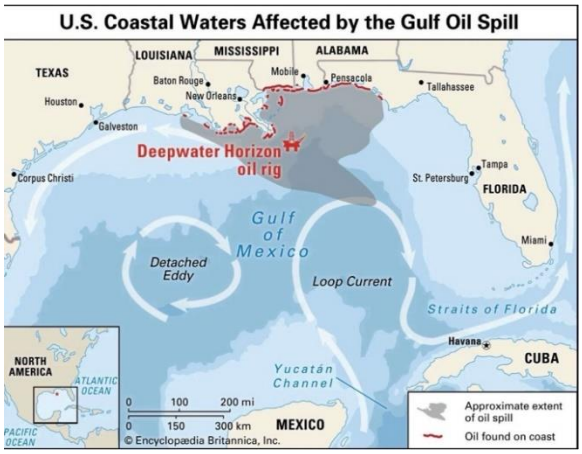
Figure 2: Burning off gases at the uncapped Deepwater Horizon Well

Root Cause

- Forensic analysis the following year revealed that the blind shear rams of the BOP malfunctioned because the pipe bent under the pressure of rising gas and oil, preventing the blades from slicing through.
- Lack of thorough risk assessment after changes in well design and procedures.
- Inadequate cement testing and result interpretation.
- Poor understanding of the physics controlling conditions at the well site.
- Poor operational decision-making.
- Improper testing of critical equipment.

Impact

- The blowout resulted in the deaths of 11 people, injuries to 17 others, and approximately 4.9 million barrels of oil spilled into the Gulf of Mexico over the months.
- More than a third of federal waters in the Gulf Coast were closed to fishing at the peak of the spill, due to fears of contamination.
- Loss of a rig.





(a) *(b)*

Figure 3 (a): U.S. Coastal Waters Affected by the Gulf of Mexico Oil Spill
(b): Fireboat response crews attempting to extinguish the blaze

B-4 Case Study 4: Advancements in Well-Control Standards Post-Macondo Disaster

Incident Summary

The Deepwater Horizon oil spill in 2010 also known as the Macondo disaster underscored critical deficiencies in the design and functionality of Blowout Preventers (BOPs). The failure of the BOP to seal the wellhead after the blowout highlighted the need for significant regulatory and technological improvements in well-control equipment.

Regulatory and Technological Improvements

1. **Rewritten and Expanded Well-Control Standards**:
    a. Following the incident, regulatory bodies such as the Bureau of Safety and Environmental Enforcement (BSEE) and the American Petroleum Institute (API) revised and expanded well-control standards to ensure better safety and operational protocols.
    b. Particularly, the API Standard 53 Blowout Equipment Systems for Drilling Wells was updated to provide comprehensive guidelines for the installation, maintenance, and testing of well-control equipment. Also, the BSEE's added to their requirements that blind shear rams be capable of cutting wireline.

c. New regulations mandated more frequent and rigorous testing of BOPs and other pressure control equipment to detect and address potential vulnerabilities.

2. **Improvements in BOP Design and Functionality**:
    a. Enhanced BOPs with dual shear rams capable of cutting through tough casings and sealing the wellhead.
    b. Improved accumulator systems to provide reliable hydraulic power for BOP activation.
    c. Advanced ROVs were developed to inspect, operate, and intervene on subsea BOPs in real time.

Challenges and Limitations

- **Fundamental Design**: Despite advancements, the fundamental design of BOPs has remained largely unchanged. The essential principles and mechanisms still face inherent limitations.
- **Increasing Toughness of Casings**: Modern wells utilise tougher casings that can pose challenges for BOP shear rams, requiring enhanced cutting capabilities.
- **Deeper Water Depths**: Drilling in deeper waters increases the complexity of well-control operations, necessitating robust and reliable equipment that can perform under extreme conditions.
- **Higher Well Pressures**: High-pressure wells demand equipment that can withstand intense pressure differentials, pushing the limits of current BOP designs.

B-5 Case Study 5: Slickline Incidence During Plug Retrieval (Hypothetical Scenario)

Incident Summary

In this hypothetical scenario, during a slickline plug retrieval operation, a gas leak was observed on the lubricator stuffing box. Attempts to increase the stuffing box pressure and close the Blowout Preventer (BOP) upper blind rams were unsuccessful. Eventually, it was discovered that several components of the Pressure Control Equipment (PCE) were incorrectly installed and not properly tested.

Root Cause

- Incorrect installation of the stuffing box packing elements.
- The equalizing port in the PCE was left open, bypassing the rams.
- Hydraulic connection failure due to improper testing.

Impact

The well control incident resulted in a gas leak and the eventual shutdown of the well by closing the Xmas tree master valve and cutting the slickline. This caused operational delays and potential safety hazards for the crew.

C. Codes and Cogs Recommendations/Justifications

Based on the documented cases of preventable failure, coupled with the expanded recommendations from API and BSEE, Codes and Cogs strongly advocates for the implementation of daily Pressure Control Equipment (PCE) and Wellhead Integrity testing. Our proposed solution comprises an integrated suite of diagnostic tests—including ultrasonic testing for corrosion and wall-thickness measurement, hydro testing, crack detection, visual inspections, and comprehensive functional checks. This daily testing regimen, combined with our real-time data transmission capabilities, will provide asset owners with immediate insight into the operational status of their PCE assets, thereby guaranteeing system integrity, instilling trust, minimise financial losses from equipment failure and production halts, and ensuring a higher level of safety and operational assurance.

Furthermore, it is known that PCEs transported between sites are exposed to mechanical shocks, vibrations, and environmental stress. In terms of operational wear and tear, daily use of PCEs in high-pressure and high-temperature environments accelerates equipment degradation. Also, there are cases of hidden defects from the manufacturers or microfractures may go undetected with infrequent testing. However, our proposed PCE testing solution with a capacity of up to 15,000psi would address these key risks. The integration of real-time data transmission and AI-driven analytics further strengthens decision-making, ensuring long-term asset integrity and financial sustainability.

Our PCE testing solution offers unparalleled attention to detail, meticulously tracking every tiny defect and promptly alerting asset owners. This proactive approach ensures that even the smallest issues are identified and addressed before they escalate into critical failures. Additionally, as a training body ourselves we offer training programs for operators on testing procedures and data interpretation, and 24/7 support for troubleshooting and guidance is available.

Investing in this service is not just about compliance; it’s about creating a safer, more efficient, and more resilient industry.

C-1 Feasibility

The technical and financial feasibility of our approach is well established. Codes and Cogs currently operates a state-of-the-art facility that includes an API 6A compliant pressure test cabin and a fully equipped workshop dedicated to testing PCE components.



Figure 4: Containerised Pressure Test Bay

Our capabilities extend to the following:

Ultrasonic Testing Equipment

Our in-house ultrasonic testing equipment is calibrated to detect minute levels of corrosion and material loss in components such as lubricators, coiled tubing, and wellhead assemblies.



Figure 5: Ultrasound Testing Device

Hydro Test Pumps and Diesel-Powered Compressors

We have high-pressure hydro test pumps and diesel-powered compressors that replicate field conditions, ensuring that our tests are both rigorous and representative of real-world scenarios.

Server Room and Real-Time Data Transmission

Our facility includes a dedicated server room that facilitates real-time data transmission and monitoring. This system is integrated with advanced AI and Machine Learning models, which are already operational. These models analyse proposed wellhead activity and risk factors to pinpoint the most appropriate testing procedures, ensuring that our testing is both targeted and comprehensive.

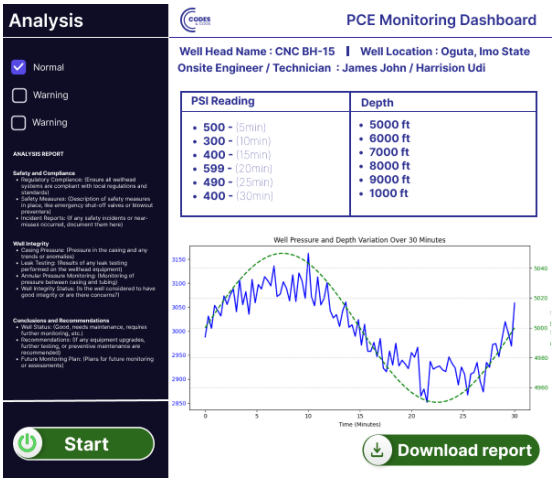


Figure 6: PCE Monitoring Dashboard

Comprehensive Test Infrastructure

All these components are currently in place and have been validated through rigorous internal testing, confirming that our solution is ready for immediate deployment in a field environment. Notably, our testing solutions that cater to the specific needs of different well environments, such as deepwater or high-pressure wells. This flexibility ensures that your services are adaptable and effective in various operational scenarios.

C-2 Value Proposition

Our novel approach is designed to significantly reduce well operation risks through proactive, daily testing. By addressing potential issues before they escalate, our process ensures that all critical PCE components—such as lubricators, coiled tubing, BOP shells, stuffing boxes, and grease heads—are functioning within safe parameters. The value proposition for asset owners is multifold:

1. **Risk Reduction:** Proactive testing detects defects, corrosion, or wear at the earliest stage, mitigating the risk of catastrophic failures and associated downtime.
2. **Enhanced Safety:** By ensuring the integrity of well control equipment on a daily basis, our solution protects crew, assets, and the environment from the dangers associated with equipment failure.
3. **Economic Efficiency:** Our integrated testing approach, powered by AI-driven analytics, optimizes maintenance schedules and reduces the likelihood of costly emergency interventions. This predictive capability translates into a superior return on investment for asset owners.
4. **Operational Assurance:** With real-time data transmission and comprehensive logging via the internet and local storage for redundancy, decision-makers are equipped with the detailed, up-to-date information they need to manage operations effectively and confidently.

In essence, Codes and Cogs' daily PCE integrity testing solution offers a transformative approach to well intervention operations—one that not only anticipates and prevents failures but also optimizes the entire asset management process, ensuring safety and economic resilience in high-stakes environments.

D. Appendix

D-1 Equipment in Details

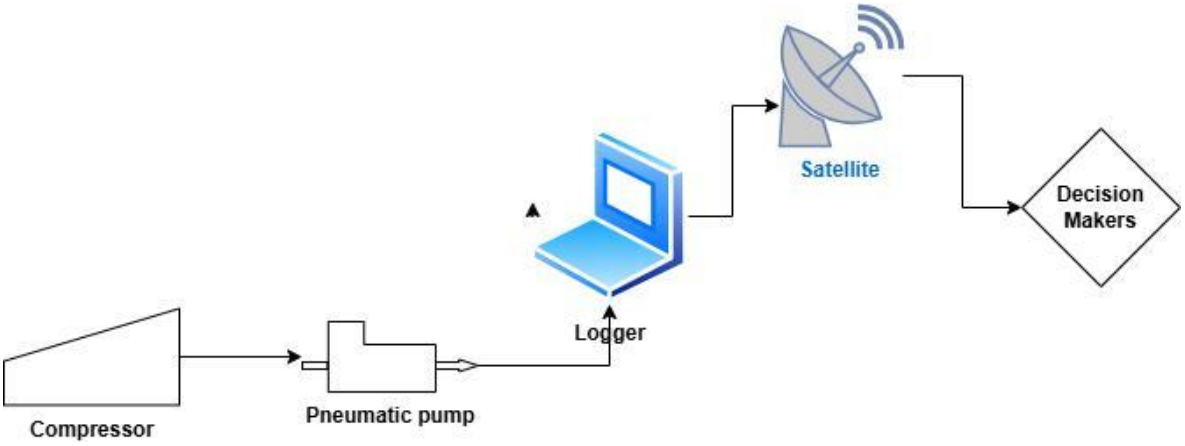


Figure 7: Schematic of Rig up System



Figure 8: Containerised Pressure Test Bay

Key Features of the Containerised Pressure-Test Bay

1. **Mobile Room**: Equipped with a mobile room that houses all necessary testing equipment, including pressure testing pumps, function testing rigs, and data acquisition systems.
2. **G-Clamps and Secure Mounting**: The container features G-clamps and secure mounting systems to ensure all equipment remains stable and safe during transit and operation.

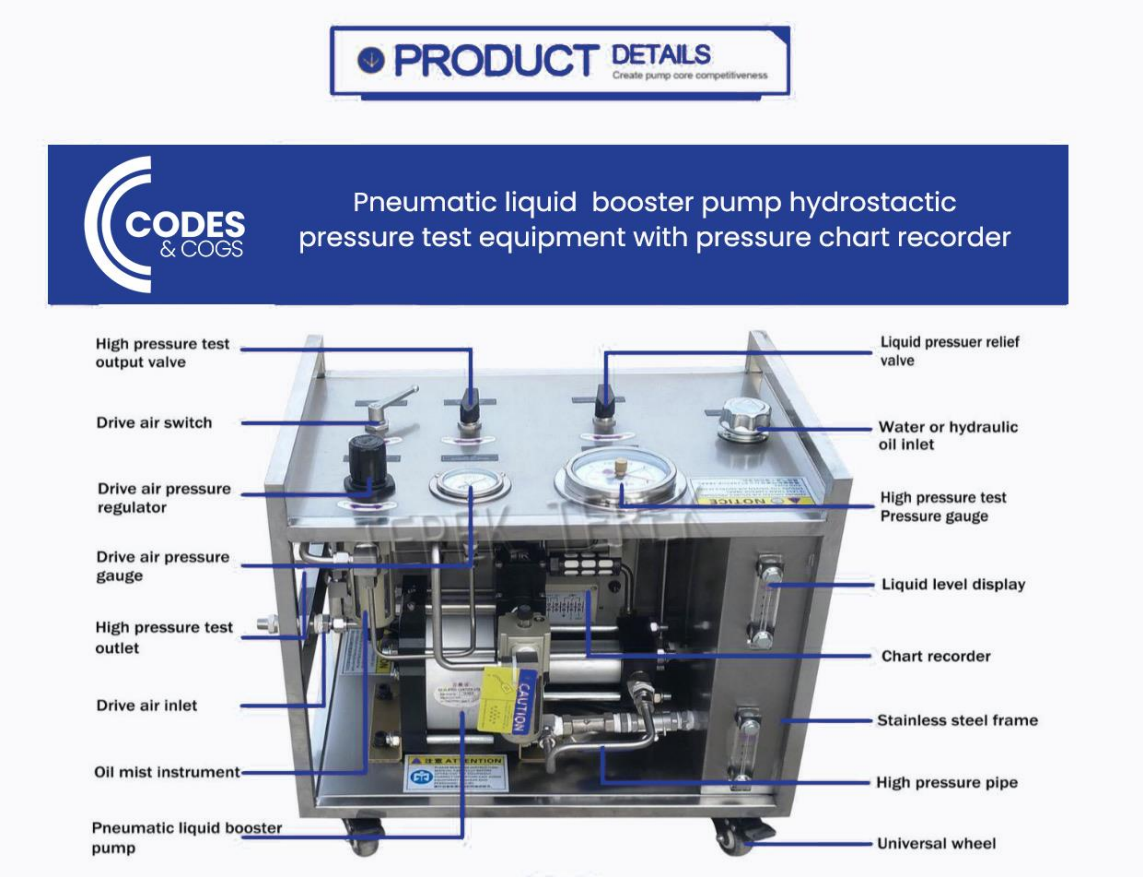


Figure 9: Pneumatic Pump

Key Features of the Pneumatic Pump

1. **Pneumatic Drive**: The pump is powered by compressed air, making it suitable for hazardous environments where electrical drives might pose a risk.
2. **High-Pressure Capability**: It can generate and maintain pressures up to 15,000 psi, ensuring thorough testing of PCE under operational conditions.
3. **Hydrostatic Testing**: The pump is used for hydrostatic pressure tests, where it pressurizes the system with liquid to detect any leaks, weaknesses, or defects.
4. **Pressure Chart Recorder**: An integrated pressure chart recorder continuously monitors and records the pressure levels during testing. This ensures accurate documentation and helps in identifying any anomalies or pressure drops.



Figure 10: Full view of Pneumatic pump

Drive air source pressure range	3-8 bar.
Medium	Hydraulic oil or water
Maximum outlet pressure	2040bar (29580psi)
When adjusting drive pressure 5.0bar	The high output pressure is 1275 bar/18487psi.
When adjusting drive pressure 5.4bar	The high output pressure is 1380 bar/20000psi
Power source	TEREK liquid booster pump
Outlet pressure Control unit	Drive air regulator valve
Pressure control accuracy	less than 1%F.S;
Pressure measurement accuracy grade	CL 1.6 pressure gauge
Frame type	304 Stainless steel
Valves and pipeline	High pressure needle valve and stainless steel tube
Round chart recorder	Record and print test data into round chart .
Test period	1hour / 4 hours /12hours/ 24 hours.（The test cycle is usually one hour)
Pressure sensor range	250MPA.
Recorder spare parts	100 paper chart, Spare print record bar
Equipment Weight	45 KG
Export wooden case Total Weight	55 KG
Equipment size:	600*480*550 mm
Package size:	640*540*570mm
Connection thread size(inch) High pressure Outlet	NPT1/4 Internal Thread

Product Specification Datasheet of the Pneumatic Pump

Product	Air Compressor
Model	FBW-1.0/8
Power	7.5 KW 10HP
Speed	860 R.P.M
Air Displacement	1000 L/min 36 C.F.M
Max Pressure	8 bar 116 psi
Tank	225 L 60 Gal
Gross Weight	290 KG
Package Dimensions	1650*650*1240 mm
Engine Type	Diesel Powered
Shipping time	It is expected to be delivered in specified address about 15-20days





Product Specification Datasheet of Rig-up Air Compressor

D-2 Digital Platform

This consists of the centralised dashboard for real-time monitoring, embedded with AI-driven analytics for anomaly detection.

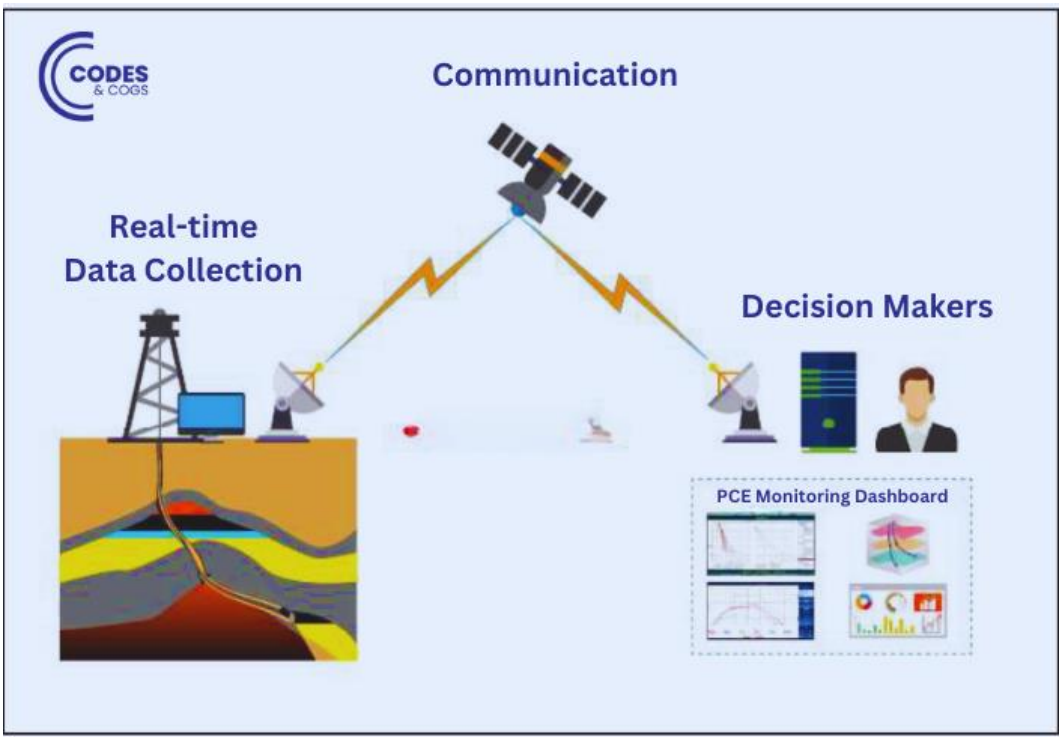


Figure 11: Representation of the Rig-up Transmitting Information to the Asset Owners

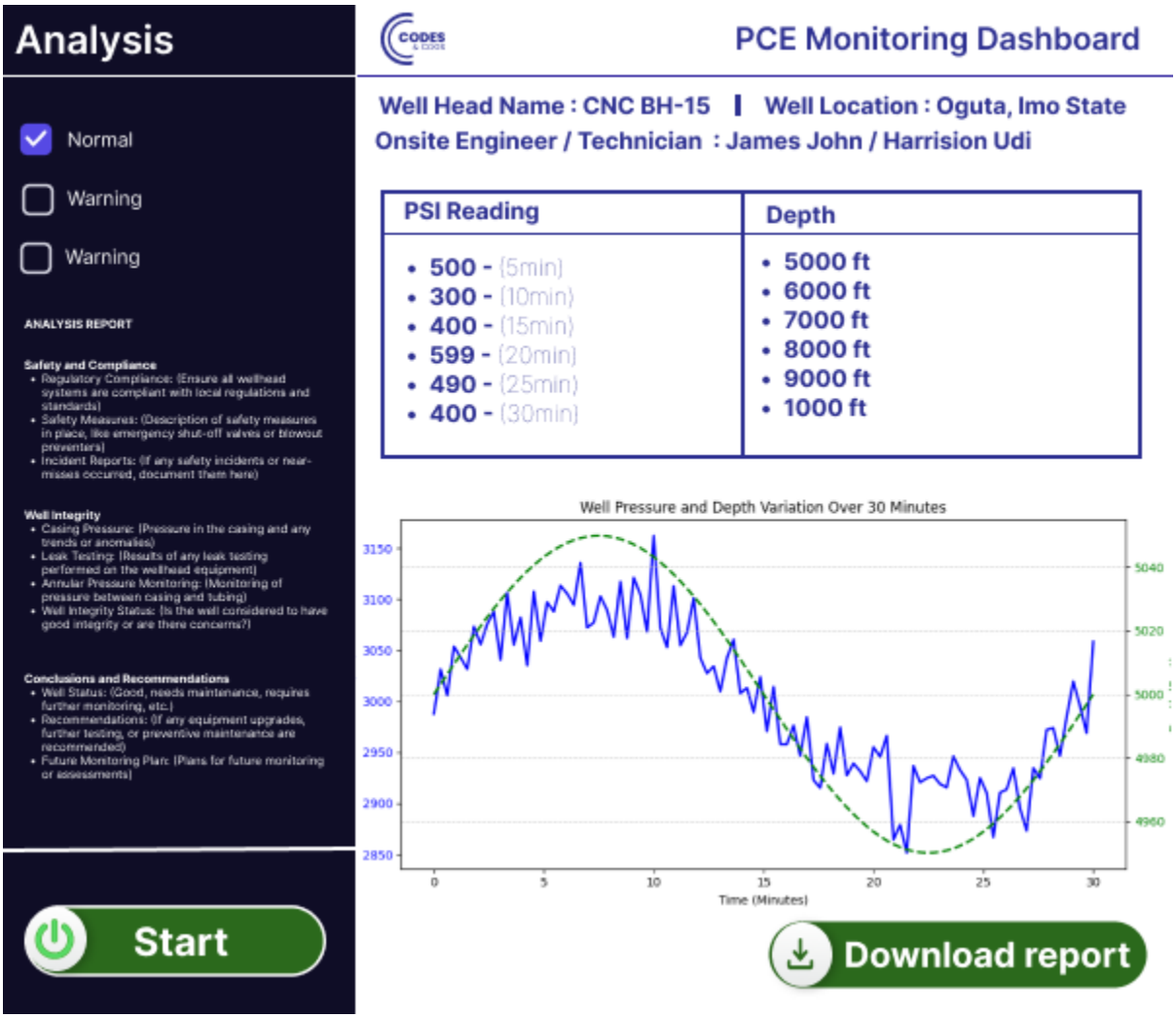


Figure 12: PCE Monitoring Dashboard Expanded

Real-Time Data Transmission

The satellite signal transmission system clamped at top of the container enables real-time data transmission. This ensures that test results and performance metrics are sent directly to asset owners and decision-makers for immediate analysis and action.

Integrated Monitoring Systems

The PCE test setup has advanced monitoring systems are integrated into the container, allowing for real-time tracking of equipment performance and detecting any anomalies. This includes AI-driven analysis in the digital platform to interprets the results and also predict potential failures.

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