Horizontal Well Downhole Dynamometer Data Acquisition (HWDDDA)

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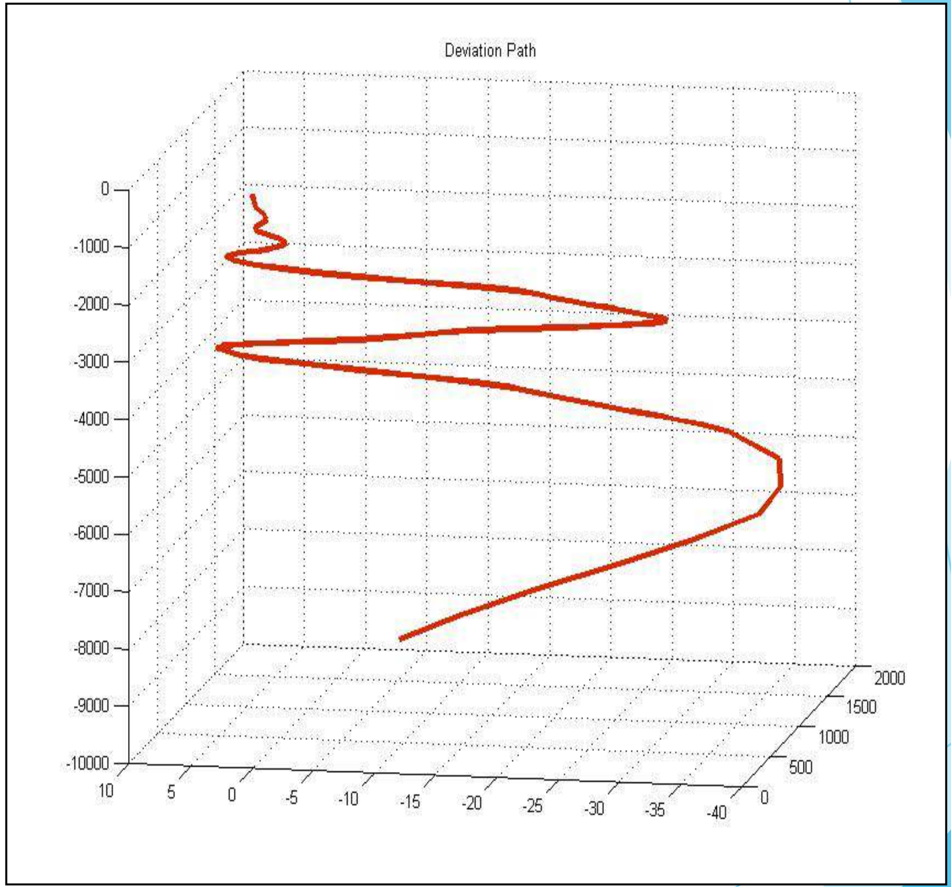
Artificial Lift R&D Council

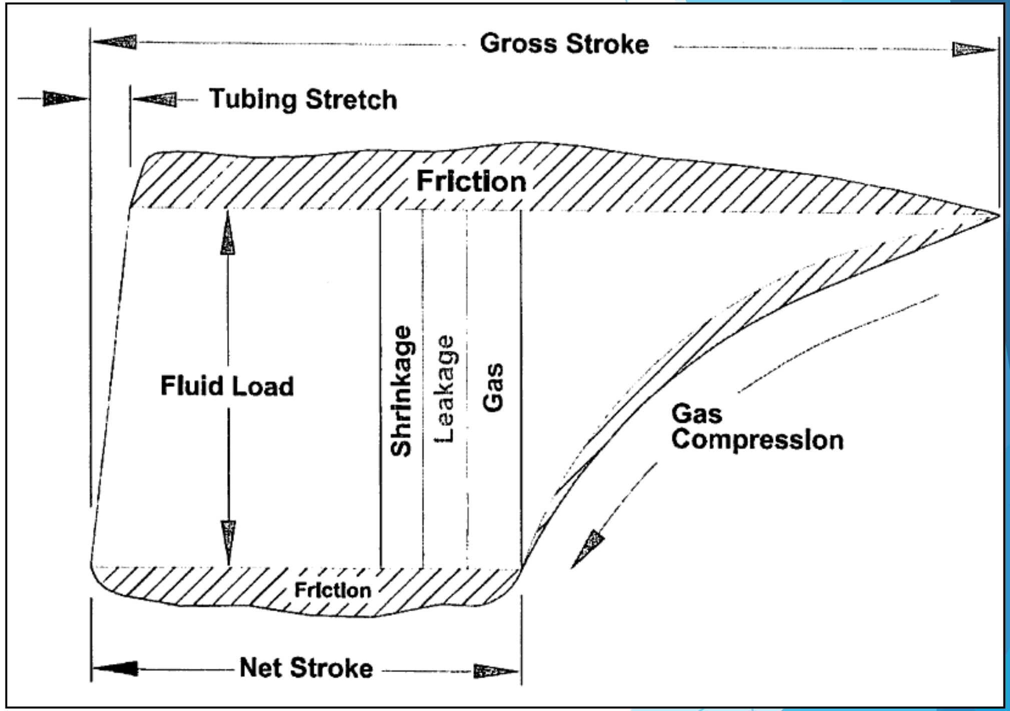
Project Goal & Overview

- Gather true measured data in both deviated & horizontal rod-pumped wells
- Plot actual downhole load & position: dynagraph cards
- Provide that measured downhole data to industry for use in developing new algorithms
- Improve our understanding of side loads, bending, friction, damping, and other factors resulting from well deviation

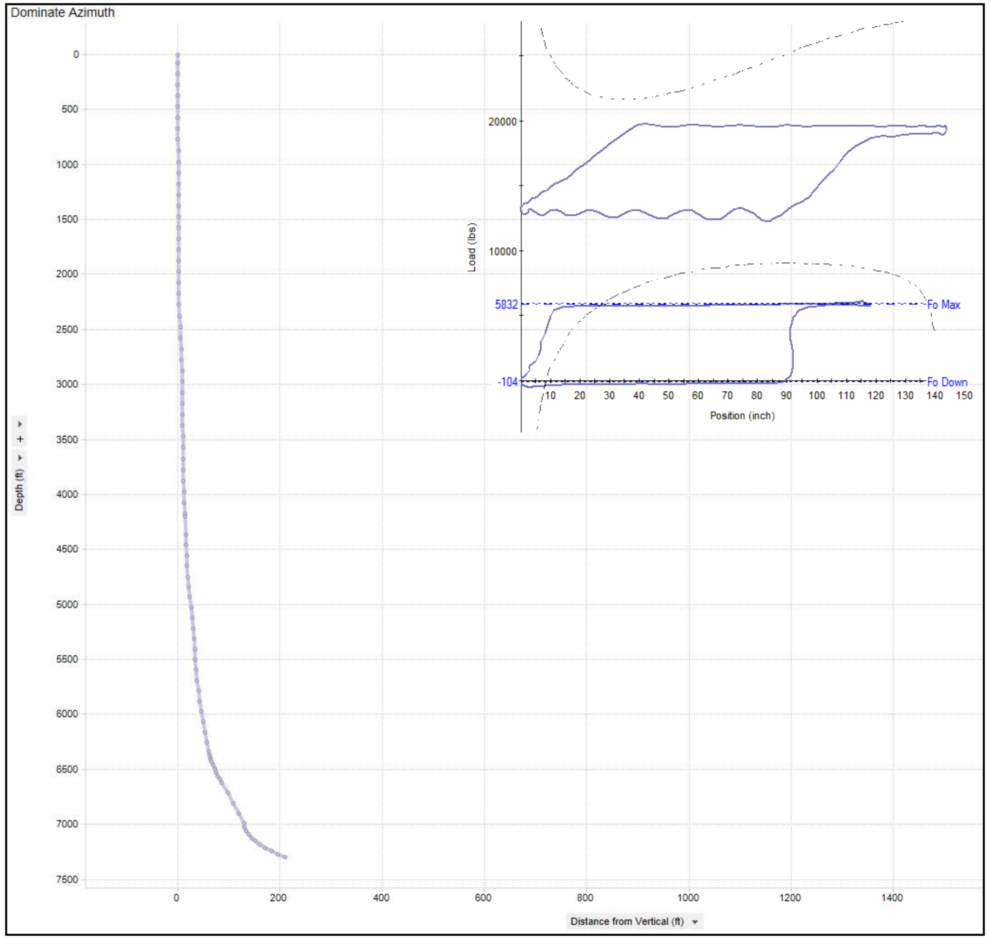


Rod Pump Diagnostics: Introduction

- Historically, the pump condition has been determined by dynamometer analysis
- A surface dynamometer measures position and load to generate a surface card
- The downhole card is calculated by solving the 1D wave equation (the surface card is projected downhole)
- The solution removes all dynamics in the surface card to show you the resulting work at the pump
- Since the rod string acts as a transmission line for the pump, any distortion in load signals result in poor downhole data resolution



Example 1: Vertical Wellbore



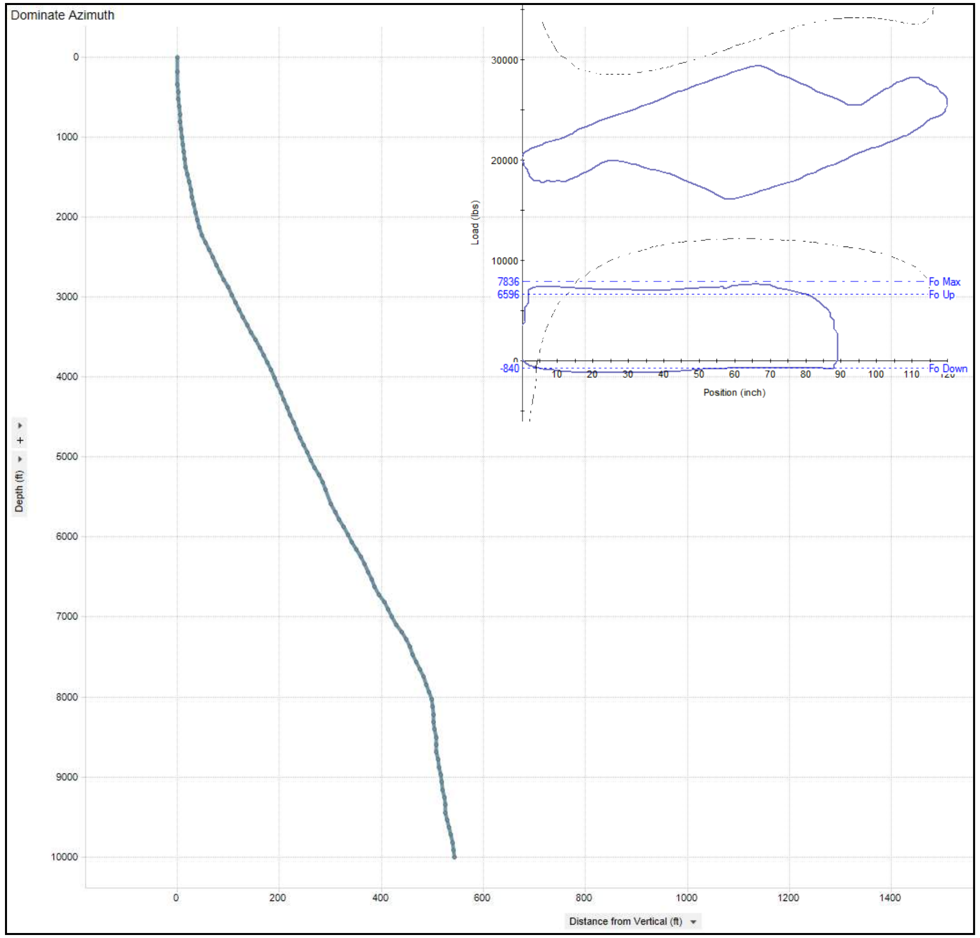
Calculations:

- Pump Intake Pressure
- Pump Efficiency
- Pump Displacement
- Rod Loading

Additional observations:

- Well is pumped off
- Tubing movement is apparent
- Confidence in original design: Pumping conditions can be duplicated by predictive software

Example 2: Deep Deviation



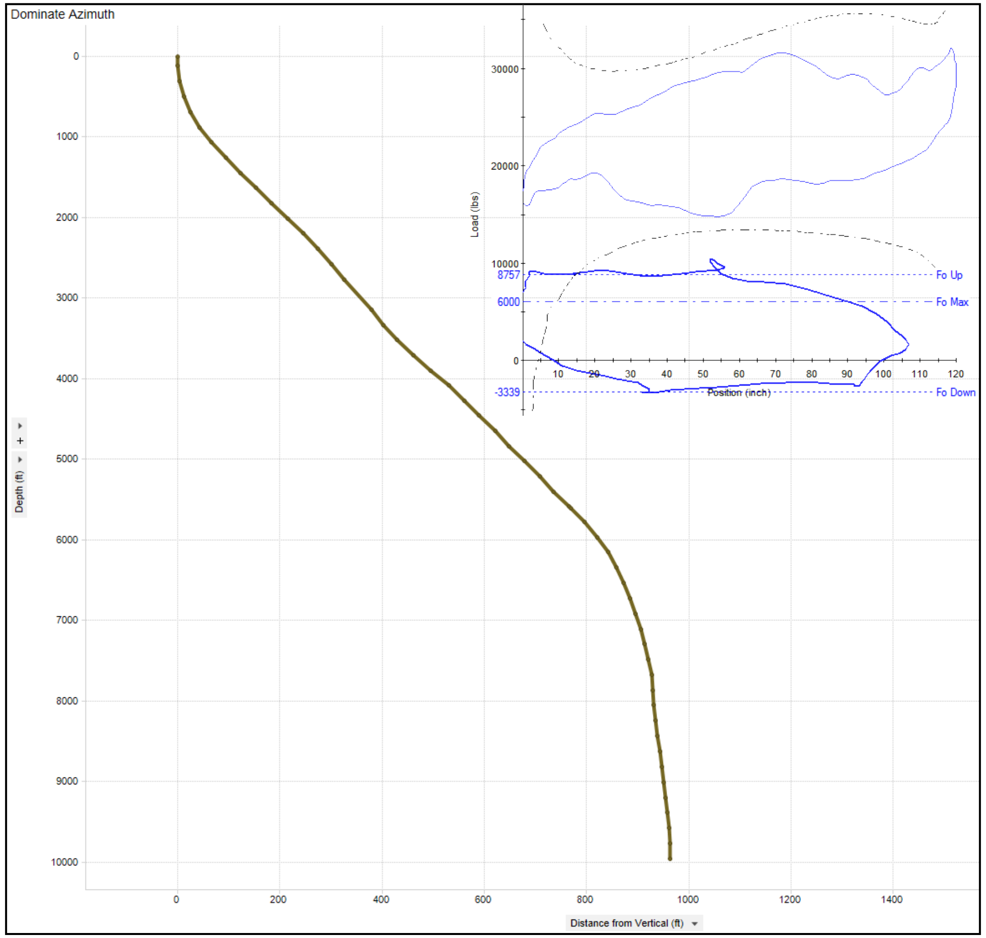
Calculations:

- Possibly Pump Intake Pressure
- Possibly Pump Efficiency
- Possibly Pump Displacement
- Possibly Rod Loading

Additional observations:

- Well is close to pumped off
- Confidence in original design: Pumping conditions can be (relatively) duplicated by predictive software

Example 3: Shallow Deviation



Calculations:

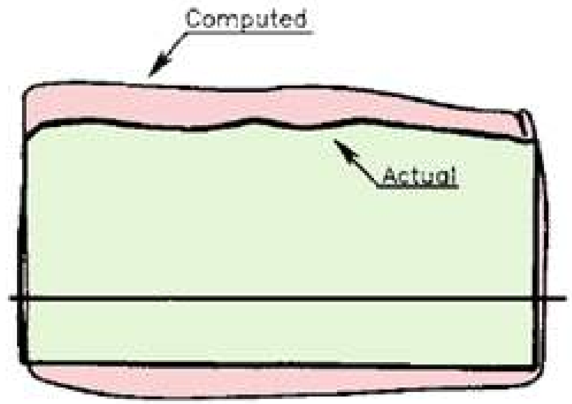
- No reliable downhole calculation available
- Both the Net Stroke and Fluid Load are distorted

Additional observations:

- Production is the only proxy for the condition of the pump
- Incomplete fillage calculations will not be reliable

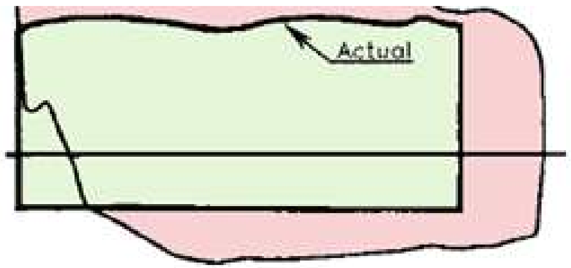
Rod Pump Diagnostics: Current Pitfalls

- The diagnostic solution to the 1D wave equation assumes all elastic deformation originates at the pump
  - Shallow friction distorts both Gross Stroke and Fluid Load
  - Deep deviation will tend to mostly affect Fluid Load
- The damping term of the wave equation is only meant to account for viscous forces, not mechanical friction
- Furthermore "…incorrect dynamometer data can give false indication of buckling anywhere in the string" - Gibbs



	Gross Stroke (in)	Load Range (lbf)
Computed	116.8	8860
Actual	114.5	6770

b) Deep Deviation



	Gross Stroke (in)	Load Range (lbf)
Computed	143.2	11242
Actual	120.4	6885

Project Overview: What is the HWDDDA

The Horizontal Well Downhole Dynamometer Data Acquisition Project (HWDDDA) has assembled operators and service companies together to solve this challenge

Project planning and tool design are both underway, but funding is needed for both tool manufacturing and testing

Project Members
Marathon
ALRDC
Echometer
WellWorx
Weatherford
Lufkin
Accutants LLC
Black Gold Pump
GyroData
DV8
Exxon Mobil

HWDDDA Project Structure & Overview

General Committee:

- Manage overall project
- Report progress to ALRDC R&D Committee

Business Sub-Committee:

- Define/manage budget and document project

Tool Design/Manufacturing Sub-Committee:

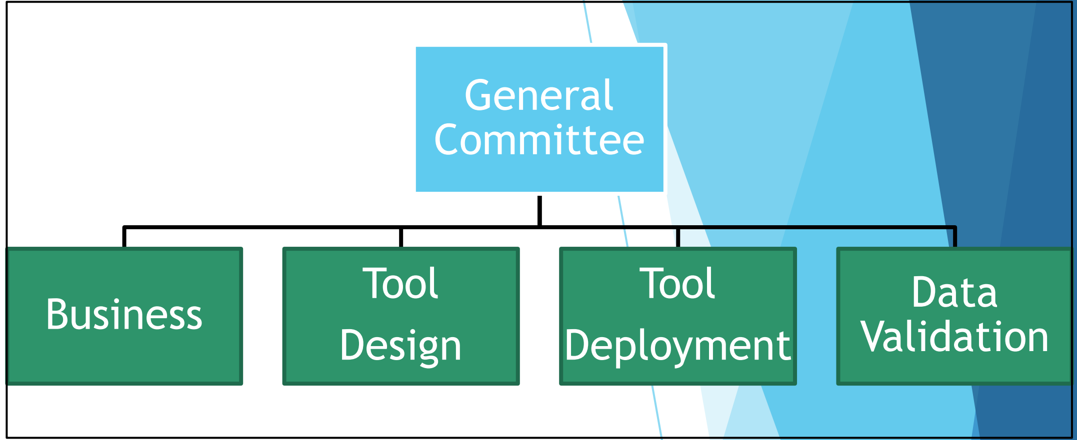
- Define tool specifications and tool testing requirements
- Select tool manufacturer

Tool Deployment/Retrieval Sub-Committee:

- Outline testing procedures and well selection criteria
- Gather data

Data Validation/Maintenance Sub-Committee:

- Validate data, build and maintain database



- ✓ Design & build downhole dynamometer tools
- ✓ Deploy those tools in deviated & horizontal wells and retrieve the tools, download the data
- ✓ Validate & maintain data in an accessible\published format

Historical Perspective - Sandia

GATHERED AND PUBLISHED DATA FROM MULTIPLE TEST WELLS

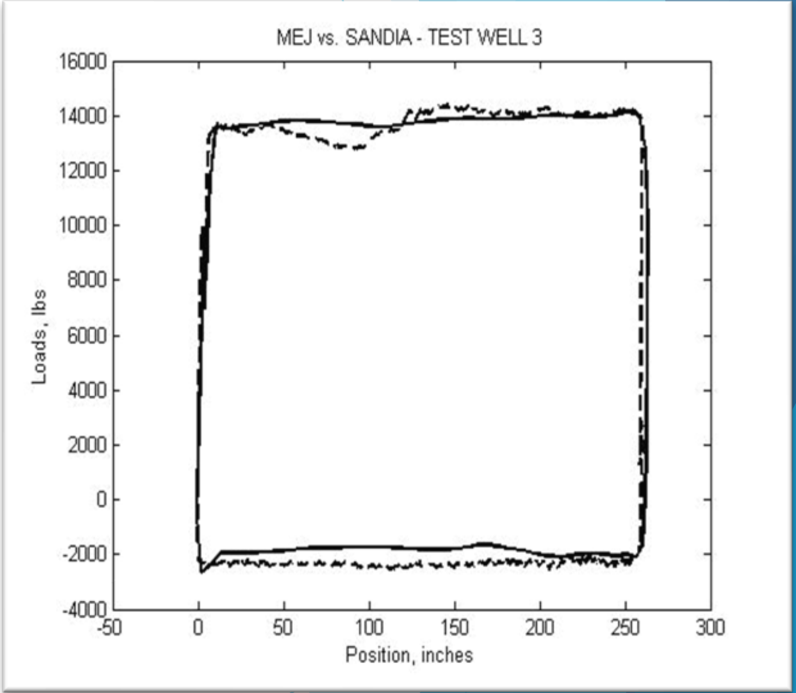
PROJECT OCCURED DURING A PERIOD OF LOW OIL PRICES

PROVED WAVE EQUATION METHODS ARE SOUND AND ACCURATE

BUT… THIS ONLY HOLDS FOR VERTICAL WELLS

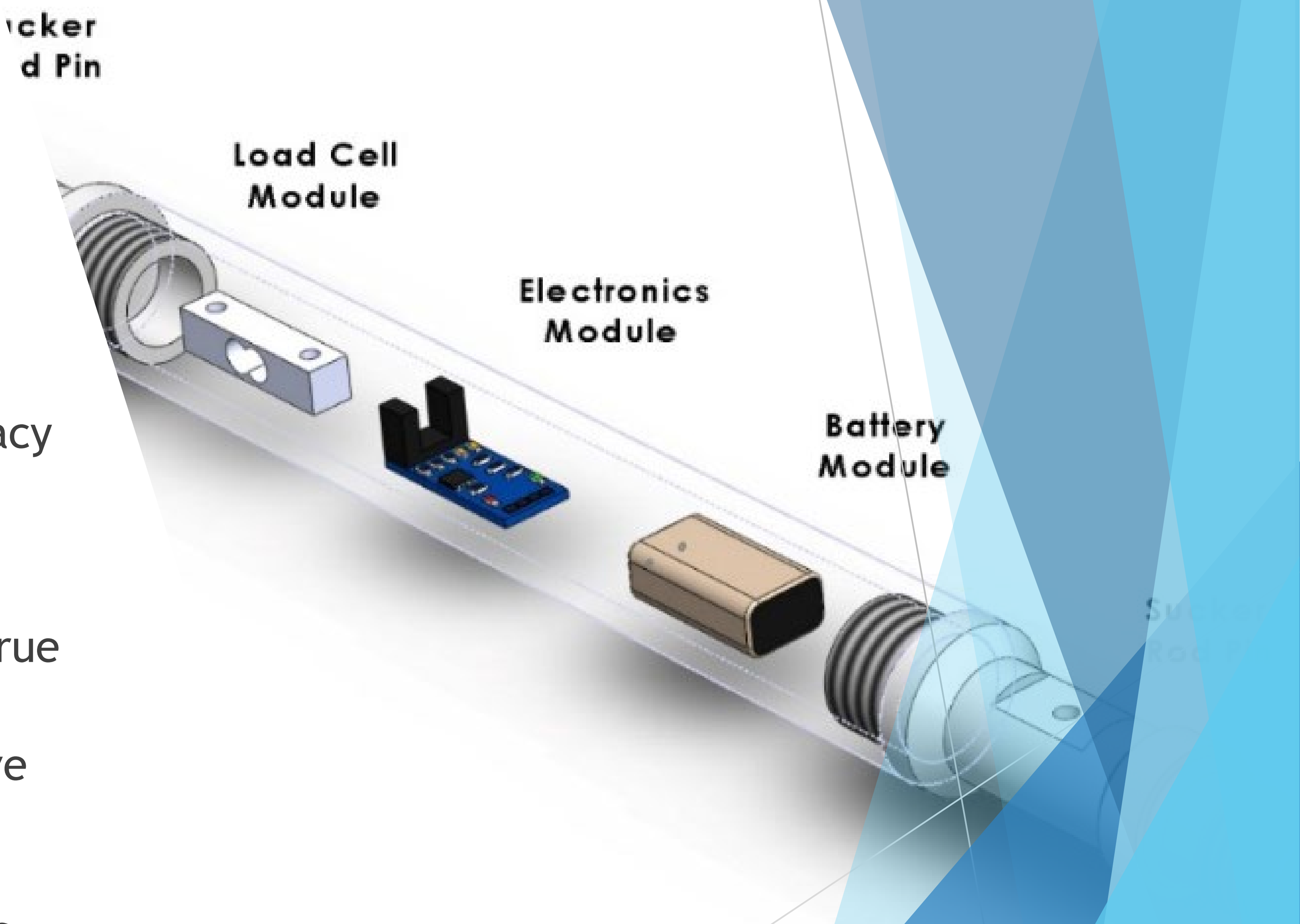
NUMBER OF WELL DRILLED SINCE 1995 (SANDIA)?

HOW MANY OF THOSE WELLS ARE STRAIGHT HOLES?



Project Overview: Tools

- Directly measured load and position data is required to validate and improve the accuracy of the existing software for deviated wells
- A new generation of downhole sensors are required to gather true measured forces and stresses
- This data will be used to improve design software for rod systems
- Participants in the project will have first access to data, results, and developed tools



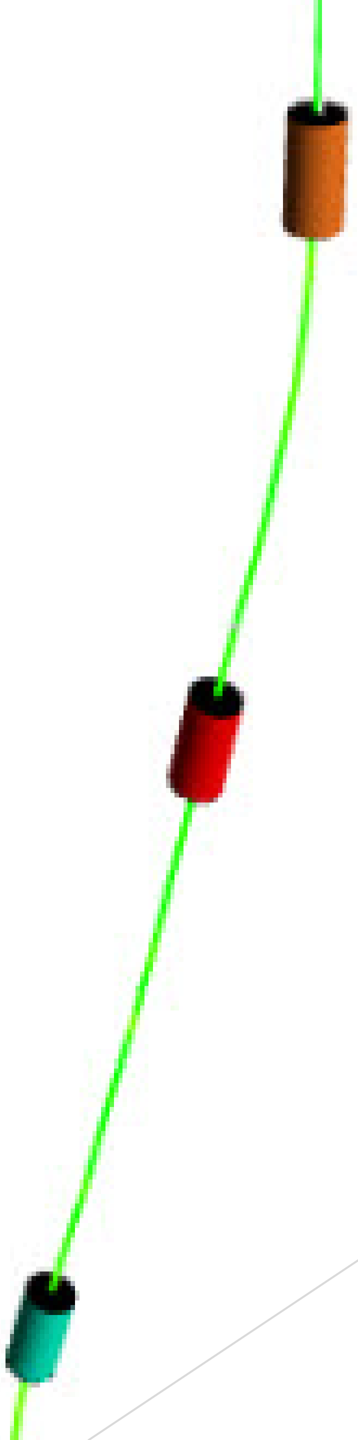
Tool Specifications

Placed along the rod string, tools store data on-board

- Location and number of tools determined by well profile (approximately 5 tools per well)

Sensors:

- Synchronized clocks – for correlating data across multiple tools
- 3 axis accelerometer – position & relative gravity vector
- Multiple load cells – linear loading, plus bending and compression
- Pressure, temperature, vibration, etc.



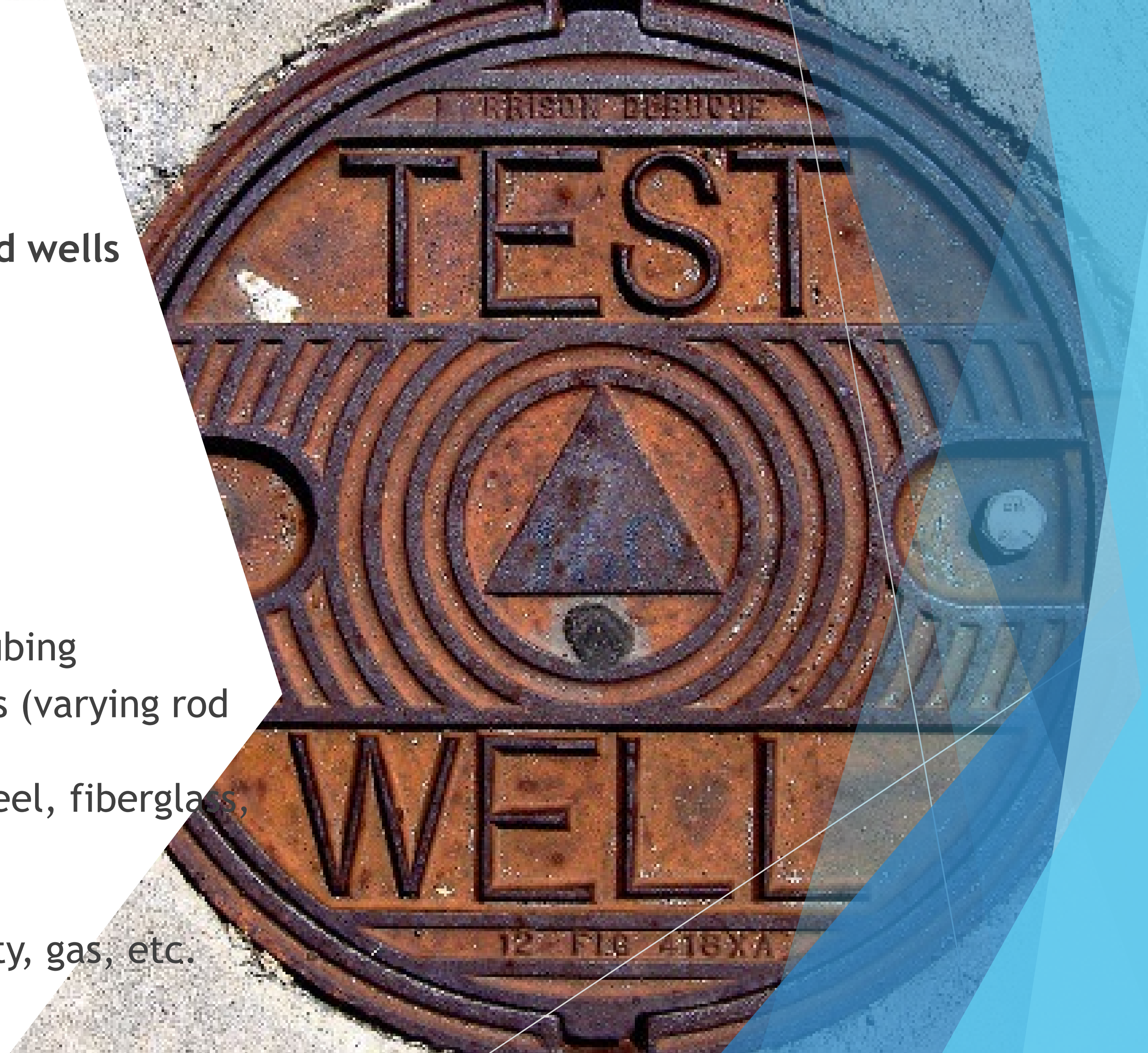
Test Wells

All distinct categories of deviated wells

- Vertical (for control test)
- Deviated
- Slant
- Horizontal

Testing Criteria

- Test at different SPM
- Anchored vs. unanchored tubing
- Rod guides vs. no rod guides (varying rod guides placement)
- Rod string configuration (steel, fiberglass, sinker bars)
- Depth of kick off point
- Fluid properties i.e. viscosity, gas, etc.



Project Overview: Test Scenarios

Pump Considerations:

- Fluid Pound
- Gas Compression

Operational Considerations:

- Vary SPM
- Vary Stroke Length
- Vary Inter-stroke Speed (proxy for pumping unit geometry testing)
- Valve Checks (PIP calculations)

Design Considerations:

- Point of Initial Deviation
- Sinker Bar Length/OD
- Taper % (87, 86, etc.)
- Specialty Pumps
- Guiding

HWDDDA First Prototype Update

- First prototype build was deemed not acceptable by TDM Sub-Committee after field testing
- Problems with tools:
  - Strain gauges leads needed to be cut each time battery was re-charged or replaced
  - Load signal outside of specifications
  - Acceleration signal could not be integrated consistently
  - Pressure resolution was outside of specifications
  - Temperature recorded was board temperature not external temperature
- Many lessons learned
- Firm understanding of what we want and don’t want in next generation prototype
- Current Status: Change of Manufacturer in process

US011021946B2

(12) **United States Patent**
Puls et al.

(10) **Patent No.: US 11,021,946 B2**
(45) **Date of Patent: Jun. 1, 2021**

(54) **SYSTEMS AND METHODS FOR MEASURING LOADS APPLIED TO DOWNHOLE STRUCTURES**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 298 days.

(21) Appl. No.: **16/046,782**

(22) Filed: **Jul. 26, 2018**

(65) **Prior Publication Data**

US 2019/0032471 A1 Jan. 31, 2019

Related U.S. Application Data

(60) Provisional application No. 62/538,294, filed on Jul. 28, 2017.

(51) **Int. Cl.**

E21B 49/00	(2006.01)
E21B 47/009	(2012.01)
E21B 43/12	(2006.01)
E21B 17/10	(2006.01)
G01L 5/00	(2006.01)

(52) **U.S. Cl.**
CPC *E21B 47/009* (2020.05); *E21B 17/1078* (2013.01); *E21B 43/127* (2013.01); *G01L 5/0033* (2013.01); *G01L 5/0085* (2013.01)

(58) **Field of Classification Search**
CPC .. E21B 17/1078; E21B 43/127; E21B 47/009; G01L 5/0033; G01L 5/0085
See application file for complete search history.

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(Continued)

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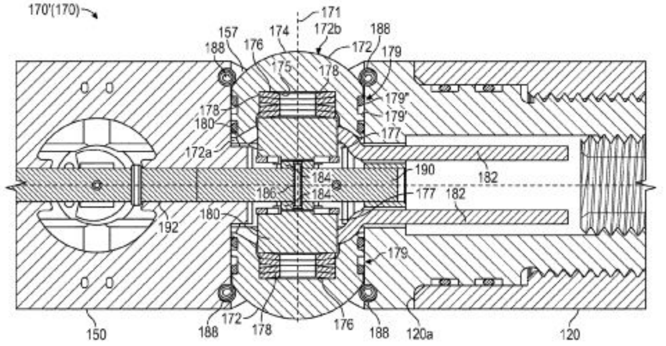
(57) **ABSTRACT**

A load measurement sub for measuring a load transferred between the sub and an inner surface of a tubing string includes a housing. The housing includes a central axis, an internal cavity, and a radially outermost surface. In addition, the load measurement sub includes a first load measurement assembly at least partially disposed within a first port extending from the radially outermost surface to the internal cavity. The first load measurement assembly includes a first button extending radially from the first port and the radially outermost surface of the housing. The first load measurement assembly also includes a first load cell. Further, the load measurement sub includes a first biasing member disposed between the first button and the first load cell. The first biasing member is configured to bias the first button away from the first load cell.

14 Claims, 11 Drawing Sheets



EOG Tools

- EOG donated 3 downhole tools for the project: 2 tension/compression & temperature tools and 1 tension/compression, side load and temperature tools
- Tension tools - ready for deployment
- Side load tool need refurbishing of essential side load (eroded buttons) and electronic components (load cell calibration)
- Refurbishment costs ~$35,000
- ETA – 2-3 months
- EOG asks for data in return for using their tools

HWDDDA vs. EOG tools comparison

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Feature	Units	HWDDDA	EOG
Axial/Bending Loads	lbf	4 strain gauges load cell	N/A
Tension	lbs.	N/A	1 tension load cell
Side Loads	lbs.	N/A	4 load cells with buttons
Stroke Position	inches	3 axis accelerometers	N/A
Lateral Acceleration	G's		
Fluid pressure	psig	Ported	N/A
Temperature	°F	Fluid temperature	Fluid temperature
Diameter	inches	1.5-1.75	2.0
Temp rating	°F	300	265
Sampling rate	Hz	60-200	20
Memory	Bytes	24 hrs @ 200Hz	168 mB
Channels	bit	16	16
Load rating	lbf	36,000	37,000
Pressure Rating	Psi	10,000	5,000

Industry Support

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- Developing & manufacturing downhole electronics is an essential part of this project
  - Need industry financing
- Need deviated & horizontal test wells
  - Wells & workover resources to be provided by Operating Companies
  - Data will be stored on the tools, which will require pulling the well
- Data validation and maintenance
  - Need funds to build and maintain software

We need you !

- Develop testing procedures
- Participate in tool & data specifications to be implemented by the operations group
- Provide resources and funding
- Identify & allow access to test wells
- Participate in testing
- Get early access to data and tools

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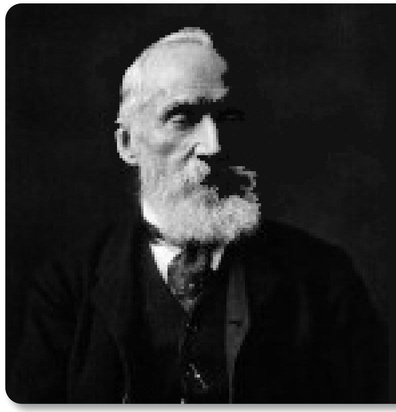
Conclusions

Improved downhole models can result in substantial reductions in operational expenses

Better decisions and well designs

Gathering real-world data is a first & significant step

We can't eliminate downhole friction, but we should be able to design and control around it, once better understood



"to measure is to know – if you cannot measure it, you cannot improve it"
– Lord Kelvin

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