The Effects of Fluid “Shock” on the Efficiencies of Milling Composite Bridge Plugs

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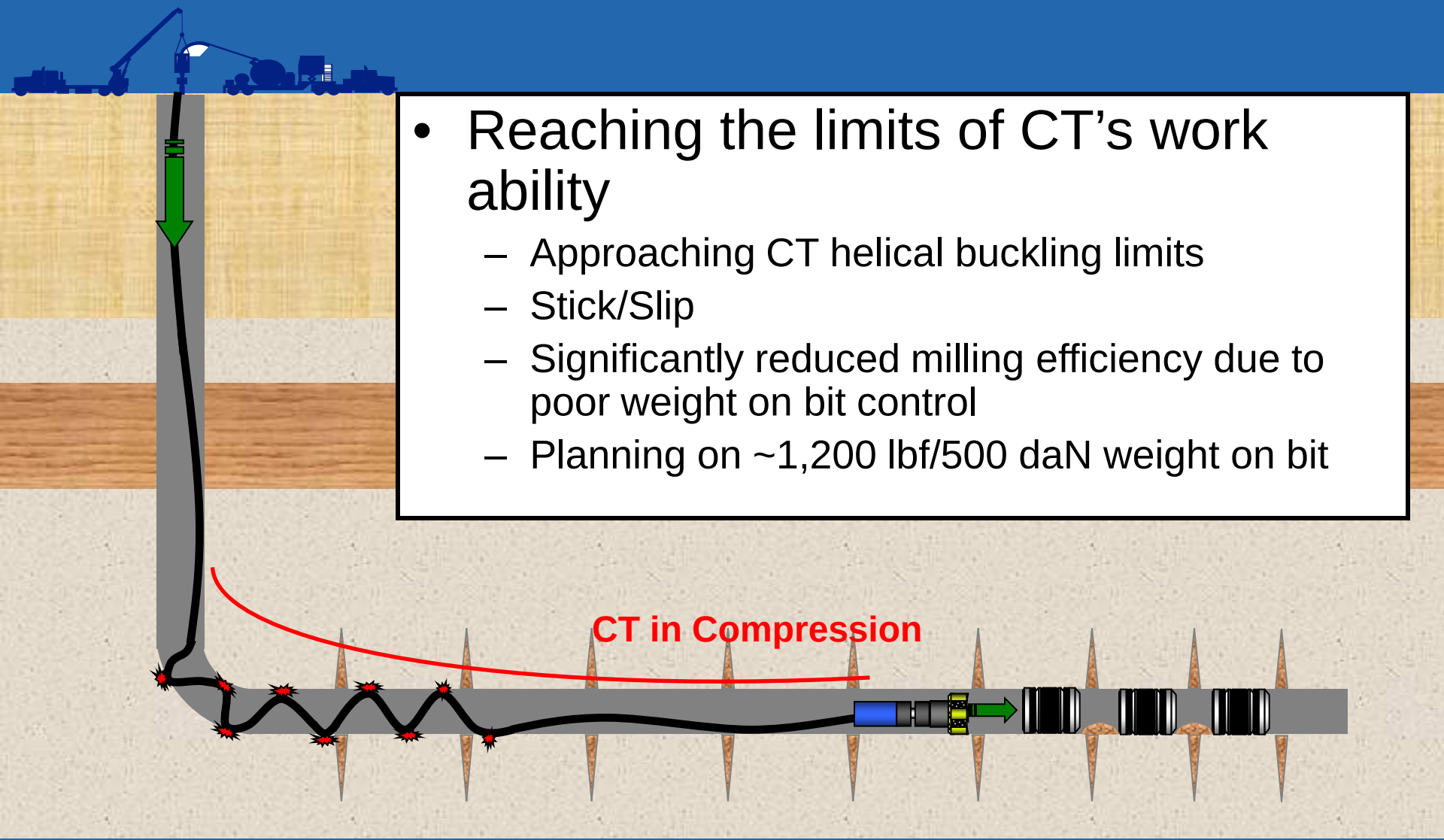
Composite Plug Milling

- Most common CT operation in USA
  - Approximately 140,000 plugs installed in 2010
  - Over 9,000 associated CT jobs
- Typically 2” CT Unit
  - 2 ⅞” or 3 ⅜” PDM
  - Mill or Bit
- Typical completions
  - 4 ½”, 5” or 5 ½”
  - Lateral reach ~ mostly 4,000 to 5,000 ft (1,200 to 1,500 m)
- Operational efficiencies reduce with reach
  - Lower weight on bit

Milling Efficiencies in Extended Reach

- Reaching the limits of CT's work ability
  - Approaching CT helical buckling limits
  - Stick/Slip
  - Significantly reduced milling efficiency due to poor weight on bit control
  - Planning on ~1,200 lbf/500 daN weight on bit



Extending Reach Options

- Coiled Tubing Size
  - Larger the pipe, the further we can go before onset of buckling
- 2 ⅜” OD Coiled Tubing
  - Reduced fatigue life, logistical challenges
- Reduced Drag/Friction
  - Metal-to-Metal Lubricants
  - Beads
- Lubricants
  - Significant volumes to reduce friction by 15-20%
  - Limited benefits observed when debris present

Extended Reach Options

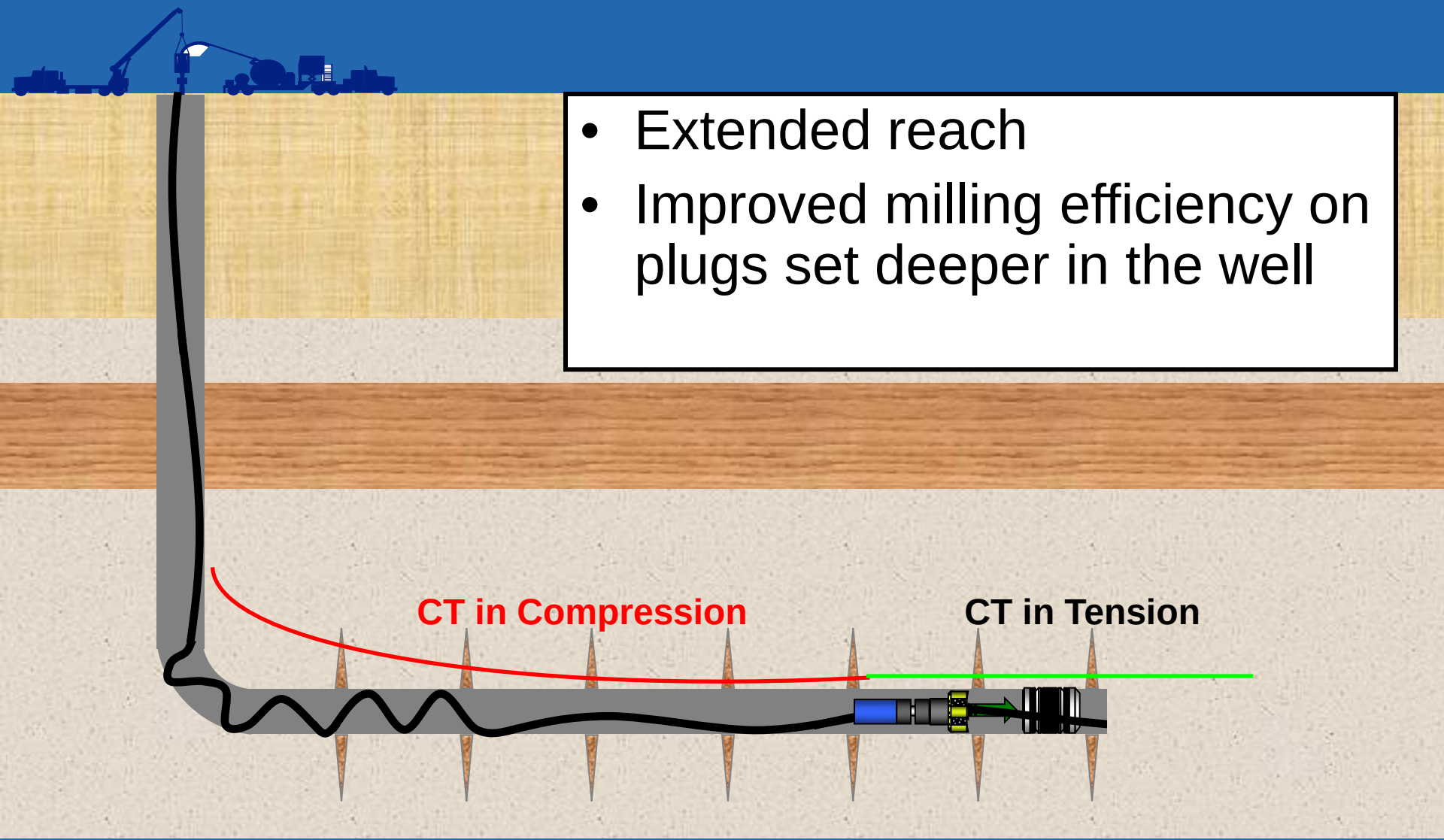
- Tractors
  - Provide tensile force at BHA
  - Increased BHA length, reduced RIH speed
  - Smooth control of weight on bit?
- Vibration/Water Hammer
  - Provide tensile load along the CT
  - For several years, most commonly used assistance method in US

Functionality of Water Hammer Tool

- Tool that temporarily restricts fluid flow to the lower BHA
  - Repeated multiple times per second
- This creates a pressure build up then release
- Resulting in a shock/pulse that is transmitted back up the coiled tubing
  - Pressure pulse negatively impacted with two phase flow

Physical Results of Water Hammer Tools

- Extended reach
- Improved milling efficiency on plugs set deeper in the well



Objectives for Field Study

- Analysis from three different water hammer tools used in 11 wells
  - Results compared to 9 well operations conducted without a hammer tool
- Calculate friction and net tensile benefit
- Calculate milling efficiency
- Other pertinent variables
  - Number of plugs milled per wiper (short) trip
  - Wiper trip speed

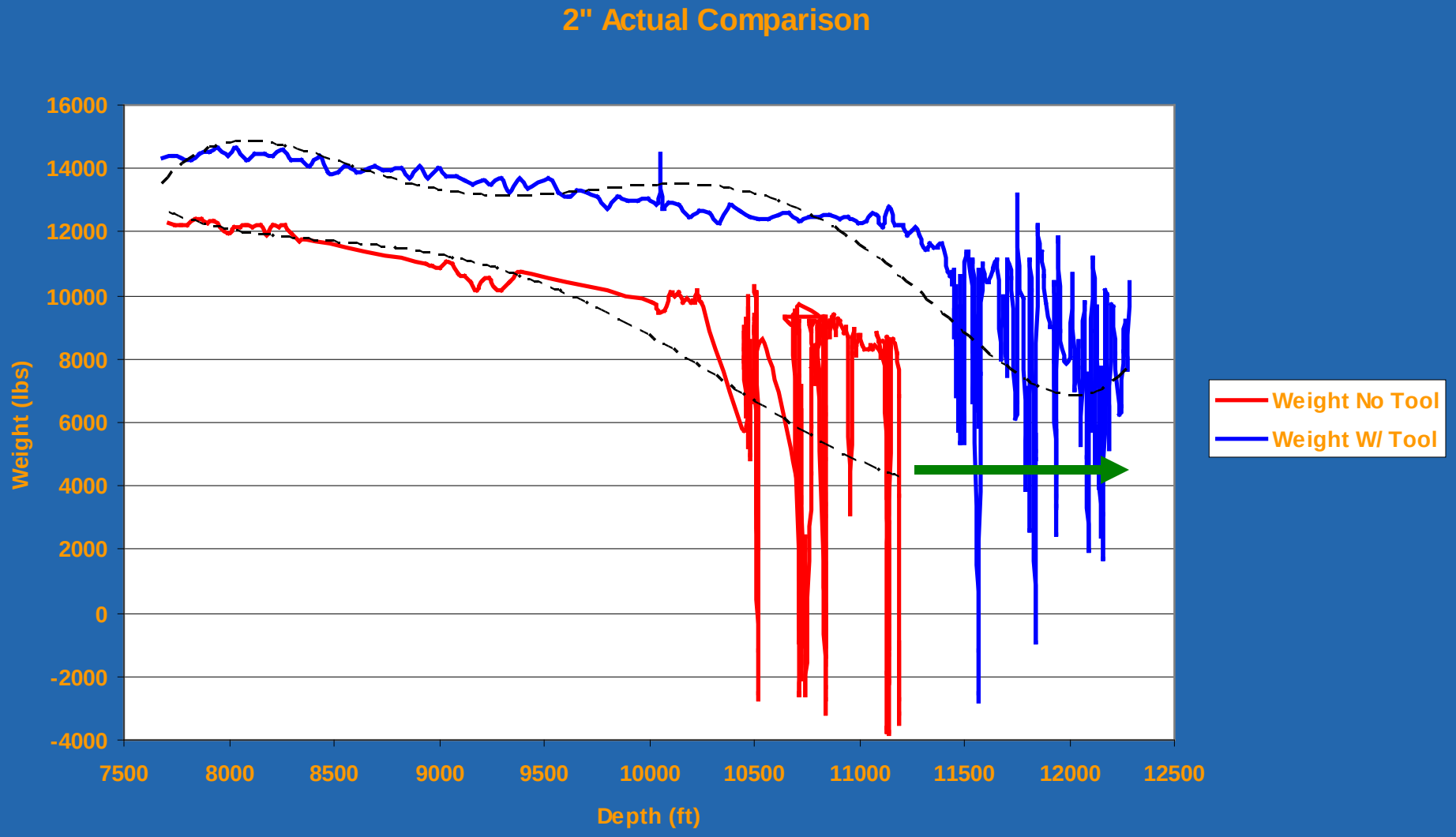
Data Set

- Common to Study
  - CT Supplier
  - CT data acquisition
  - Force analysis software
  - Personnel reviewing the results
- Variables in Study
  - BHA supplier
  - Type of mill or bit
  - Composite plug type
  - Client and location
  - Completion size
  - Personnel
    - CT operator
    - Company rep
    - Motor hand

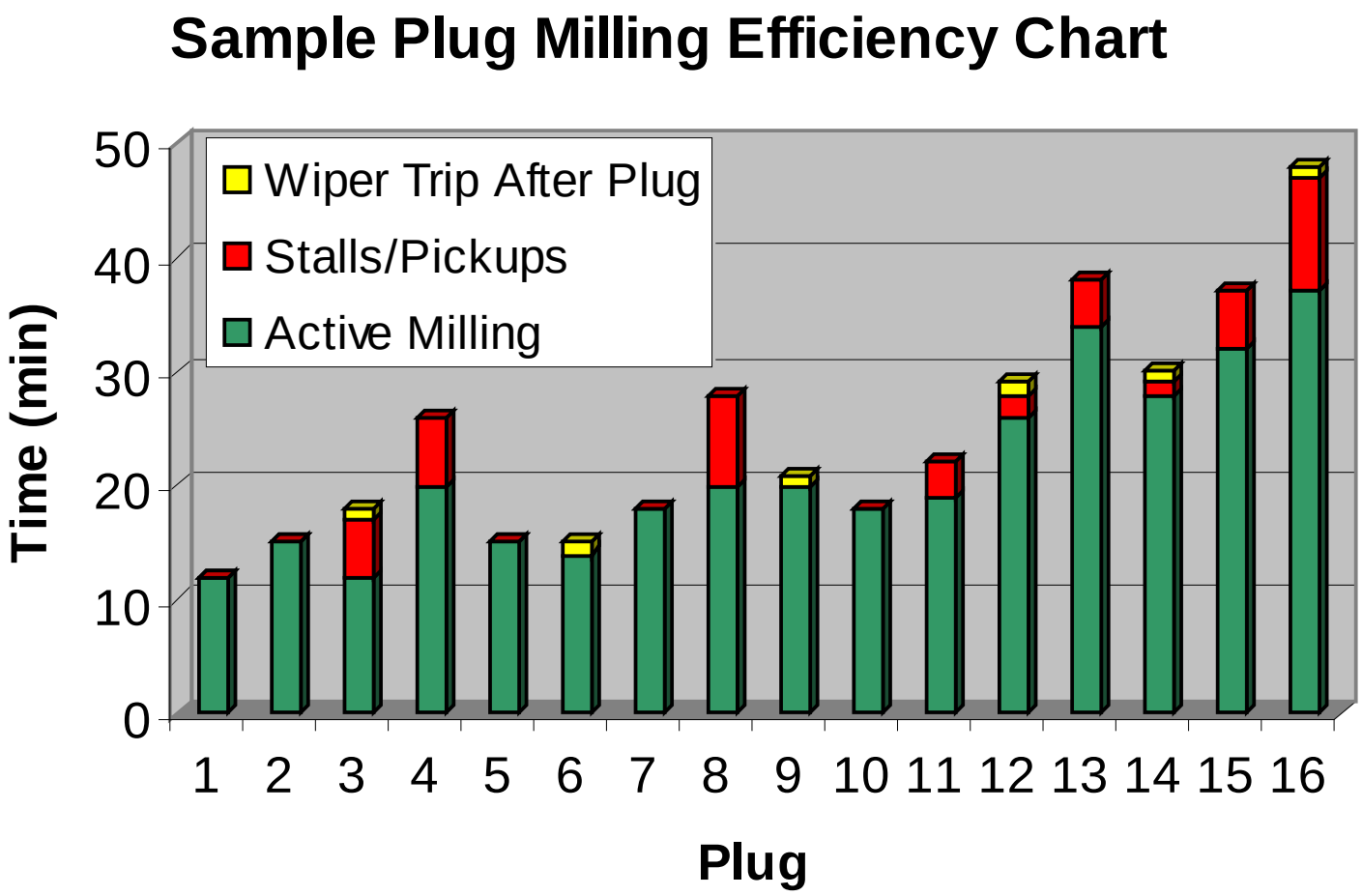
Method of Analysis

- Force Analysis
  - Perform force matching to determine coefficient of friction and
  - Calculate the associated tensile load created by each water hammer tool
- Milling Efficiency
  - Review milling time for each plug
  - Confirm efficiency by removing any NPT from motor stalls, resetting the tool etc

Tensile Benefits



Sample Of Milling Efficiency



Results – No Hammer Tool
9 Wells in 3 States

- Force Analysis
  - 6 wells 0.24 coefficient of friction, 3 wells 0.19 – 0.22, lubricants used in 8 of 9 wells
  - No tensile benefits observed (no hammer tools)
- Plug Milling Efficiency
  - 93 plugs milled
  - Average milling time 37.95 mins
  - Average active milling time 30.78 mins
  - Efficiency 81.1%
- Other Data
  - Wiper trips ever 2.2 plugs at speeds of 35-45 ft/min/10-14 m/min
  - Some speeds in excess of 60 ft/min / 18 m/min
  - Lateral lengths 3,500 ft to 5,500 ft/1,000 m to 1,400 m

Results – Hammer Tool A
5 Wells in 2 States

- Force Analysis
  - 4 wells 0.24 coefficient of friction, 1 wells 0.16 lubricants used in 2 of 5 wells
  - No tensile benefits observed
- Plug Milling Efficiency
  - 33 plugs milled
  - Average milling time 41.27 mins
  - Average active milling time 32.97 mins
  - Efficiency 79.9%
- Other Data
  - Wiper trips ever 2.2 plugs at speeds of 45-75 ft/min / 14-23 m/min
    - Stuck in hole issues
  - Circulation rate too low for effective use ?

Results – Hammer Tool B
3 Wells in 1 States

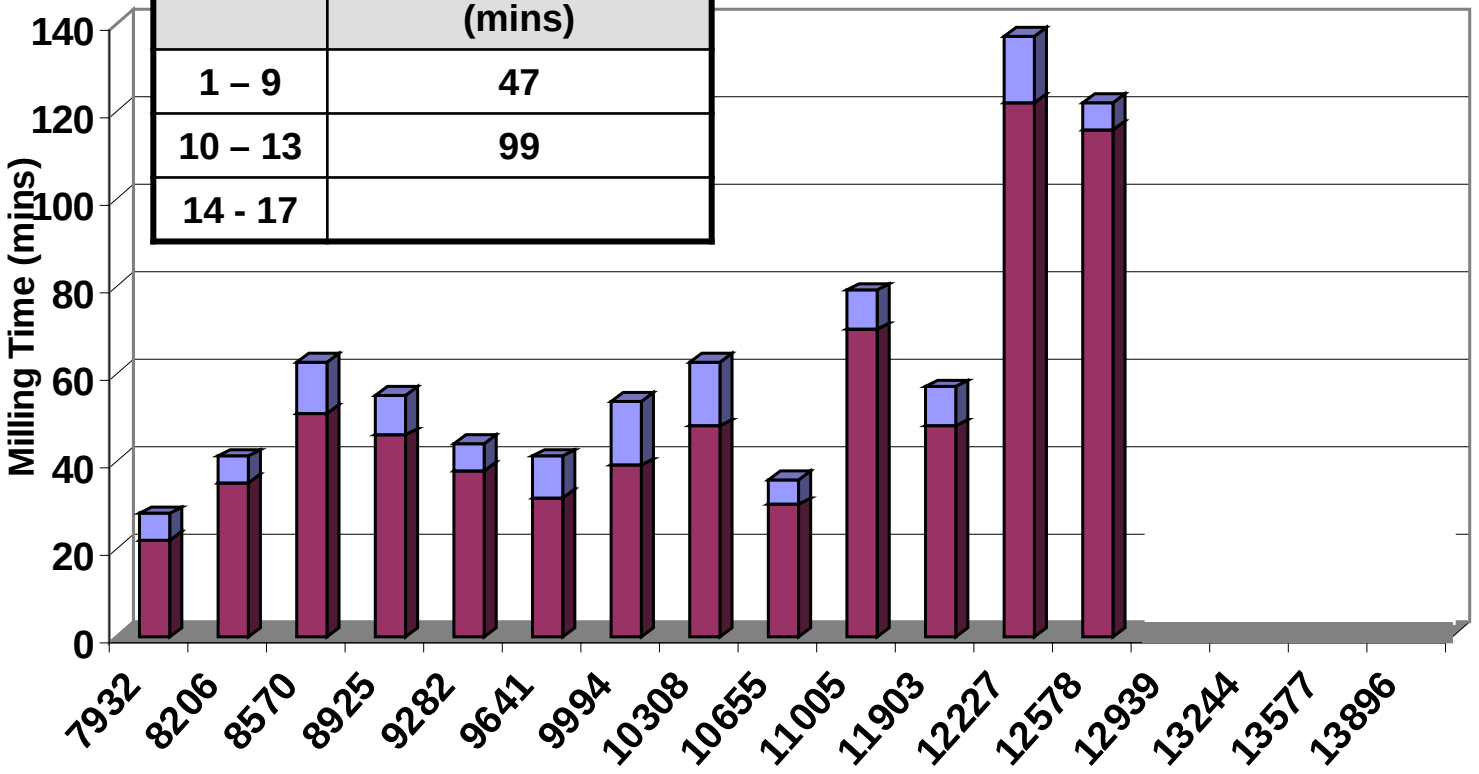
- Force Analysis
  - 3 wells 0.24 coefficient of friction, lubricants
  - No tensile benefits observed – significant debris in well working against reach
- Plug Milling Efficiency
  - 20 plugs milled
  - Average milling time 91.45 mins
  - Average active milling time 80.4 mins
  - Efficiency 87.9%
- Other Data
  - Wiper trips ever 2.3 plugs at speeds of 35-45 ft/min/10-14 m/min
  - One well exhibited very poor milling times from plug one, resulting in extreme milling times
  - Lateral lengths approx 4,000 ft/1,200 m

Results – Hammer Tool C
3 Wells in 1 States

- Force Analysis
  - 3 wells 0.24 coefficient of friction, no lubricants
  - 1,200 to 1,400 lbs tensile benefit observed
- Plug Milling Efficiency
  - 18 plugs milled
  - Average milling time 25 mins
  - Average active milling time 22.2 mins
  - Efficiency 88.9%
- Other Data
  - Wiper trips ever 2.3 plugs at speeds of 35-45 ft/min / 10-14 m/min
  - Most positive tensile benefits seen
  - Lateral length 4,700 to 5,800 ft / 1,400 to 1,750 m

Results Comparison Well

Plugs	Avg Milling Time (mins)
1 – 9	47
10 – 13	99
14 - 17	



Use of Water Hammer Tools Conclusions

- On correctly planned and executed operations, water hammers have reduced average plug milling times
- On incorrectly planned and executed operations no hammer tool benefits were observed
- Achievable lateral depths for efficient plug milling can be increased
- Recording and calculating milling times and force analysis promotes an engineered approach to operational planning

Reference

- SPE 147158 ‘The Effects of Fluid Hammer Tools on the Efficiencies of Coiled Tubing Plug Milling – A Comparative Best Practices Study’
- SPE ATC Denver 2011

Questions?

Thank you to ICoTA Canada for the opportunity to present today

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