HWDDDA: MEASURING DOWNHOLE POSITION AND LOAD IN DEVIATED WELLS, 2025 UPDATE

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ABSTRACT

Current models for design and analysis of rod-pumped wells are based on field data from vertical wells. The assumption that these models work is only theoretical. Such models have never been validated with actual measurements from deviated or horizontal wells.

The result has been rod string designs for deviated wells which are either too conservative or overly optimistic. This can result in excess rod string weight which constrains production rates; or premature rod failures that necessitate well interventions and production interruptions. The software that is used today for analysis and in wellsite controllers still relies on the vertical hole model, which is inadequate at dealing with deviated wells and the mechanical friction responsible for most of today's failures.

The Horizontal Well Downhole Dynamometer Data Acquisition (HWDDDA) project aims to gather true measured data such as axial load and triaxial acceleration to help improve design and control software for rod systems. The goal of the HWDDDA project is to design and manufacture downhole tools and deploy those tools in deviated and horizontal wells. Data gathered during the HWDDDA project can be used to validate existing models and develop models better equipped to handle the complicated balance of forces occurring during pumping in deviated and horizontal wells. Data collected by the HWDDDA tools will be validated, archived, and distributed to the industry.

Thanks to the generous contributions of our member companies, the design and manufacturing of downhole tools is underway. Progress including the rigorous calibration, testing and validation of the downhole tools will be discussed. Plans for initial field testing will also be presented and reviewed.

INTRODUCTION

Rod Pump Diagnostics

In sucker rod pumps, a surface dynamometer measures position and load, which generates a surface card. The rod string connects the pump to the polished rod at the surface.

The movement of the rod string is slowed by three factors. The first factor is elasticity. The rod string is thousands of feet of elastic material cycling between tension and compression with the motion of the pumping unit. This creates stress waves which attenuate the stroke at the pump. Secondly, the produced fluids impart a viscous force on the outer diameter of the rod string further dampening its progress. Finally, contact between the rod string/couplings and pump with the tubing creates mechanical friction which further reduces the work available at the pump.

An effective tool to diagnose the condition and work available at the pump is to calculate a dynamometer card. The downhole pump dynamometer is calculated by solving the 1D damped wave equation.

Figure 1 depicts a downhole card with highlighted key control parameters such as the gross stroke, net stroke, and fluid load. The gross stroke is the horizontal span of the card, the net stroke is the horizontal portion of the barrel which contains fluid. The fluid load is the vertical span of the downhole card minus the friction, which is both of viscous and mechanical origin.

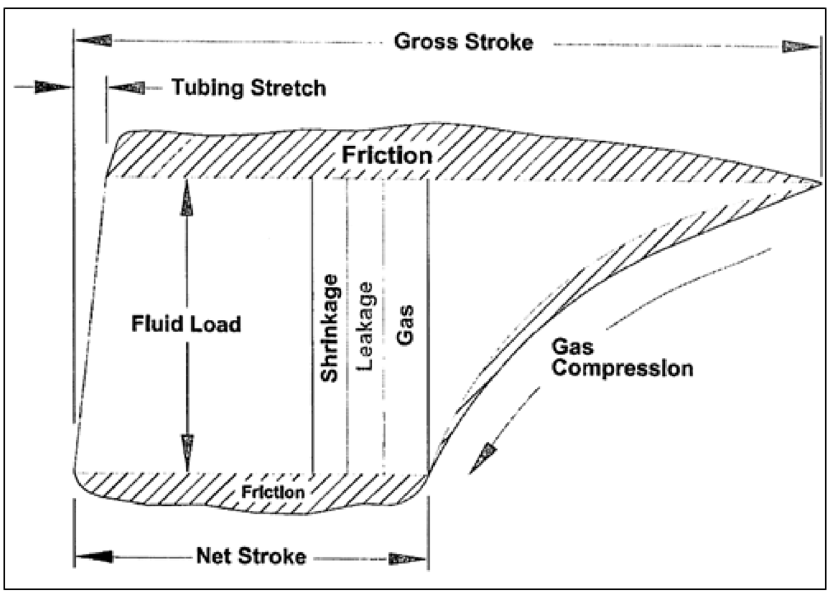

Figure 1 – Depiction of downhole card showing key control parameters.

The use of the 1D wave equation is possible through the assumption that the rod string only moves up and down and that lateral movement is non-existent or negligible. The damping term in the 1D damped wave equation only accounts for viscous forces as it removes energy from the system to mimic the energy lost to viscous friction during pumping.

This is not the case in deviated wells, which comprise most wells today. Deviation affects pump action and generates mechanical friction which obscures downhole data and the essential quantities that operators need to derive from it.

This translates into erroneous calculation of downhole data. Deep deviation errors will mostly affect the fluid load. In shallow deviation cases, where the kickoff point occurs within the first few thousand feet of rod string, friction has the most detrimental effect on the computed loads.

The rod elements affected by shallow deviation must support most of the weight of the rod string below as well as the fluid being lifted. This relatively high axial loading combined with areas of heavy sideloading from normal forces can have a disastrous effect on the downhole data calculated. This means that in the shallow deviation case, the gross and net stroke calculations will be affected along with the fluid load.

A comparison of the above-mentioned cases is shown in Figure 2.

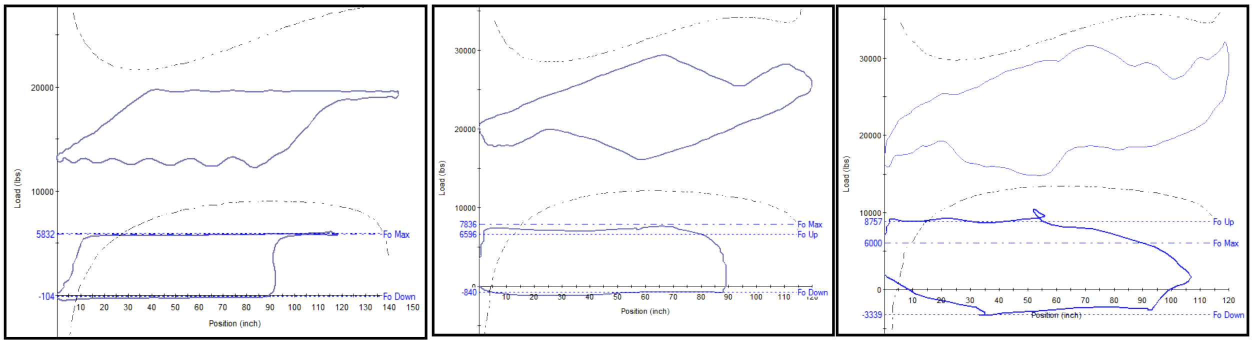

Figure 2 –Vertical (left), deep deviation (middle), and shallow deviation (right) cases.

Background and Historical Perspective

In the 1990s, due to high rod pumping failure frequency in the Oil & Gas industry, the government contracted Sandia National Laboratory to conduct a series of experiments to measure downhole position and load in rod strings operating in vertical wellbores.

Downhole dynamometer tools were built and deployed at different locations along the rod string in five wells. The tool measurements were compared to the calculated solution of the wave equation and were shown to agree, which validated the use of the wave equation to calculate downhole data and ultimately optimize and control vertical rod-pumped wells.

Figure 3 shows the comparison of measured data (solid line) with calculated data (dashed line) using the Gibbs method, cf. [1]. Note that the measured and calculated data in the case of a vertical well are very similar.

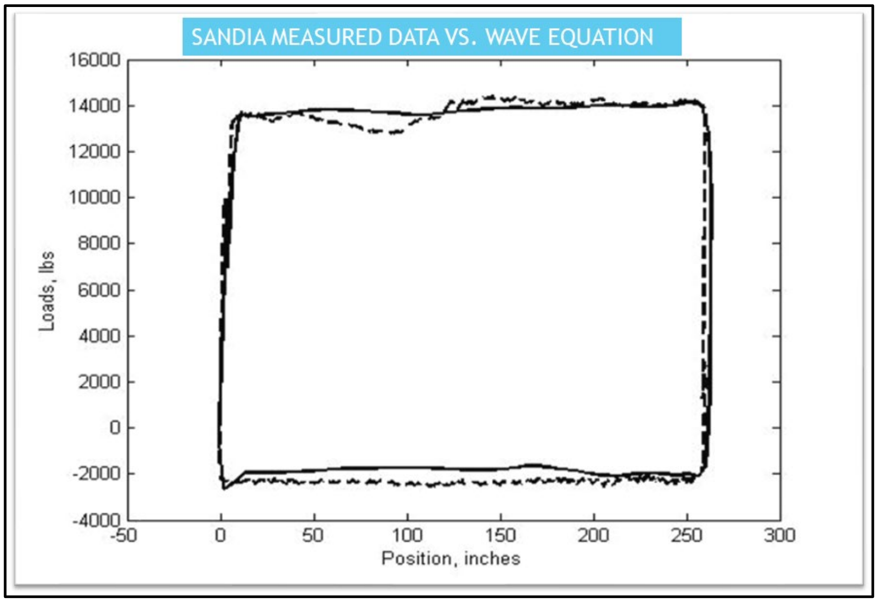

Figure 3 – Comparison of measured vs. wave equation dynagraph.

The purpose of the Sandia project was to understand the rod loading at any point throughout the rod string. Calculated results from every model, be it diagnostic or predictive, have been compared to the measured Sandia data.

However, all wells tested were vertical wells, which means that the measured data does not represent what happens in a deviated well. Most wells today are deviated either intentionally or accidentally. This means that the solution to the wave equation is no longer adequate.

To shed some light on this problem and offer the industry a chance to move forward, the Artificial Lift Research and Development Council (ALRDC) provided seed funding for the HWDDDA project. The project quickly gathered the support of the industry and will provide the collected data to the industry after five years, just as was done with the Sandia data.

Project Goals and Overview

The goal of the HWDDDA project is to reproduce experiments like Sandia with a focus on deviated wells.

To this end, high-temperature downhole dynamometer tools, a.k.a. downhole load cells (DHLCs), are to be built and deployed to measure data in both deviated and horizontal rod-pumped wells. The measured data will be plotted in the form of dynagraph cards and will be shared with the Oil & Gas industry for development of new algorithms. Better knowledge of the effects of deviation on the rod string will improve our understanding of side loads, bending, friction, damping, and other factors.

How will measuring data help? Mathematical models available today were built using vertical Sandia data and need to be validated for deviated wells. The frictional components in deviated wells are not thoroughly understood.

The HWDDDA project has assembled operators and service companies to solve this challenge.

First DHLC Prototype

An initial manufacturer was selected, but the first prototype built was deemed unacceptable by the HWDDDA team after preliminary field testing.

Problems with the tools included improper placement of strain gauge leads, which needed to be cut each time the battery was recharged or replaced. This caused major calibration issues with the tool, as tool calibration depends on the length and placement of the leads. The load signal was also outside of specifications and the load probable error too high. The acceleration signal could not be consistently integrated due to excess noise drowning the signal. Pressure resolution was outside of specifications as well.

Finally, the temperature recorded by the tool was the board temperature rather than the external temperature. External temperature and pressure are necessary to correct the output signal drift when measuring at the bottom of the wellbore near the pump.

Even though this setback cost valuable time and resources, the team gained a firm understanding of what was needed for the next generation prototype and learned many lessons.

EOG Tools

In 2021, operator EOG Resources donated three downhole tools for the project: two tension/compression and temperature tools and one tension/compression, side load and temperature tool. These tools were originally designed by ETA International and Micro-Smart Systems to capture side loading. The EOG tools were not capable of measuring position, which is critical to the goals of the HWDDDA project. It was determined that the three functional tools could be redesigned to achieve the project objectives while reducing overall design costs.

A partnership with ETA and Micro-Smart began and a new HWDDDA tool design was completed.

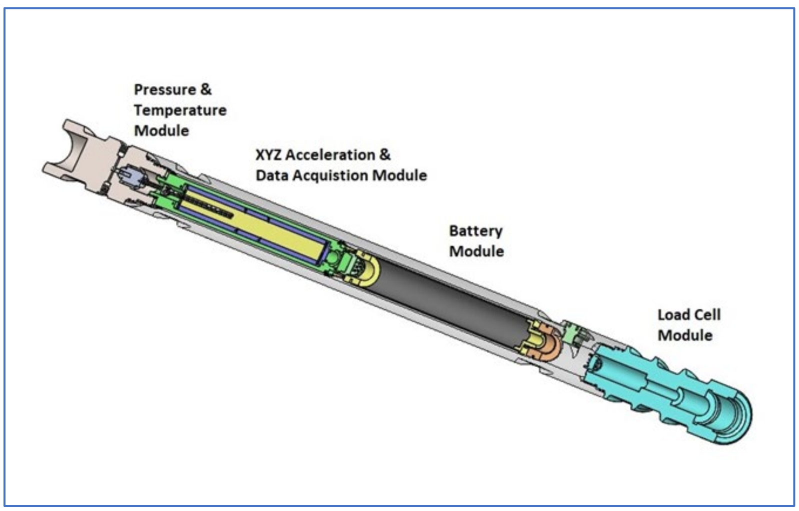

Figure 4 – New design HWDDDA tool.

Figure 4 shows the updated 5 ft length, 1.85 in diameter HWDDDA tool. On the left side is the pressure and temperature module. The X, Y, Z acceleration and data acquisition module and the battery module are in the center. The load cell module is on the right side of the tool.

Second Prototype HWDDDA Tool

Manufacturing and testing of the new tools are underway. A new generation of downhole sensors for gathering true measured forces and stresses has been constructed. Tool specifications:

Sensors

- Synchronized clocks – for correlating data across multiple tools
- Triaxial accelerometer – position and relative gravity vector
- Low zero shift, pressure balanced load cells – linear tension and compression
- Pressure, internal temperature, fluid temperature
- Powered by Lithium Thionyl Chloride Battery

Footprint

- Matches existing API 11B specifications and can easily be placed within the string
- Box/box connection – 7/8” API sucker rod thread
- Stainless steel 17-4PH H900 construction – meets or exceeds artificial lift operating conditions
- All leak paths have dual seals, and most seals use back-up rings to resist high pressure and temperature.

Milestones

The following milestones were set in place to efficiently track progress, stay on schedule, keep teams and stakeholders aligned, and ultimately lead to successful completion of the project.

Milestone 1: ALRDC, ETA and Micro-Smart worked on goals for how the EOG tool could be upgraded to meet the requirements of the HWDDDA project. The EOG tool was developed primarily to measure side-loads and tension. The HWDDDA tool needed to measure downhole position and tension to create a dynagraph. A design guidelines document was developed by the team to capture the requirements of the tool and testing results.

Milestone 2: Micro-Smart Systems upgraded the tool’s Data Acquisition System (DAS) to include triaxial accelerometers to measure downhole position. Micro-Smart fabricated a “daughter board” that provided additional printed circuit board area for mounting the triaxial accelerometer and reworked other areas of the DAS to record pressure and temperature.

Milestone 3: The tension/compression load cells on the EOG tools recorded 1–4% zero shifts during downhole testing. This zero shift was determined to be unacceptable by ALRDC, so ETA contacted multiple load cell companies and found one that guaranteed a 1% or less zero shift. ETA designed the load cell to have high fatigue life connections and contracted the load cell company to build three new high-performance tension/compression load cells.

Milestone 4: ETA redesigned the DAS Housings to accommodate the new high fatigue life connection and provide a robust side port. The side port allows the operator to access the power connection with simple hand tools to turn the tool on and off. ETA also designed new bulkheads to house the pressure and temperature sensors with metal-to-metal seal connections.

Milestone 5: The upgraded tools needed new bulkheads and housings. ETA created custom drawings and worked with several machine shops to build the new parts.

Milestone 6: Micro-Smart assembled, calibrated and tested the DAS and sensors to confirm proper operation. Stable data was acquired at 8 temperatures with 12 pressure steps at each temperature for pressure calibration. Stable data was also acquired at 9 temperatures with 8 voltage steps at each temperature for tension channel calibrations. Voltage measurements were acquired with a 6.5-digit precision multimeter. Accelerometer data was collected at stable ambient temperature while the tool was mounted in a tilting rotary table. A precision digital level was utilized for horizontal and vertical tool alignment within 0.01°. The tool was precisely tilted 90° and rotated 180° to acquire +1G and -1G data for the X, Y, and Z axis. A 12" stroke test was setup with a rotary table, pulley, and PVC pipe to create sinusoidal motions similar to the motion the tools would experience in the well.

Milestone 7: ETA designed and assembled a tubing test fixture that would simulate rod pumping motion and independently measure the tool's position in a deviated well. The tubing test fixture is usable at any angle from horizontal to vertical.

Milestone 8: ETA tested the tools at 90° and 45° in the tubing test fixture while acquiring the tool's position with a separate standalone instrument. This data allowed ALRDC to verify the accuracy of the tool accelerometers and ALRDC's computer algorithms.

Milestone 9: ETA upgraded the calibration check test fixture that was used for the EOG sideload tools. Custom pony rods were manufactured to support 15,000 lbf of tension to be applied to the tool inside of the vessel. ETA recalibrated all the fixture instruments and verified proper operation through the standalone DAS system using a dead weight tester, thermowell, and 5000 lbf of steel weights. Next ETA installed each tool in the fixture and subjected it to inclination, rotation, tension, pressure, and temperature corresponding to 3000, 6000, and 9000 feet of depth.

HWDDDA TOOL BUILDING AND TESTING

DAS Modification and Test

The three EOG tools were reacquired and functionally tested prior to disassembly and modifications.

Functional modifications were made to the internal printed circuit board, the tool firmware, and the computer software. Figure 5 shows a screenshot of the main screen from the computer software interface.

These modifications were implemented to support the addition of the triaxial accelerometer, the pressure/temperature transducer, the upgraded load cell, and an increased sampling/storage rate. Mechanical changes were also applied to the internal chassis, pressure bulkhead, and pressure housing.

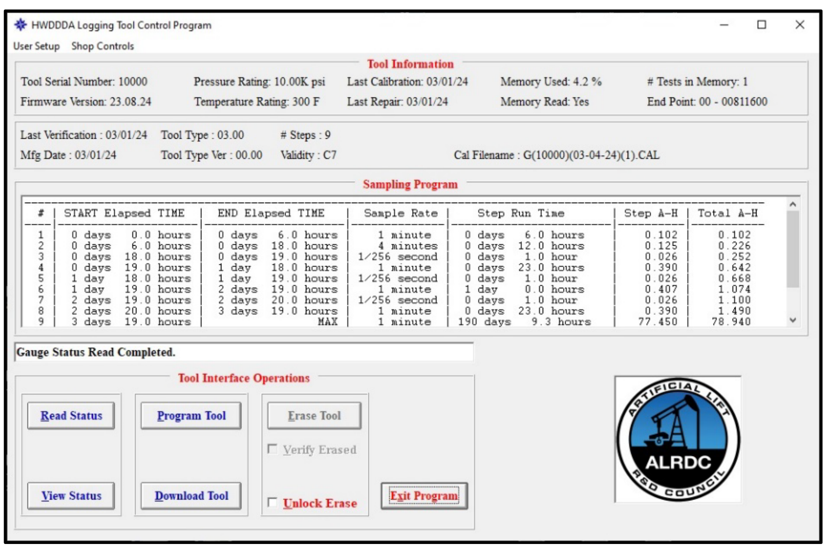

Figure 5 – Computer software interface main screen.

Following the modifications, the tools were subjected to preliminary testing prior to calibration. The pressure bulkheads were cycled up to 11,000 psi and from 5°C to 150°C, shown in Figure 6. The chassis assemblies were also thermally cycled from 5°C to 150°C in the environmental chamber pictured in Figure 7. Finally, the chassis assemblies were subjected to a low frequency vibration test, swept from 0 Hz to 120 Hz. The vibration setup is shown in Figure 8.

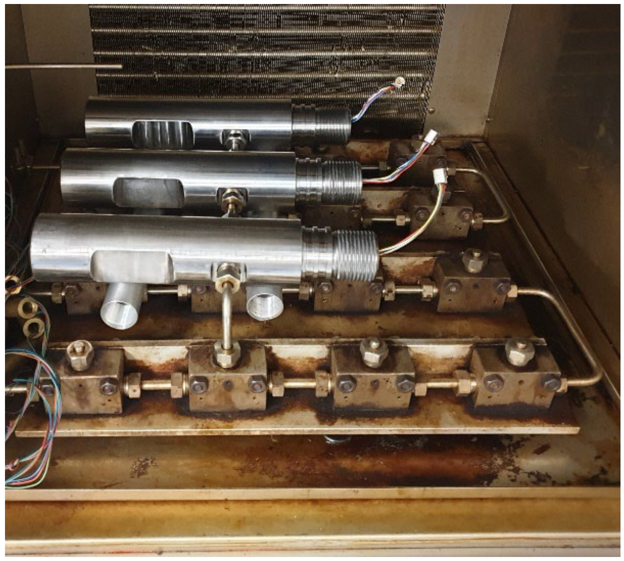

Figure 6 – Pressure / thermal testing of the DAS pressure bulkhead assembly.

Figure 7 – Thermal testing of the DAS chassis assembly.

Figure 8 – Low frequency vibration testing of the DAS chassis assembly.

DAS Pressure / Temperature Calibration

Pressure and temperature calibrations were performed with an environmental chamber (Figure 9) for temperature control and a dead weight pressure standard for pressure measurement (Figure 10). The DAS tool assemblies acquired stable data at 8 temperatures and 12 pressure steps at each temperature. The applied temperatures ranged from 5°C to 150°C and the applied pressures ranged from 0 to 10,000 psi.

After post-processing the collected data, the curve-fit results yielded temperature-compensated pressure accuracies better than +/- 2 psi and temperature accuracies better than 0.2°C. Calibrated units were in psia and °C.

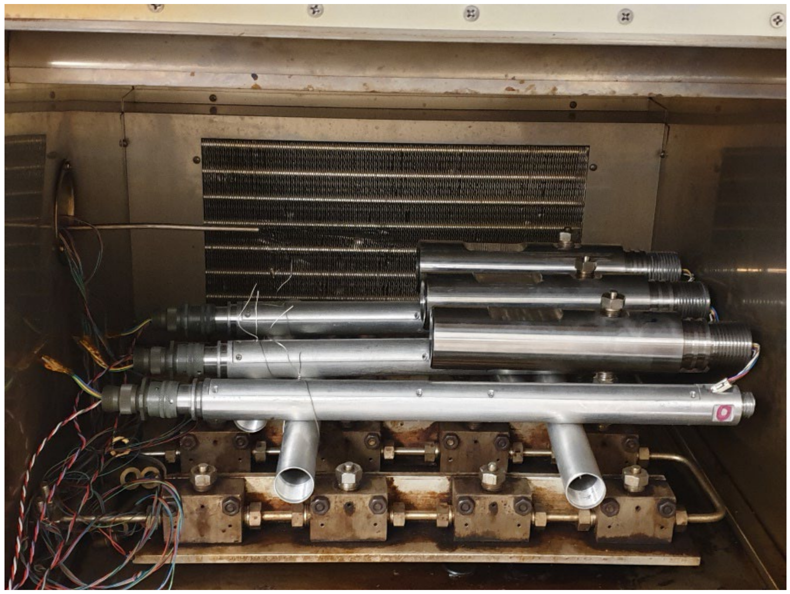

Figure 9 – DAS tools ported in the environmental chamber for calibration.

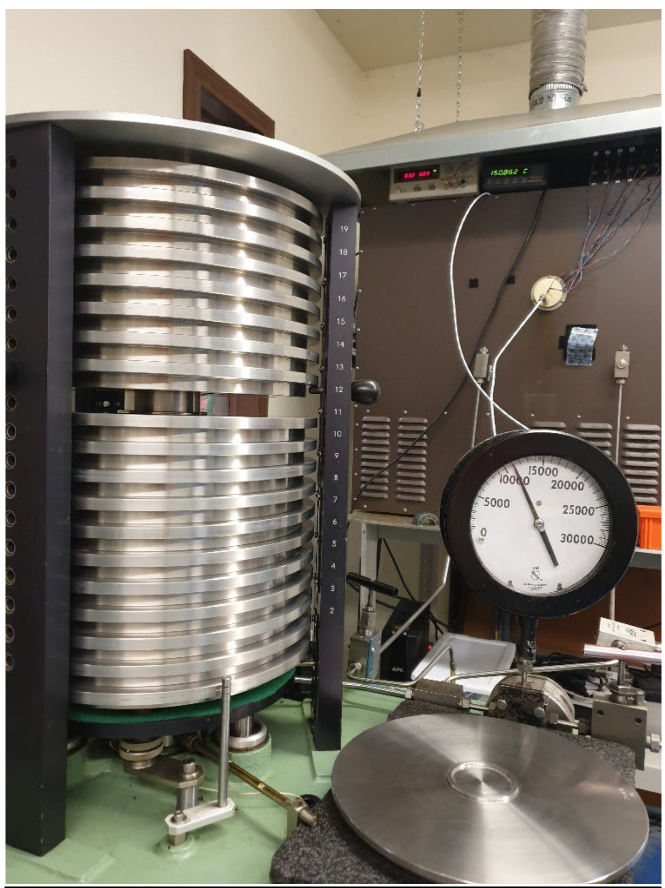

Figure 10 – Dead weight pressure standard used for pressure calibration.

DAS Load Channel Calibration

Load channel calibrations were performed with an environmental chamber, a 6.5-digit precision multimeter, and a custom adjustable-output Wheatstone bridge. The equipment setup is shown in Figure 11. The DAS tool assemblies acquired stable data at 9 temperatures and 8 voltage steps at each temperature. Measurements of the reference voltage were also taken. The applied temperatures ranged from 5°C to 150°C and the applied voltages ranged from -2 to +6.5 millivolts.

After post-processing the collected data, the curve-fit results yielded temperature-compensated voltage accuracies better than +/-0.002 millivolts. Calibrated units were in millivolts and volts. The downhole load cell coefficients supplied by the load cell manufacturer will be used to obtain the final calculated data in units of pound-force (lbf).

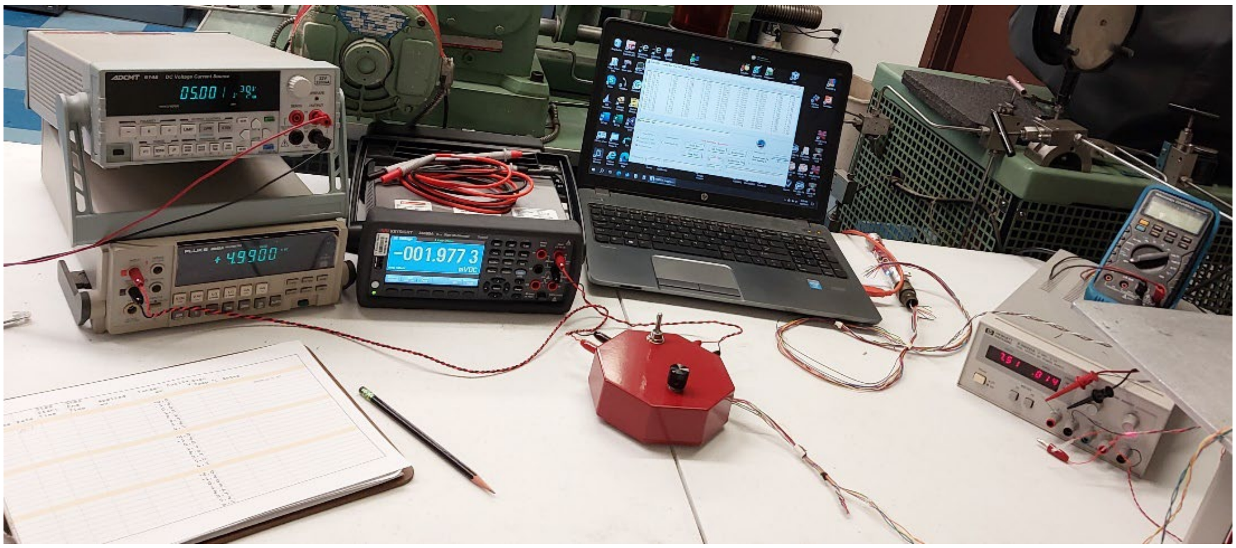

Figure 11 – Equipment setup for load channel calibration.

DAS Acceleration Channel Calibration

Acceleration channel calibrations were performed at a stable ambient temperature. The DAS tool assemblies were mounted on a tilting rotary table in the lab. A precision digital inclinometer was used to adjust horizontal & vertical tool angular alignment to within 0.01° as shown in Figures 12 and 13. Through a process of precisely tilting 90° and rotating 180°, the DAS tools were repositioned to acquire static +1G and -1G data for the X, Y, and Z axis.

Endpoint fit coefficients were calculated to equate each axis to +1G and -1G. Subsequent rechecks of each axis showed the calibration results to be repeatable.

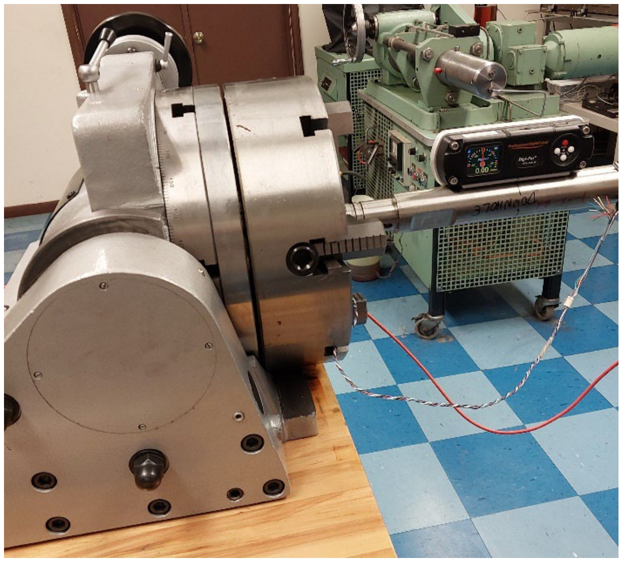

Figure 12 – Horizontal tool alignment in rotary table using precision inclinometer.

Figure 13 – Vertical tool alignment in rotary table using precision inclinometer.

Acceleration Movement Test

As a precursor to more elaborate testing, continuous tool movement tests were performed in the lab to validate that Z-axis movement could be detected within the data. The tools were oriented for both inclined and vertical movement inside of a PVC pipe. The DAS tools were attached to the rotary table via braided cable as shown in Figures 14 and 15. The rotary table was spun with a drill motor to create continuous sinusoidal strokes. The DAS tools were programmed to record data at 256 samples/second. The achievable stroke length was approximately 11.5 inches with speeds up to 4 strokes/min.

The strokes were evident in the acceleration data after post-processing.

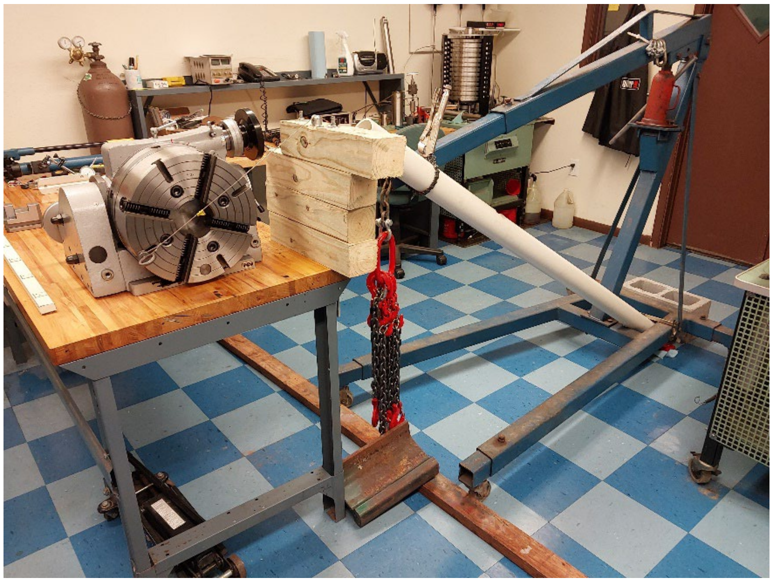

Figure 14 – Setup for angle stroke movement test setup.

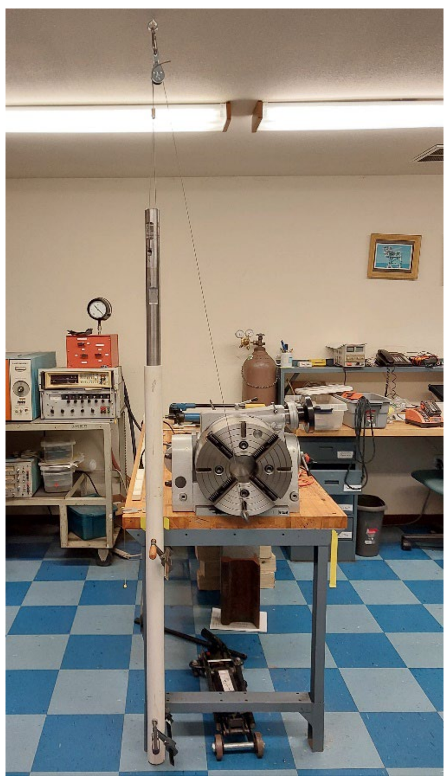

Figure 15 – Vertical stroke movement test setup.

Simultaneous Acceleration, Temperature, Pressure & Load Testing

Figure 16 – ETA calibration check test fixture

Figure 16 shows the fixture that is used to simulate downhole conditions for the tool. The fixture consists of a 4 in. inside diameter thick wall pipe, flanges with instrumentation and tension penetrations, and 1-3/8" diameter B7 studs that resist loads from pressure. The fixture can provide 5000 psi, 400F, and 15,000 lbf of tension to the tool inside. The tension applied to the tools is measured by an external load washer on the flange. The pressure, temperature, and tension are recorded by a standalone National Instruments cDAQ DAS.

Figure 17 contains two graphs: the top one shows the tension of the tool compared to the tension recorded by the external load cell when cycled to 15,000 lb. The bottom graph shows the data from rotating the tool about the z-axis from -1G to +1G. These two graphs demonstrate how the tool accurately records the tension (15,000 lbf) and acceleration signals (+/- 1G) during simulated depths of 3000 to 9000 feet.

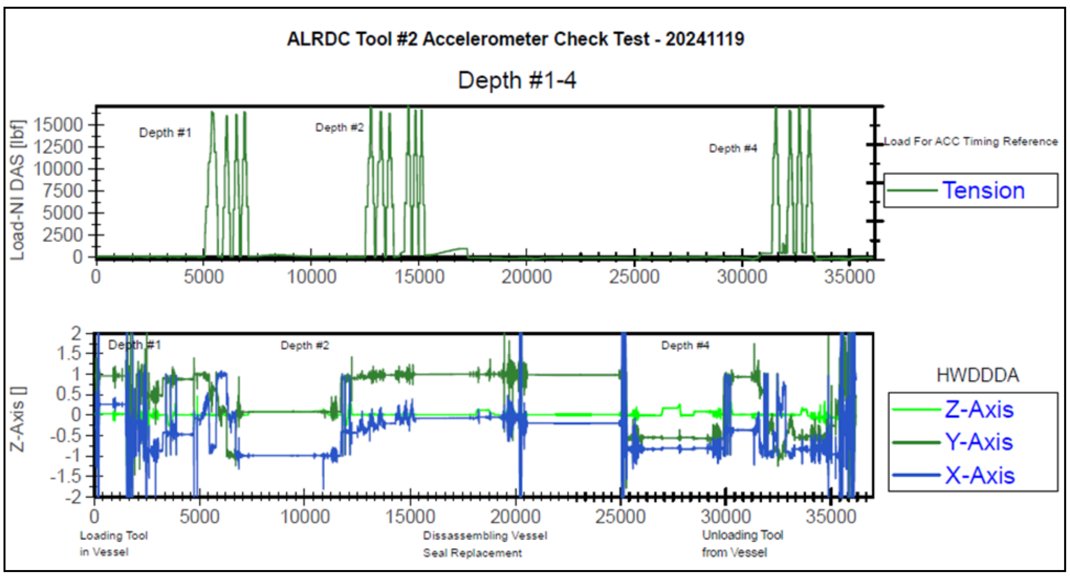

Figure 17 – Calibration check testing tension and accelerometer data.

After initial testing in the calibration check test fixture, the load washer and tool load cell were showing 5–9% load differences even though both the load washer and tool load cell were recently calibrated by a NIST-certified test lab. ETA thus needed to determine if the load cell and the load washer were correctly calibrated, so 1000 five-pound weights were used to perform a simultaneous load test, as shown in Figure 18. The results showed the load washer was not properly calibrated, so it was replaced to improve calibration check testing accuracy.

Figure 18 – Verification of load cell and load washer with 5250 lbm.

Figure 19 compares the HWDDDA fluid and internal tool temperatures to the calibration test fixture temperature recorded on the standalone NI DAS from 70 to 240 degrees Fahrenheit. The graphs show maximum differences of a few degrees when corrected for the timing offset, which is expected as the sensor measured the temperature in different places inside the test fixture.

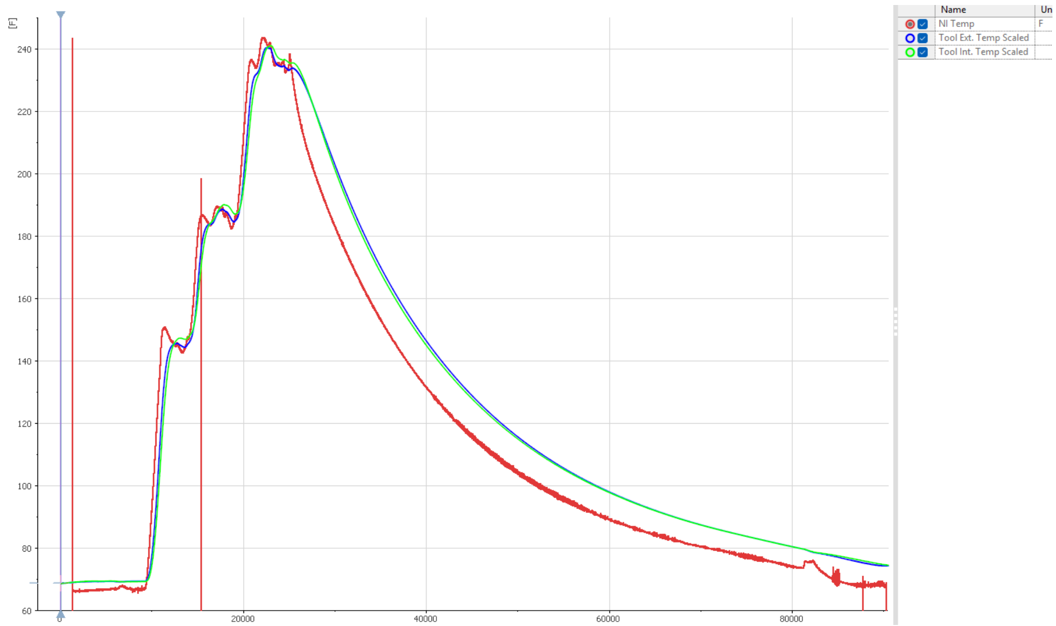

Figure 19 – Temperature calibration check tests HWDDDA #1

Figure 20 compares the HWDDDA tension to the calibration test fixture load at a simulated depth of 6000ft (2220 psi, 185 F). The graphs show differences of 2% or less, which is close to the same offset when both sensors were loaded with 5000 lbs of hanging weight.

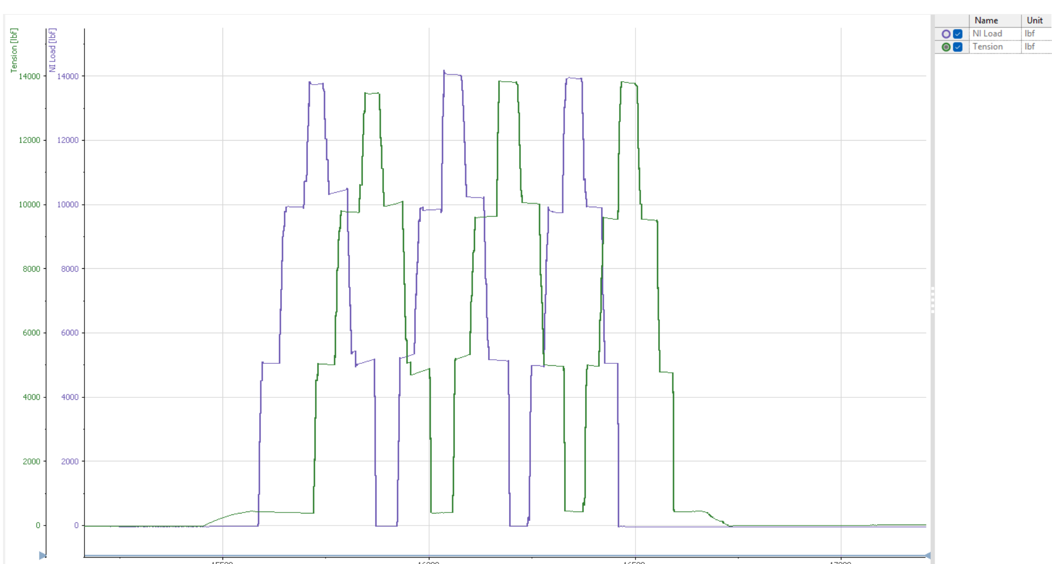

Figure 20 – Tensile calibration check Tests HWDDDA #1 at simulated depth of 6000 feet

Figure 21 compares the HWDDDA tension to the calibration test fixture load at a simulated depth of 9000ft (3300 psi, 238 F). The graph shows a 700 lb increase in tension when the vessel is pressurized just before the tension cycles. This increase in tension matches closely to the reduction in compression area due to the ½" vessel penetrations. The ½" penetrations are required to apply tension to the tools inside the test fixture. Once the pressure induced tension is accounted for, difference in tension is approximately 3% or less.

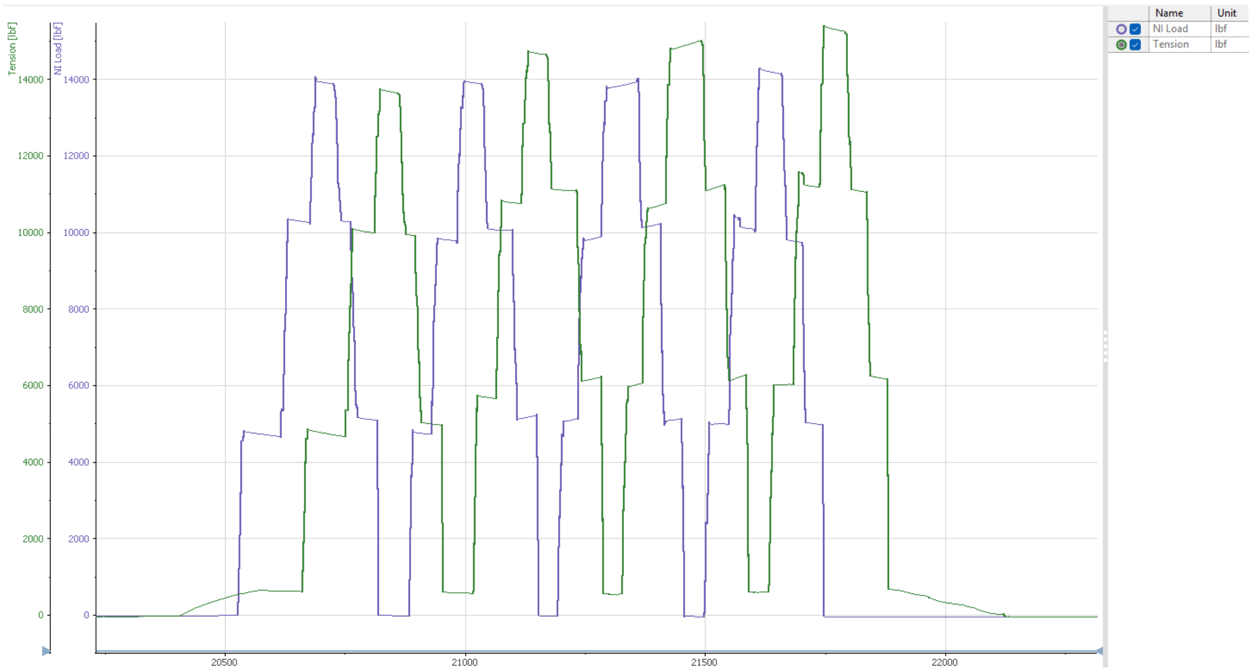

Figure 21 – Tensile calibration check tests HWDDDA #1 at simulated depth of 9000 feet

Figure 22 compares the HWDDDA pressure to the calibration test fixture pressure at simulated depths of 3000, 6000 and of 9000 feet (1100, 2200, 3300 psi). The graph shows differences less than 0.2%.

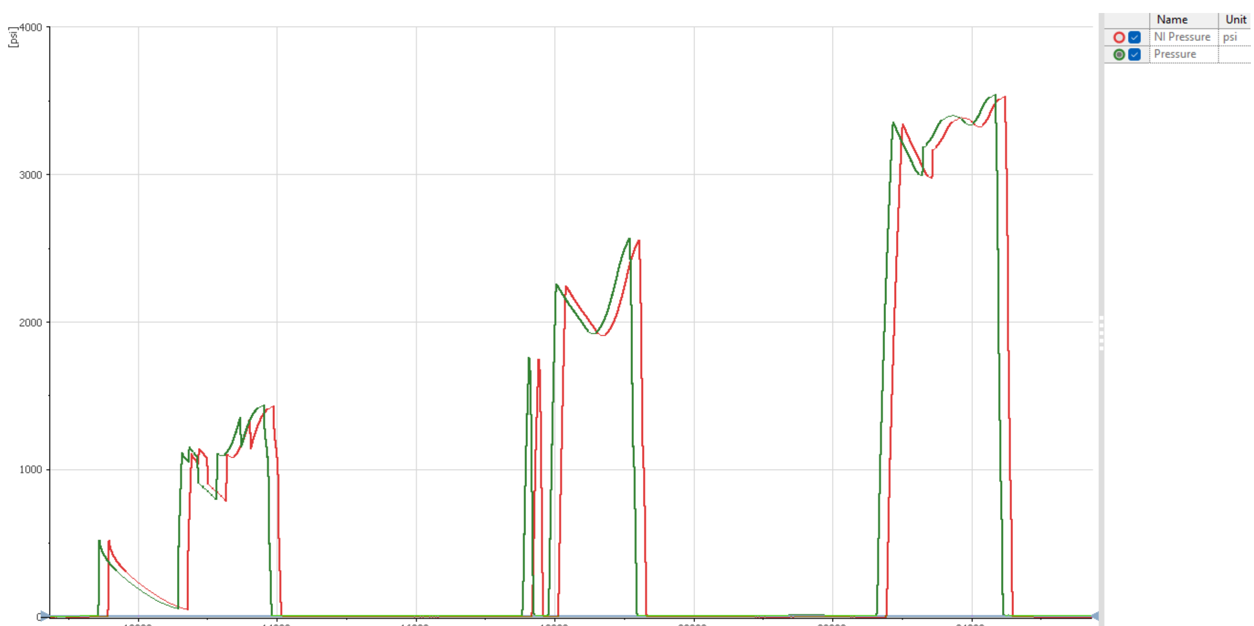

Figure 22 – Pressure calibration check tests tool #2 at simulated depths of 3000, 6000, and 9000 feet

Figure 20 shows the angled tubing test fixture that simulates a deviated wellbore. The test fixture consists of a 20 ft section of tubing, a hoist to move the tool, a string pot, and a DAS to record the tool's actual position. The tubing test fixture can be oriented at any angle from horizontal to vertical.

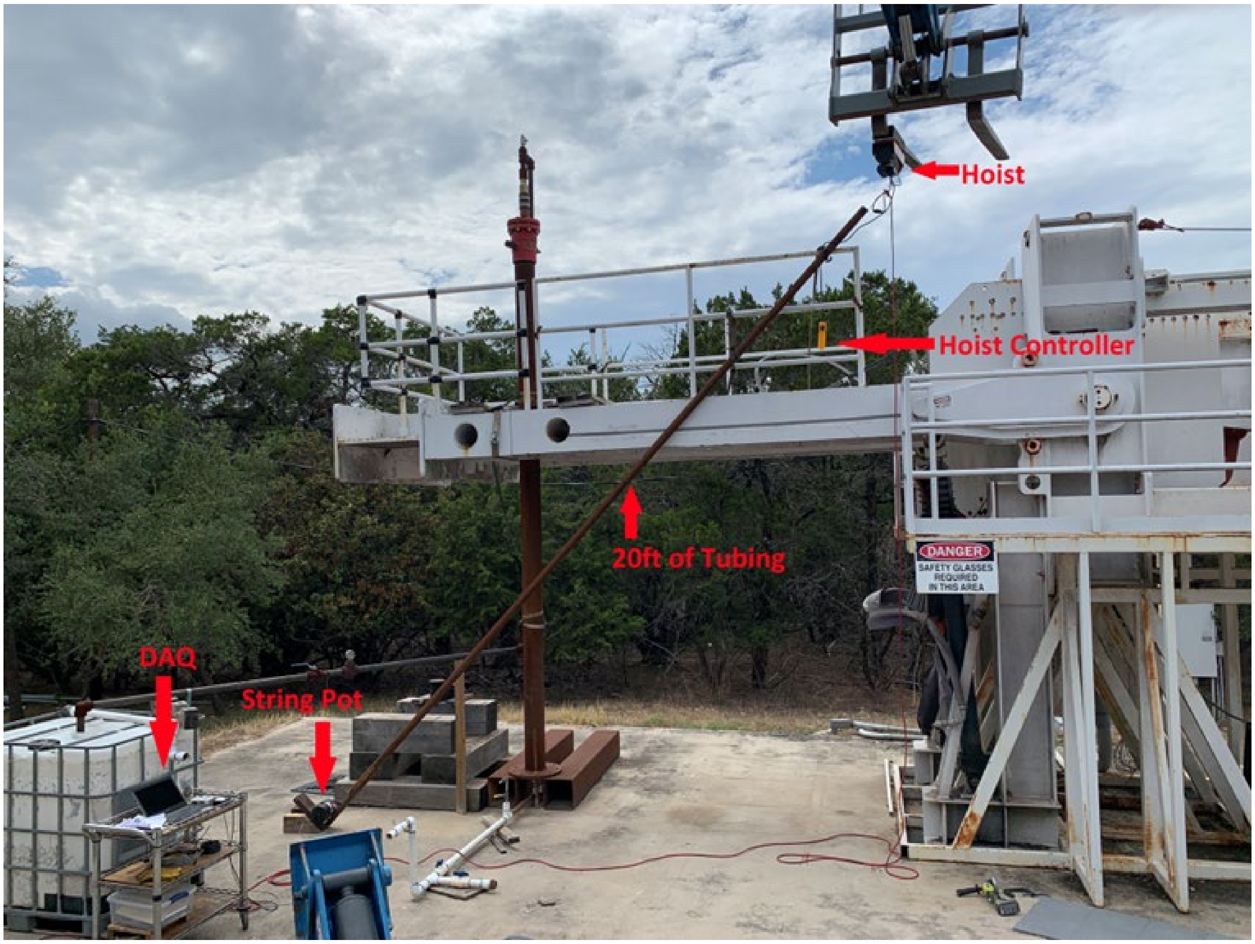

Figure 20 – ETA angled tubing test fixture that simulates deviated wellbores.

RESULTS

The ultimate goal of the HWDDDA project is to produce rod string position and load data sets from different depth in the wellbore. Therefore processing of the accelerometer data recorded by the tool is crucial.

The accelerometer data is integrated twice to determine position data. This is a tricky computation especially in a lab environment. Figures 16 and 17 show results of the integration of the accelerometer data from vertical and 45° tubing tests. The top graph is the output of the z-axis accelerometer reading (G), the second graph represents the x-axis and y-axis accelerometer reading (G), and the third graph shows the tilt of the tool (°). The post-processed acceleration (in./sec^2) is shown in fourth graph, the velocity (in./sec) is shown in the fifth graph, and the position (in.) is in the sixth graph.

3D position recording is essential in the lab and in the wells where the tools will be placed. As mentioned above, a string potentiometer was used during the tubing test to directly measure the movement of the tool. Ideally, the integrated position data should be an exact match for the potentiometer output. This is shown to be the case for both tests as can be seen in the bottom graph in Figures 16 and 17.

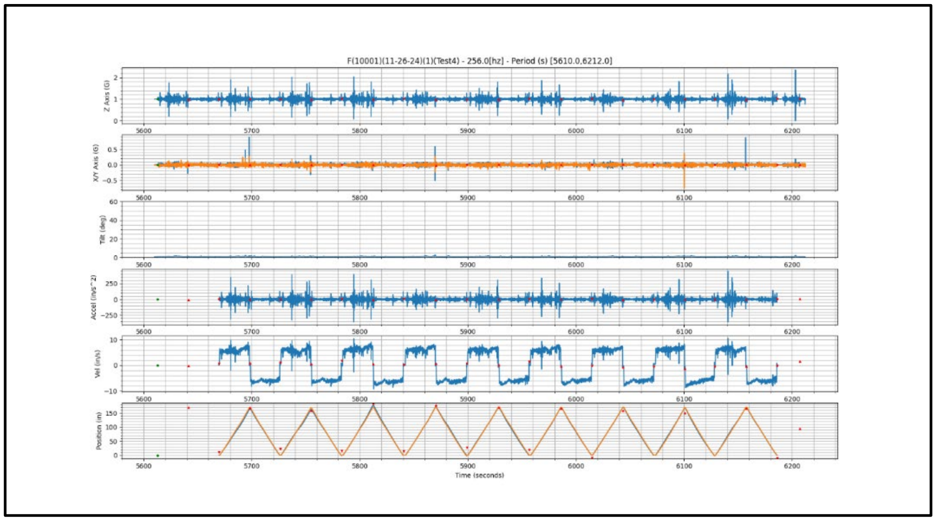

Figure 16 – Integration of acceleration data from the vertical tubing test. Position integrated from acceleration data is overlaid with output from string potentiometer reading (bottom traces).

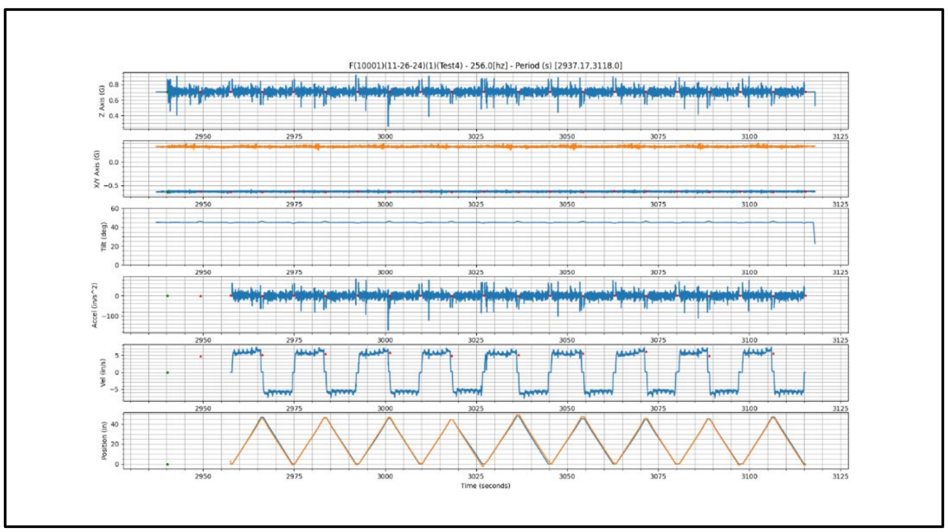

Figure 17 – Integration of acceleration data from 45° angled tubing test. Position integrated from acceleration data is overlaid with output from string potentiometer reading (bottom traces).

In Figure 17, some very slight differences can be seen in the sixth graph between the potentiometer reading (orange) and the integrated position data (blue). This is due to a slight tilting of the tool during the experiment.

Both the vertical and 45° angle tests were deemed successful and the tools were approved for the next phase of the project, which is live well testing as described below.

WELL TEST PLANS

The initial one-day field test near Wichita Falls, Texas with all three DHLCs installed beneath the polished rod in a well is scheduled for April 2025. The purpose of the test is to verify that the tools are working as commissioned. The three DHLCs will be installed in series inside the tubing of a pumping well below the stuffing box and directly attached to the bottom of the polished rod and will acquire data from all channels over an extended time. The acquired data will be compared with data acquired simultaneously at the surface of the well using industry standard dynamometer sensors installed on the carrier bar. Proper functioning of the DHLCs at wellbore conditions will be evaluated.

Downhole Measurements

The DHLCs are each approximately 5 ft in length and the three tools' assembly length will be equivalent to one 25 ft sucker rod as follows:

2 ft pony rod + 5 ft DHLC #1 + 2 ft pony rod + 5 ft DHLC #2 + 2 ft pony rod + 5 ft DHLC #3 + 4 ft pony rod = 25 ft

The 25 ft 3-DHLC assembly, when installed directly at the bottom of the polished rod, will substitute for the first 25 ft sucker rod at the top of the original rod string. Consequently, the plunger spacing at the pump will not be altered significantly.

Each DHLC will be programmed to have the same acquisition time schedule to collect simultaneous synced records.

Surface Measurements

Dynamometer and fluid level measurements will be made concurrently with the downhole measurements using an Echometer Wireless well analyzer system with TAM 1.9 release software. Measurements will include

1) Load and vertical acceleration data from a wireless 50,000 lbf load cell (WLC) installed on the carrier bar
2) Vertical acceleration and load data from a wireless polished rod transducer (WPRT) dynamometer
3) Tubing pressure, power, current, and voltage
4) Fluid levels every 5 min. during the test period

Echometer measurements will be automated using the RAM system programmed in synch with the downhole measurements.

Sequence of Operations

The following is a preliminary draft of the proposed procedures for the test:

1. Synchronize each DHLC clock with the clock in the laptop that will acquire the Echometer Wireless well analyzer data. The Tools will be synchronized within 1 second by plugging in each tool at the same time and starting the Echometer analyzer. The Tool-to-Tool synchronization can be verified by the light inside that blinks at 1 Hz for 1 minute. Once the tools are assembled with the pony rods on the surface, a small hammer will strike the end of the pony rod 5 times at 1 Hz to provide a more accurate synchronization before going down-hole.

2. Program the downhole tools to acquire data for two separate 1-hour acquisitions:

    a. Hour 1: Acquire at 64 Hz sampling using DHLC tool for 60 min. consecutive test. Simultaneously acquire WLC load data, WPRT dynamometer data, tubing pressure, and electrical power data at 60 Hz sampling plus fluid level records every 5 min. Within each 20 min. time interval the well will be OFF for the initial 2 min., ON for 5 min., a valve test will be performed for approximately 8 min., zero acceleration tests will be performed at three polished rod positions, and the pump will then stay ON until the end of the 20 min. period.

b. Hour 2: Acquire at 256 Hz sampling using DHLC tool for 60 min. consecutive test. Simultaneously acquire WLC load data, WPRT dynamometer data, tubing pressure, and electrical power data at 240 Hz sampling plus fluid level records every 5 min. Within each 20 min. time interval the well will be OFF for the initial 2 min., ON for 5 min., a valve test will be performed for approximately 8 min., zero acceleration tests will be performed at three polished rod positions, and the pump will then stay ON until the end of the 20 min. period.

Test Completion

After the test is completed, the DHLCs will be pulled from the well and the rod string returned to its original condition. ETA will download, process, and verify the DHLC data acquired. Echometer will verify the surface data acquired and provide an export file that can be analyzed with the TAM 1.9 application. The DHLC data plus the Echometer data will be shared in a downloadable compressed file.

Additional Field Tests

The current plan is to collect DHLC data on 10–15 total wells. Casing/tubing schematics or wellbore diagrams will be provided for test wells at least two weeks prior to performing any onsite work. It's preferable that DHLC candidate wells have measured surface dynamometer cards displaying excessive mechanical friction loads. A gyro survey will be acquired prior to running the DHLCs in such wells. The DHLCs will be placed in wellbore locations having 2°/100 ft or higher doglegs. The DHLCs will be placed above and below the dogleg.

Surface sensors will be configured to acquire measurements in sync with the DHLCs. Well information, oil and water production rate, gyro/deviation survey, wellbore schematic, etc. provided by the operator will be input to describe the well and used in calculations. Data collected at the well will be analyzed and a summary report of conditions during the acquisition will be provided. Echometer TAM Software will be used to acquire and display surface measured data. The surface data will be exported in the standard Echometer format and provided to the well operator and all members of the HWDDA project.

The data acquired from the DHLCs will be used to analyze mechanical forces applied to the rod string. These external forces impact measured surface loads, downhole stroke length, consumed horsepower, plunger velocity, and calculated rod loading at the pump and other locations along the rod string. Knowledge gained from running DHLCs in difficult wells could be the key to understanding and correctly modeling mechanical force applied to the rod string.

CONCLUSIONS

Measured data from the HWDDDA tools will provide a true, historically unseen picture of the tension, compression, side load, and drag forces acting on the rod element in a deviated wellbore. The data gathered in this project will be available to the Oil & Gas industry to improve pumping models from both a predictive and diagnostic point of view.

Better understanding and models translate into better control and optimization of rod-pumped installations, which result in fewer failures and longer equipment life.

The HWDDDA project needs additional sponsors—particularly operators willing to run the tools in their tortuous wells to increase the variety of wellbore geometries analyzed. If you are interested in participating in the project, please contact any of the authors.

REFERENCES

1. Gibbs, S.G.:" Method of Determining Sucker-Rod Pump Performance," U.S. Patent No. 3,343,409 (Sept. 26, 1967).

NOMENCLATURE

ALRDC = Artificial Lift Research and Development Council
API = American Petroleum Institute
DAS = Data Acquisition System
DHLC = Downhole Load Cell
HWDDDA = Horizontal Well Downhole Dynamometer Data Acquisition
NIST = National Institute of Standards and Technology
WLC = 50,000 lbf Wireless Load Cell
WPRT = Wireless Polished Rod Transducer