Optimising Hydraulic Energy to Dramatically Improve Lateral Reach

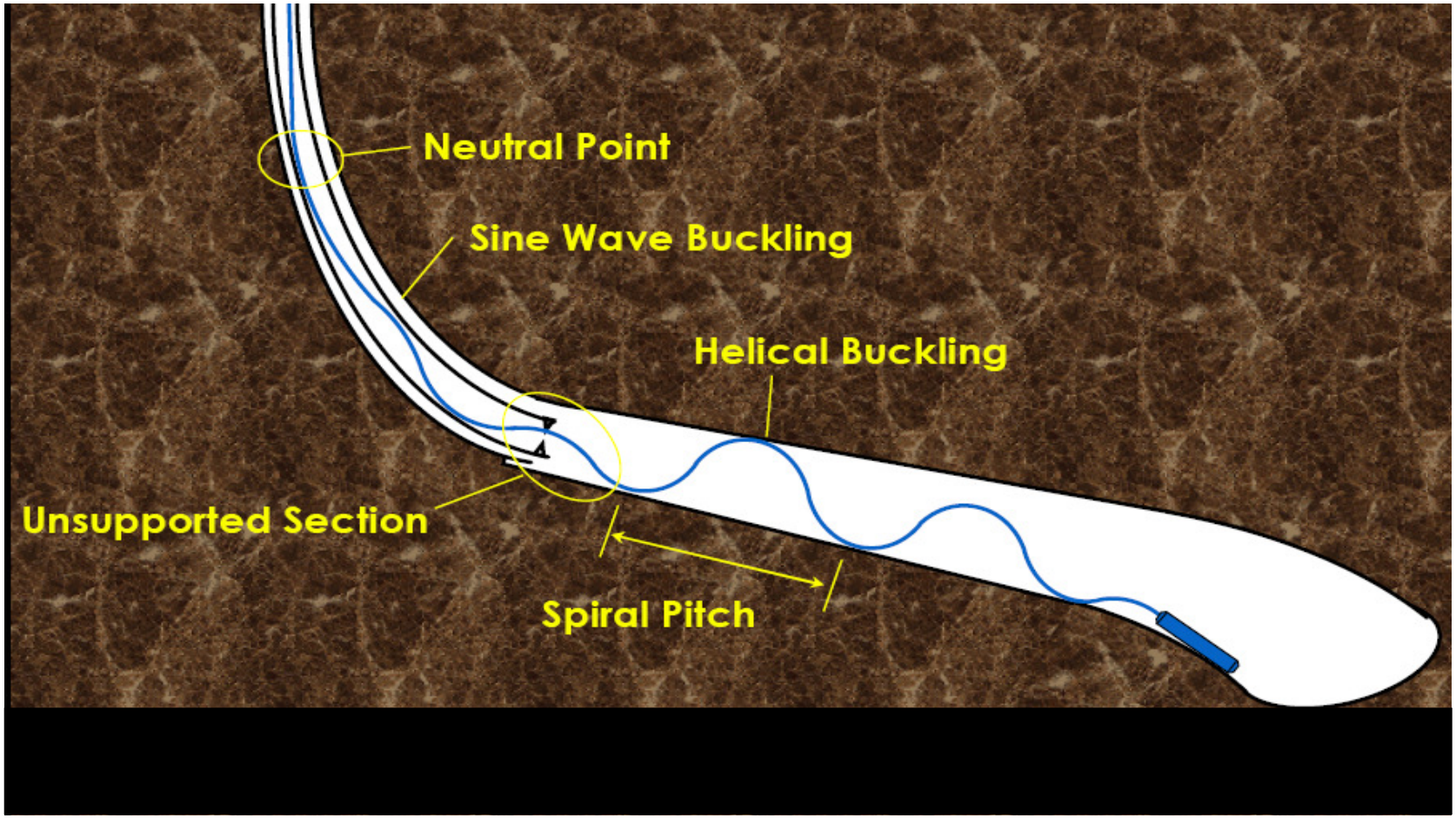
What Affects Reach?

- Build angle
- Size of completion
- CT size
- Drag
  - Mechanical
  - Fluid
- Debris in well
- BHA size
- End load

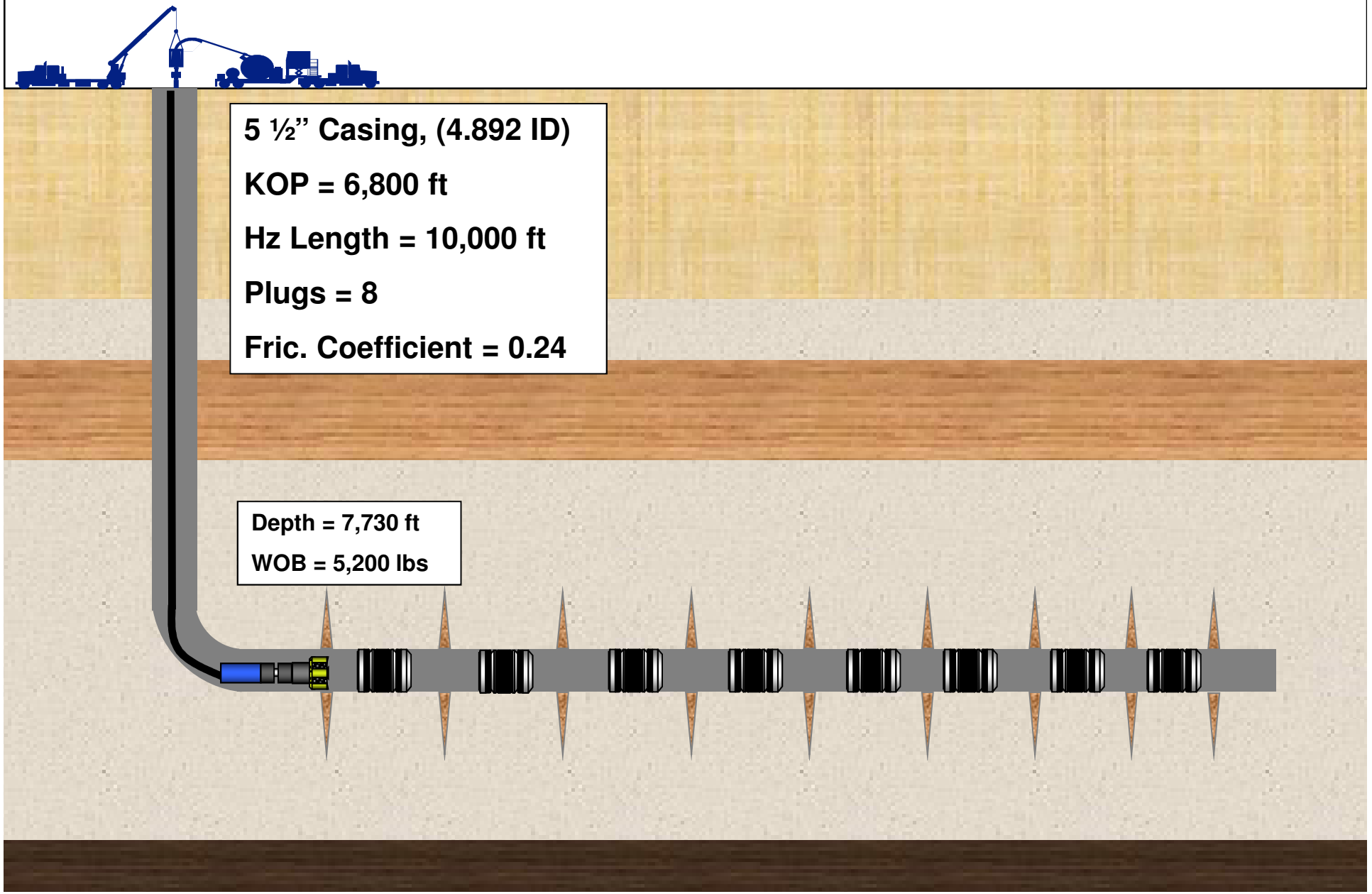
What Can We Control?

- CT size
- End load
- Buoyancy
- Drag

Helical Buckling



2” CT Simulated Plug Mill out



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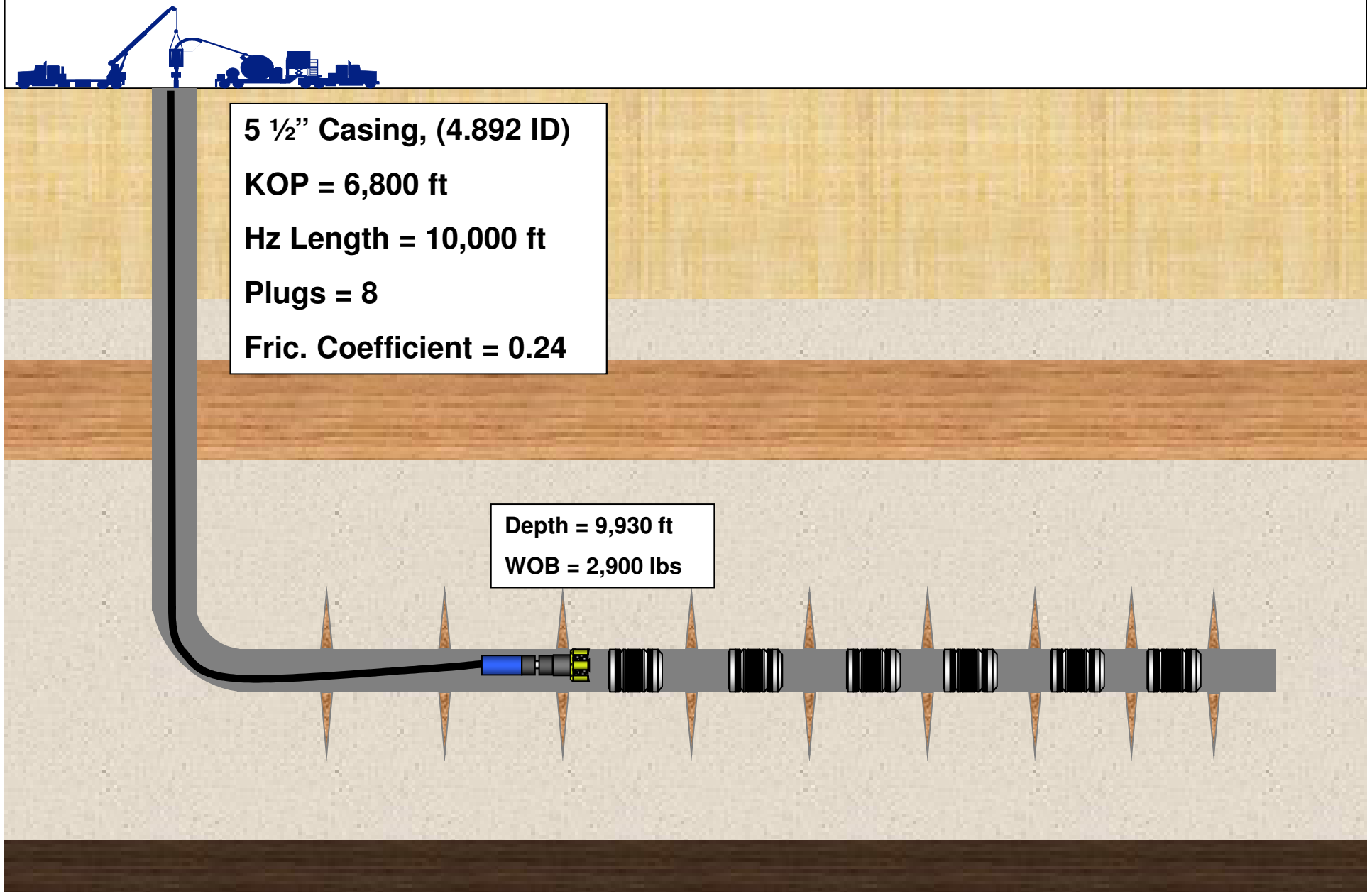
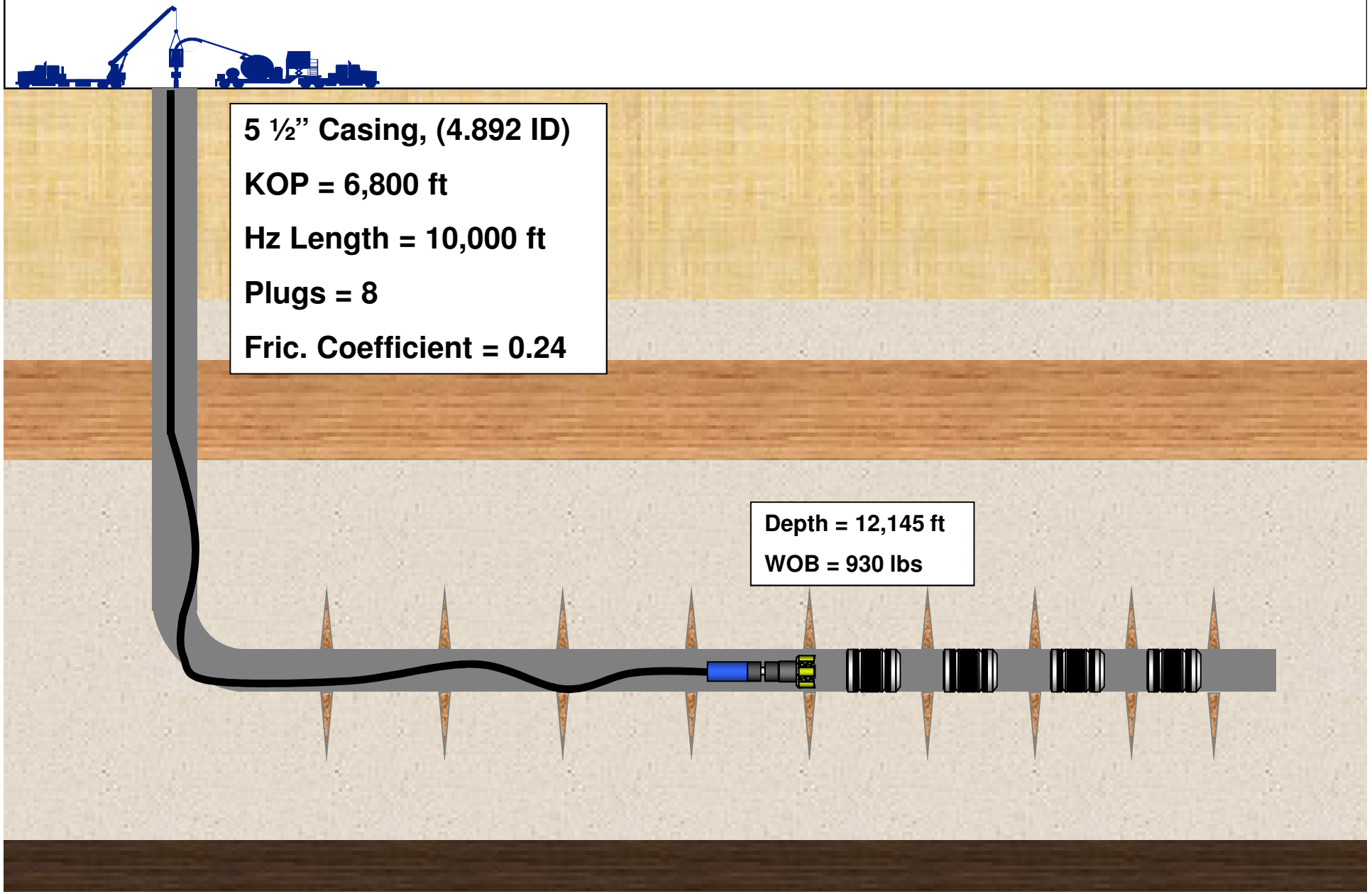
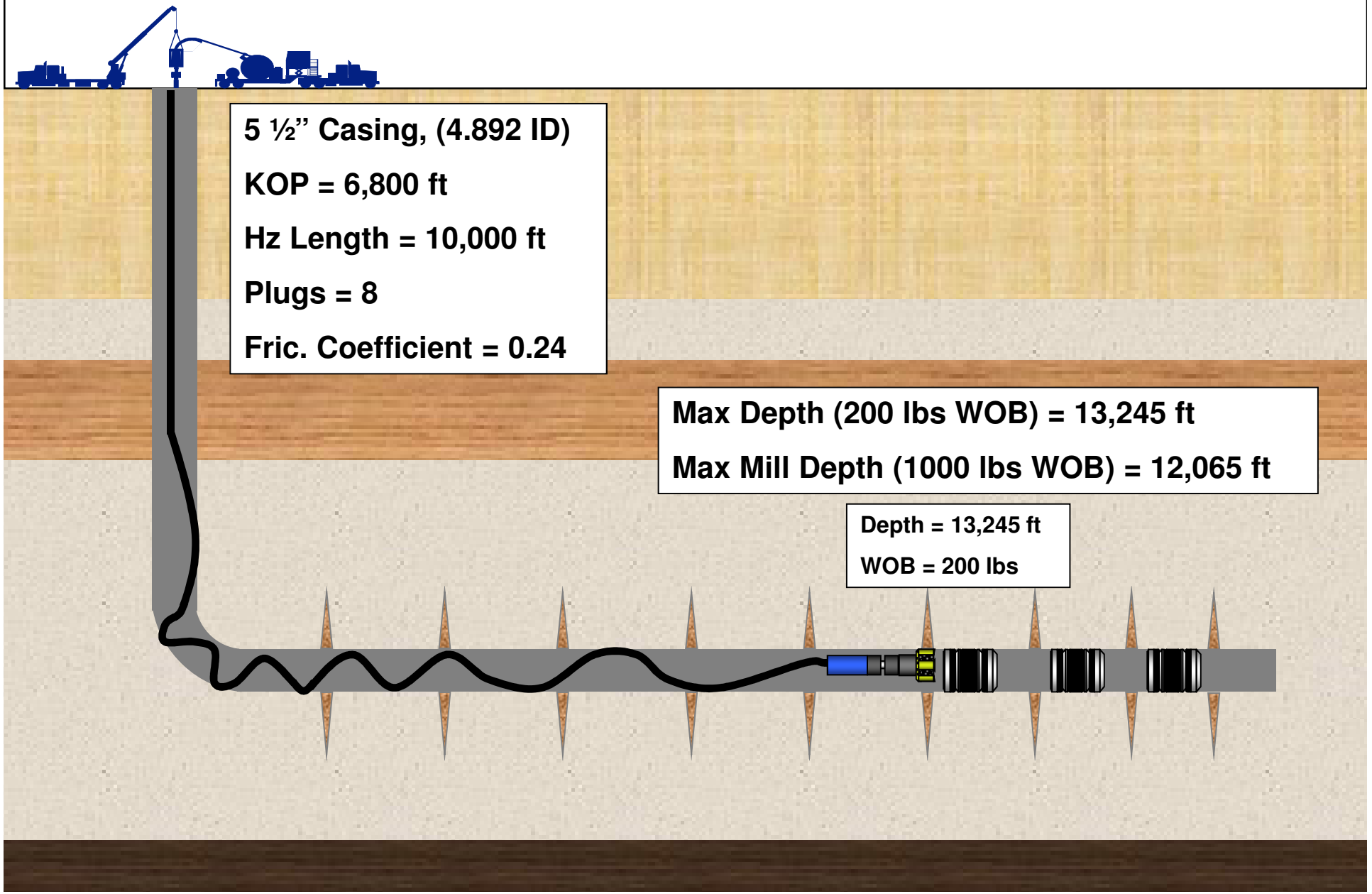


2” CT Simulated Plug Mill out

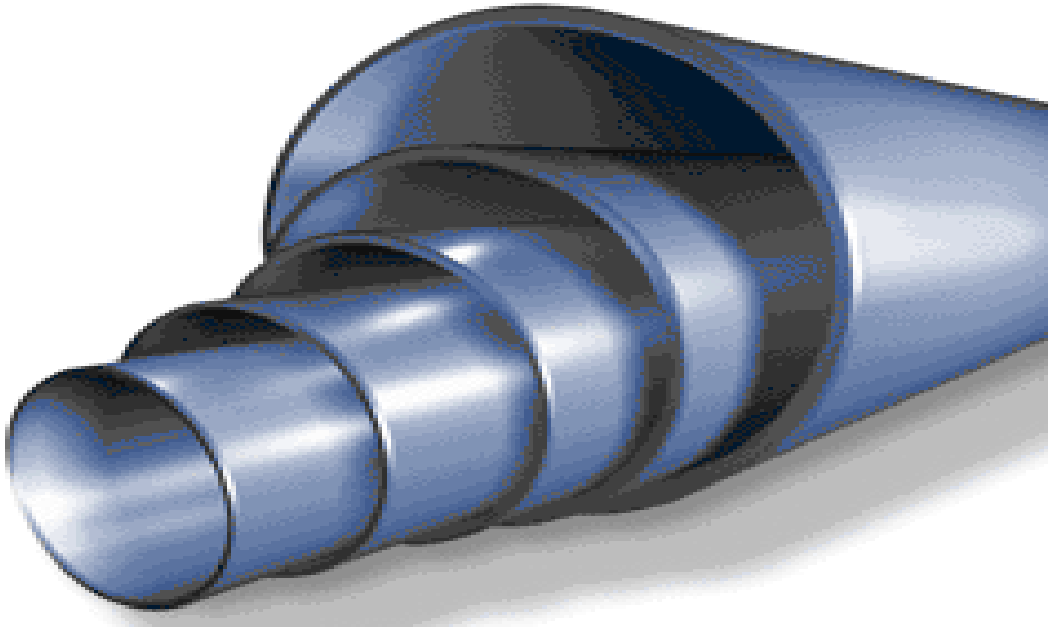


2” CT Simulated Plug Mill out



Solutions

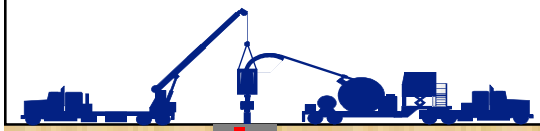
- Larger CT
  - 2-3/8” CT or greater



2-3/8” CT Limitations

- Higher cost: 30% more than conventional 2”
- Length and reel capacity limitations
- Travel limitations (DOT, special permits)
- Equipment availability
- Less fatigue life

2” CT Simulated Plug Mill out



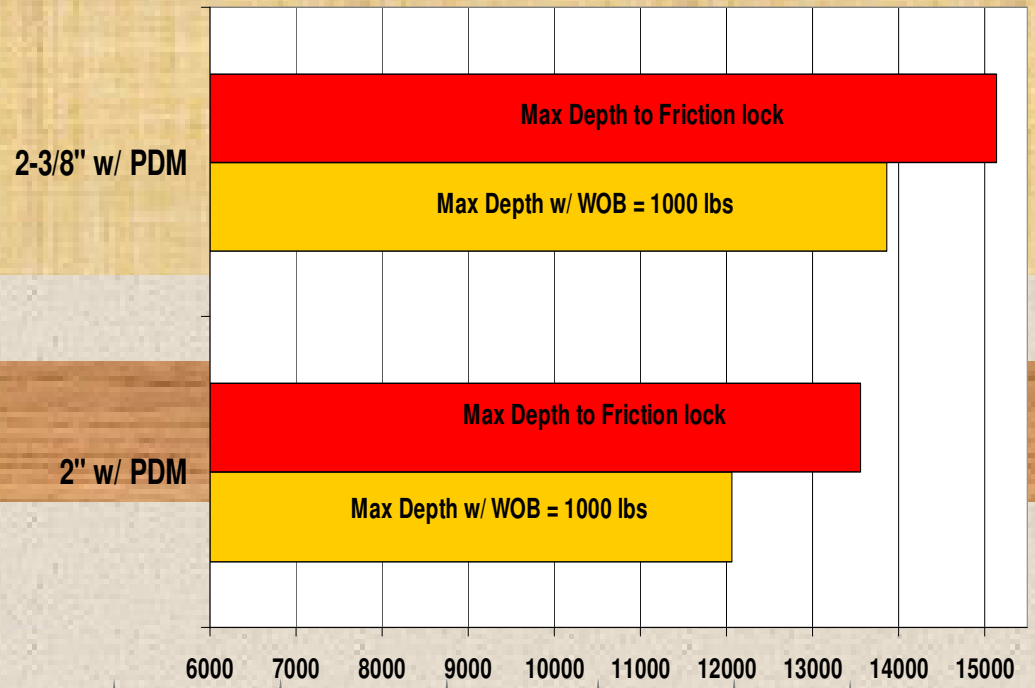
5 ½” Casing, (4.892 ID)

KOP = 6,800 ft

Hz Length = 10,000 ft

Plugs = 8

Fric. Coefficient = 0.24



2” w/ PDM Max Depth: Fric. Lock = 13,565 ft, 1,000 lb WOB = 12,065 ft

2-3/8” w/ PDM Max Depth: Fric. Lock = 15,140 ft, 1,000 lb WOB = 13,870 ft

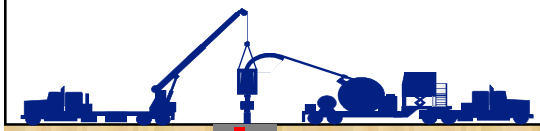
Solutions

- Metal to metal lubricants
  - Fatty acid esters
  - Fatty alcohols
  - Polymer beads

Metal on Metal Lubricants

- 15-25% friction reduction
- Can be used in most situations
- Only pumped if needed
- Cost varies depending on volume used

2” Simulated Plug Mill out w/ Lubricant



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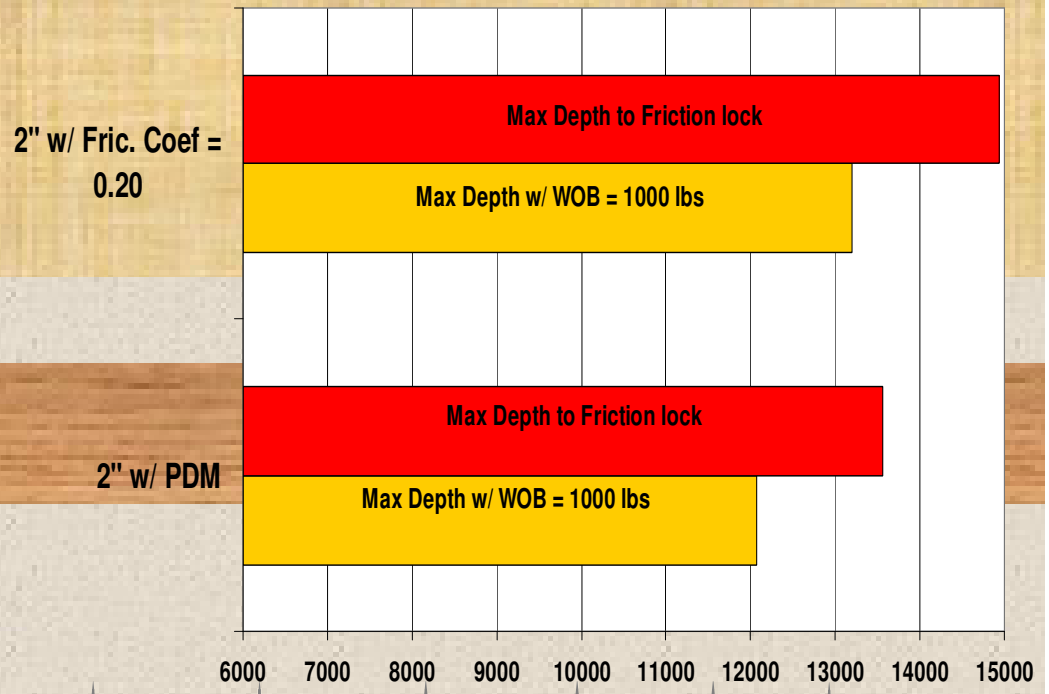
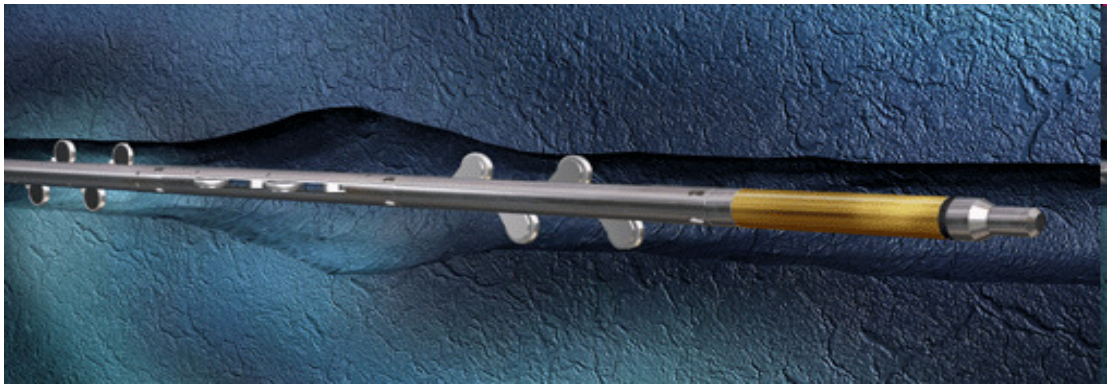


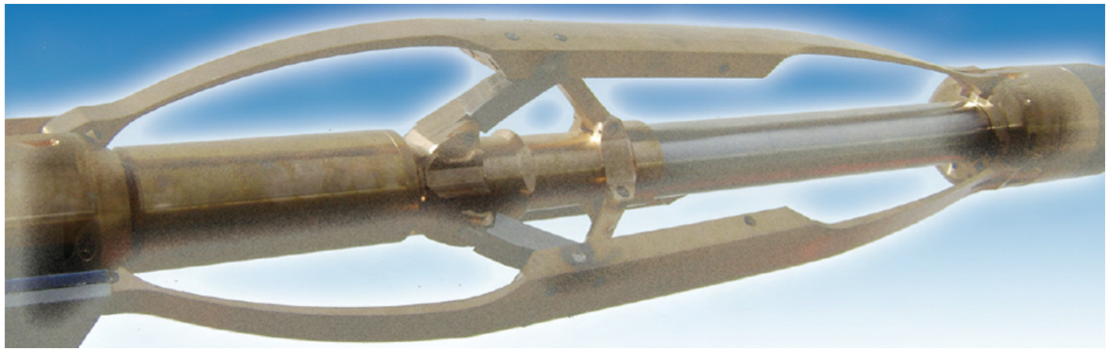
2” w/ PDM Max Depth: Fric. Lock = 13,565 ft, 1,000 lb WOB = 12,065 ft

2” w/ PDM Max Depth Lubricant: Fric. Lock = 14,935 ft, 1,000 lb WOB = 13,200 ft

Solutions

- Mechanical devices such as tractors

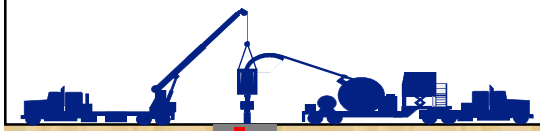




Tractors

- Give large pulling force
- Increase risk of getting stuck
- Long tool length, longer lubricator/larger crane
- Less reliable in sand environments
- Limited use in open hole completions
- Complex tools with lots of moving parts

2” CT Simulated Plug Mill out w/ Tractor



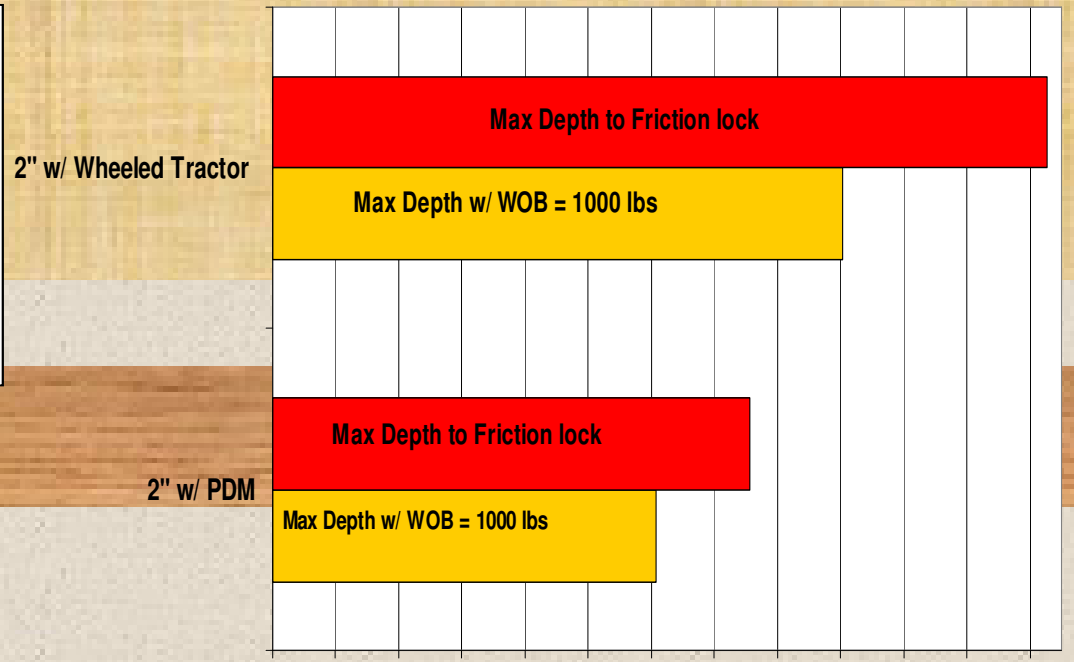
5 ½” Casing, (4.892 ID)

KOP = 6,800 ft

Hz Length = 10,000 ft

Plugs = 8

Fric. Coefficient = 0.24

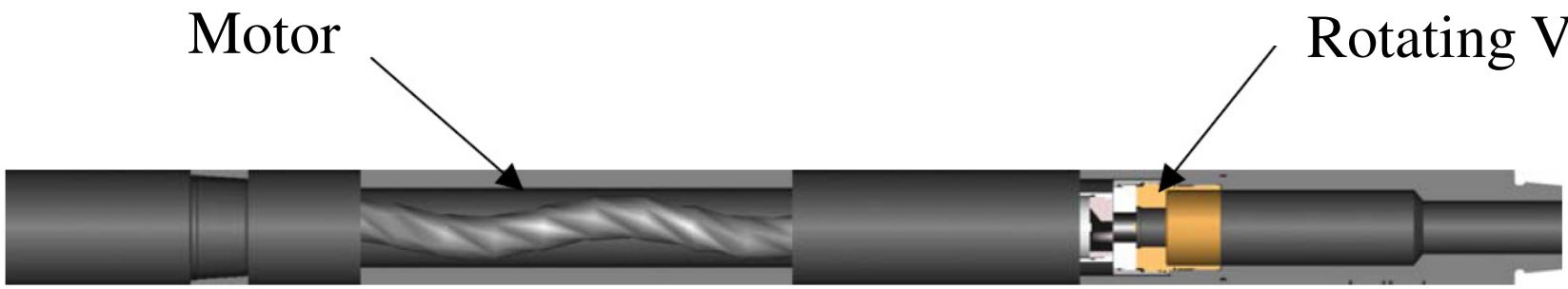


2” w/ PDM Max Depth: Fric. Lock = 13,565 ft, 1,000 lb WOB = 12,065 ft

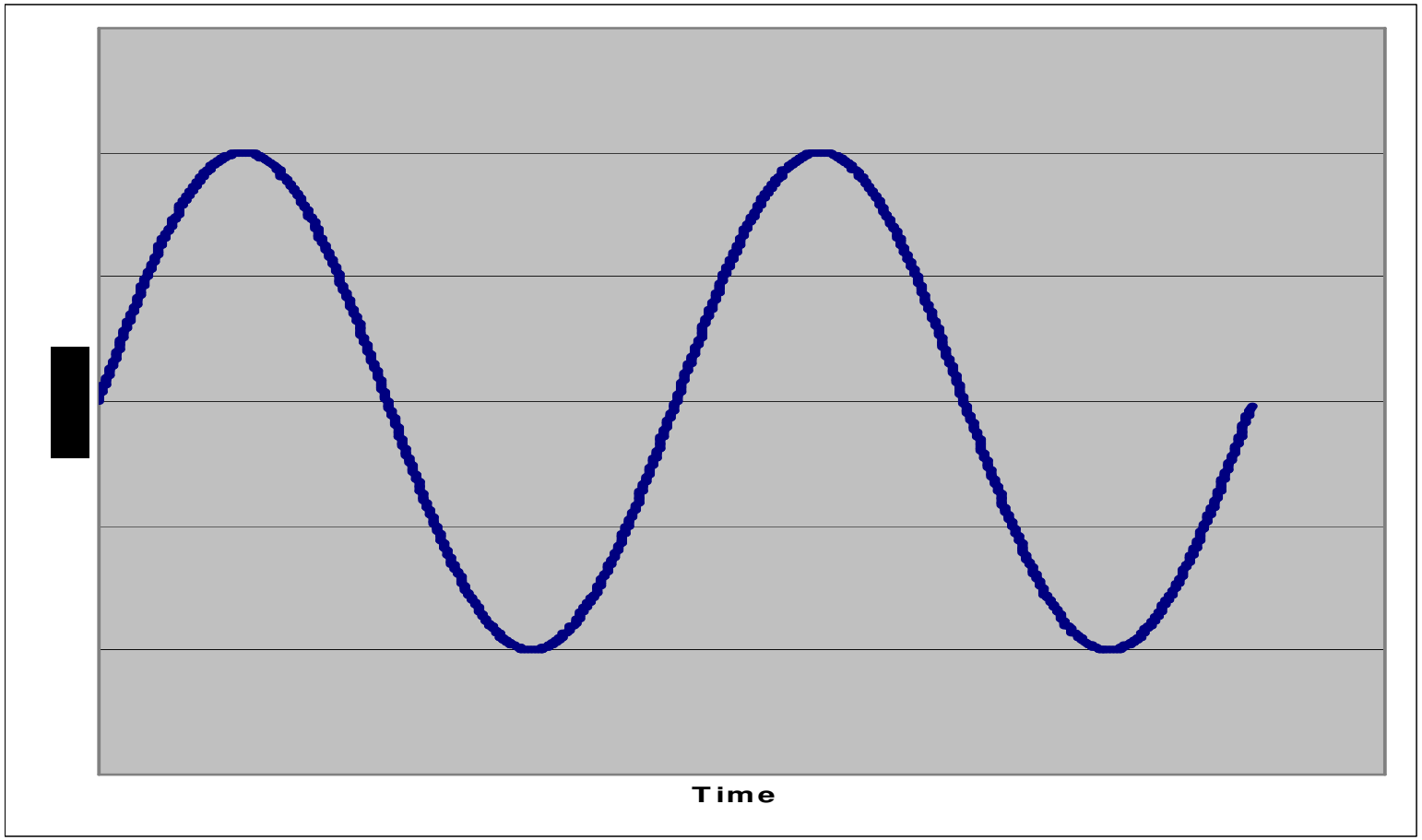
2” w/ PDM Max Depth w/tractor: Fric. Lock = 18,266 ft, 1,000 lb WOB = 15,038 ft

Solution

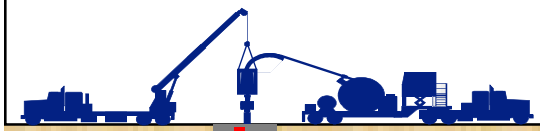
- Rotating valve water hammer tools
- Motor operates a rotating valve
- Valve partially interrupts pumped fluid
- Interruptions create water hammer
- Creates sinusoidal pressure wave
- Frequency depends on flow rate



Sinusoidal Wave from Rotating Valve



2” Simulated Plug Mill out w/Rotating Valve water Hammer Tool



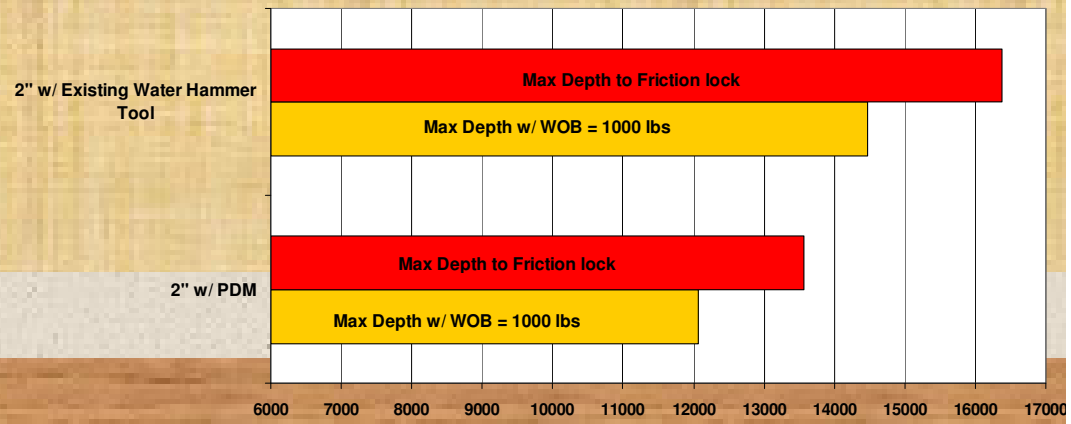
5 ½” Casing, (4.892 ID)

KOP = 6,800 ft

Hz Length = 10,000 ft

Plugs = 8

Fric. Coefficient = 0.24



2” w/ PDM Max Depth: Fric. Lock = 13,565 ft, 1,000 lb WOB = 12,065 ft

2” w/ PDM Max Depth w/Rotating Valve Water Hammer Tool: Fric. Lock = 16,372 ft, 1,000 lb WOB = 14,465 ft

Solutions

- A new tool design was needed

New Tool

- Extensive computer flow modelling was required
- Optimum frequency and wave shape were determined to achieve maximum benefit
- Best results are with a square wave with a 50% open to 50% closed ratio
- Exhaustive laboratory testing was done
- Prototypes were built and tested

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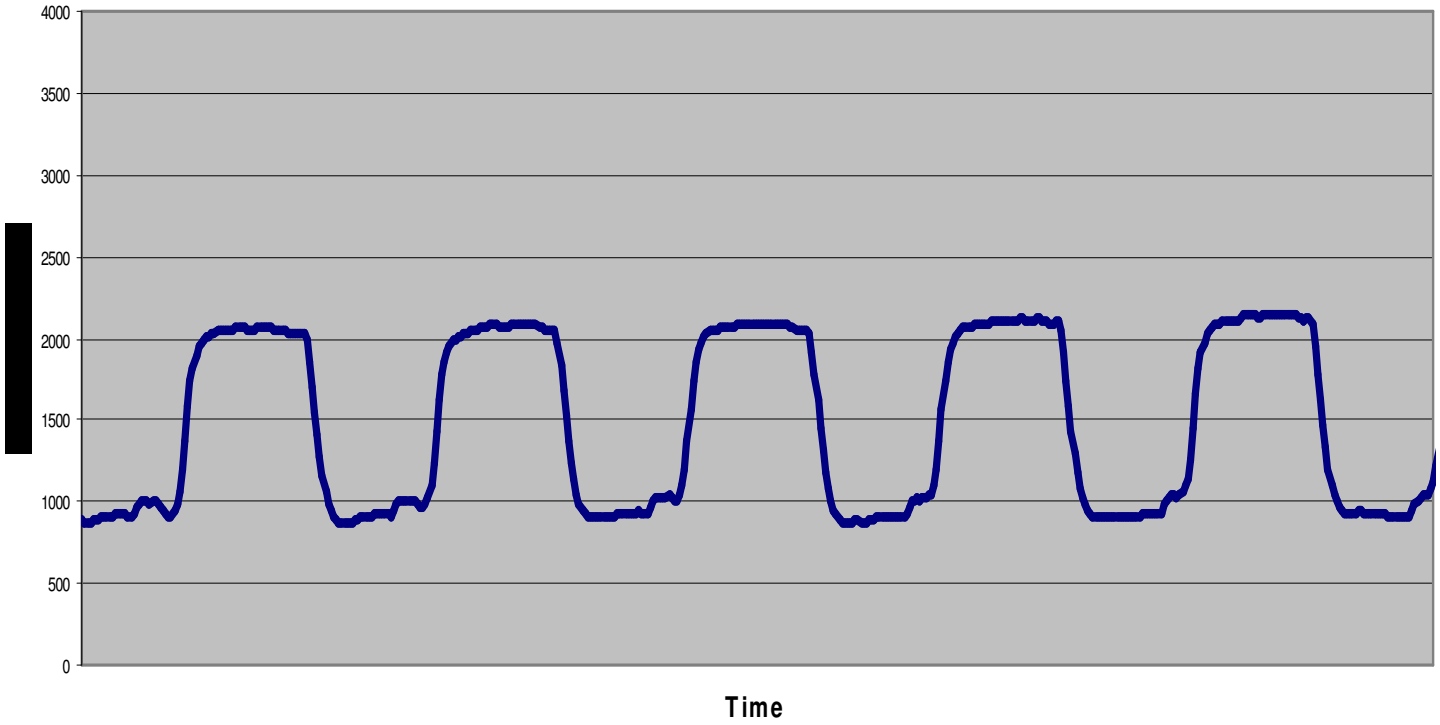
Typical Lab Test Setup

Solutions

- New Square Wave Water Hammer Extended Reach Tool

Pressure Wave Created by New Tool

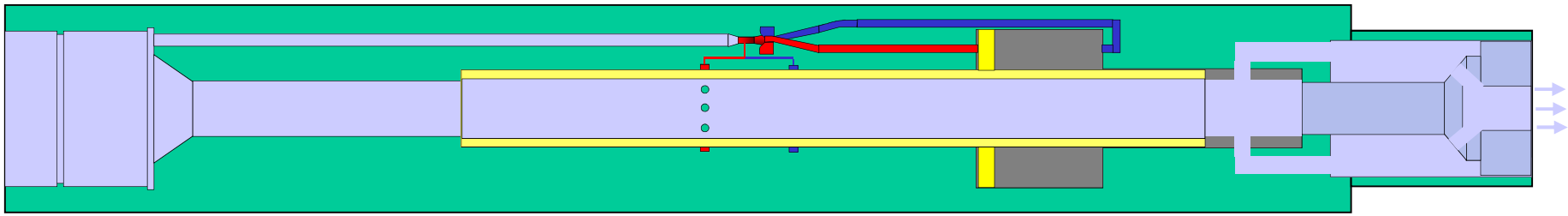


Square Wave Tool

- A high power water hammer tool
  - Produces square wave pressure pulses (<10 Hz)
  - Frequency is independent of flow rate
  - 50% open to 50% closed ratio
  - Tunable to accept flows from 1 – 5 bpm
- Efficient
  - Can be tuned to give only the required water hammer to reach the target depth regardless of the total flow rate being pumped
- Mechanically simple
  - 1 moving part (piston)
  - Does not have limitations of down hole motors
    - Gas swelling, temp limits, chem. compatibility, etc
- Compatible with typical CT BHAs
  - Jetting
  - Clean outs
  - Milling

Tool Operation

- Piston opens and closes valve to interrupt flow of treatment fluids
- Piston is controlled by a fluidic switch
  - Coanda effect
- Large forces can be created at the end of the coil to pull the coil into the well



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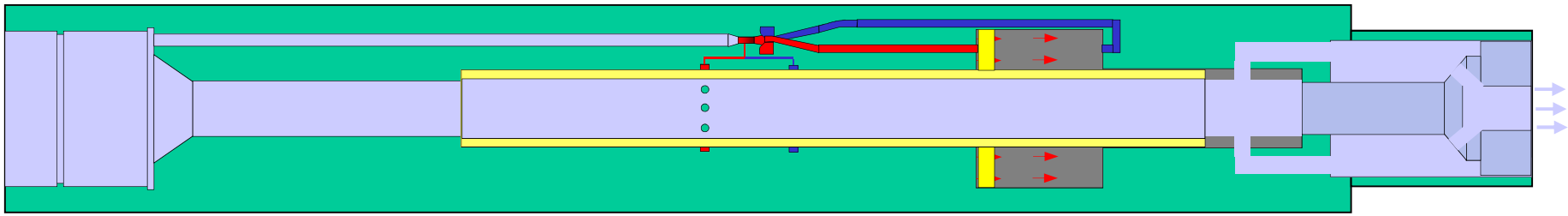

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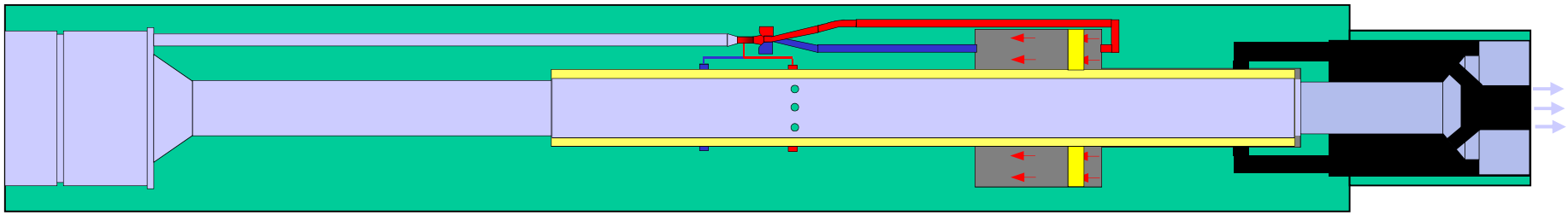

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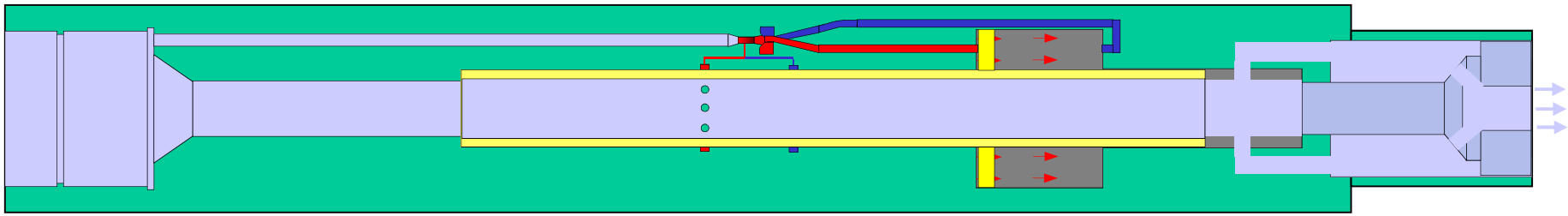

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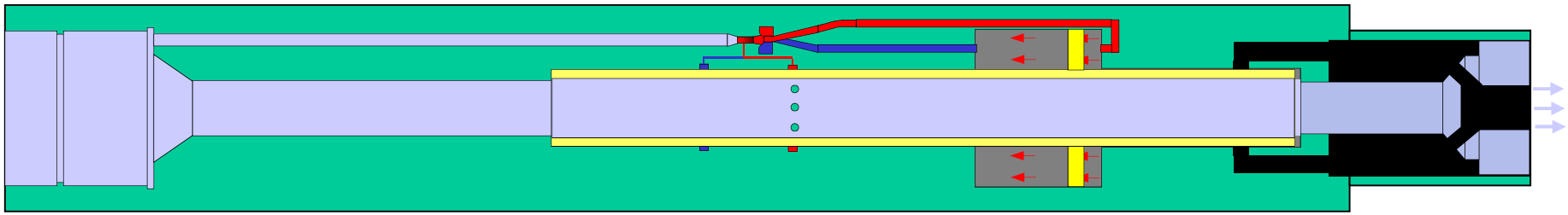

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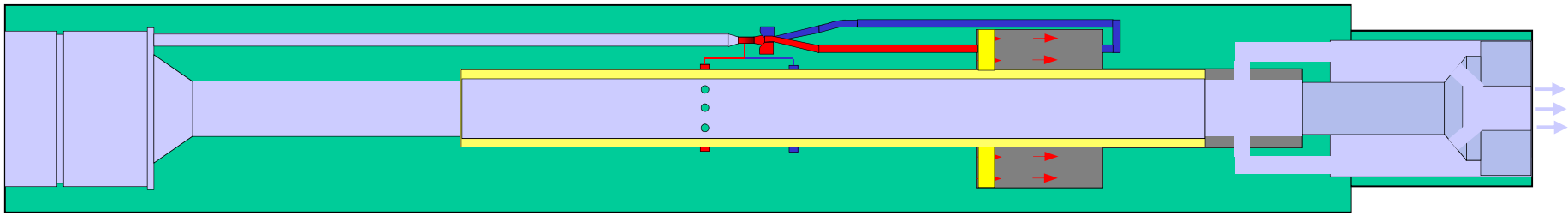

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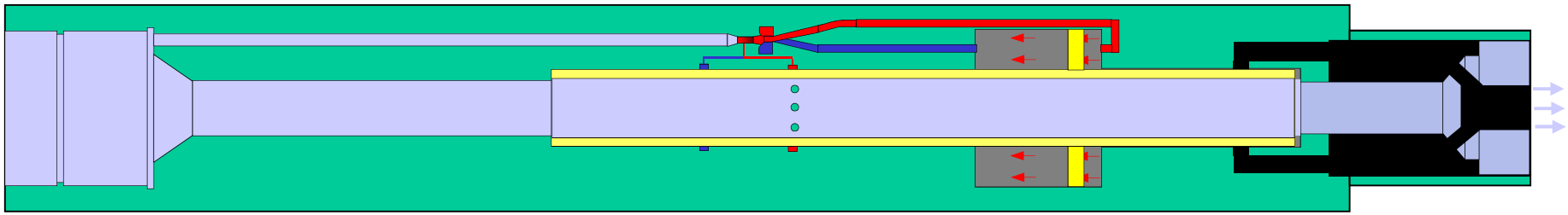

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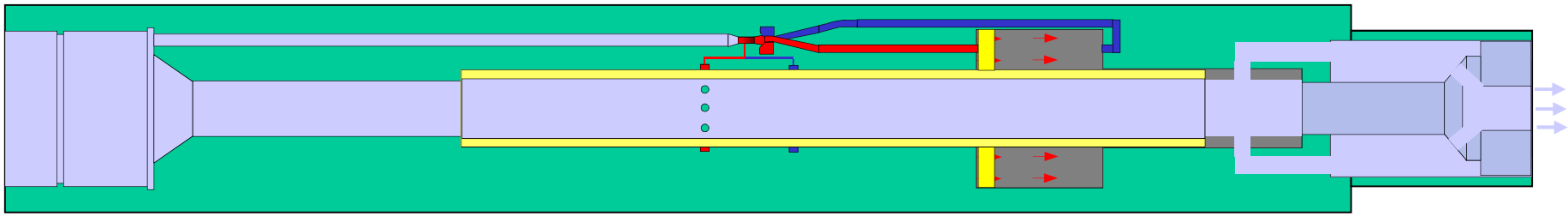

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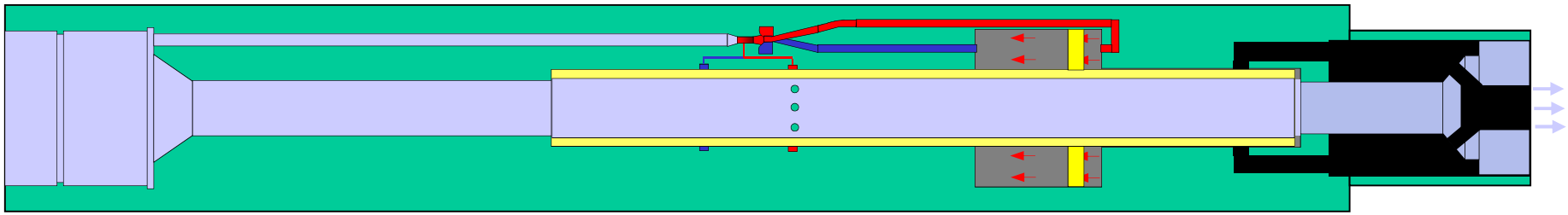

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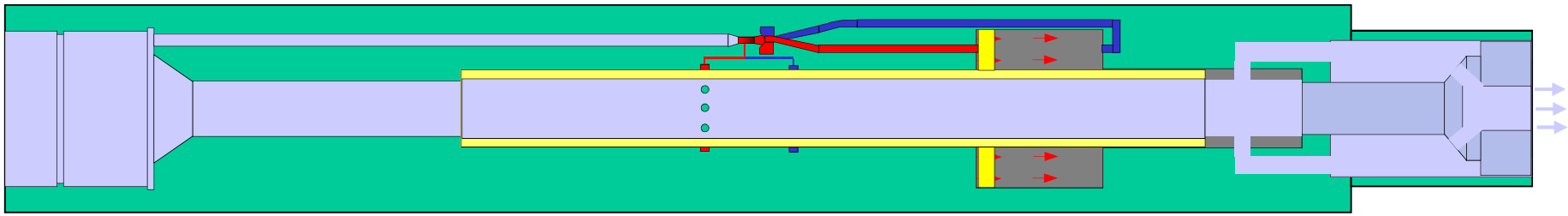

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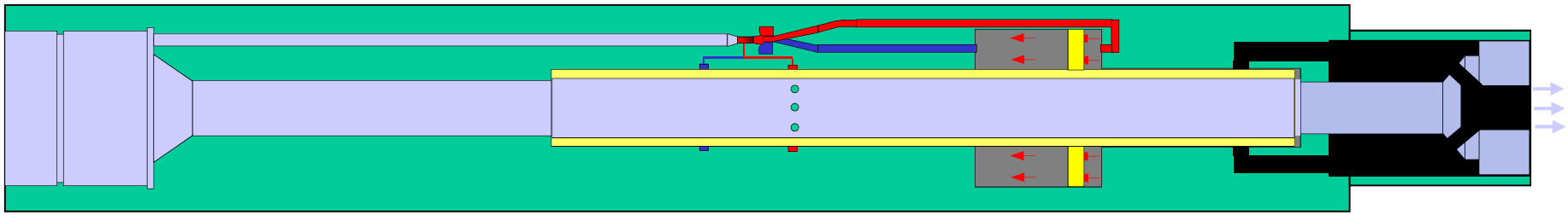

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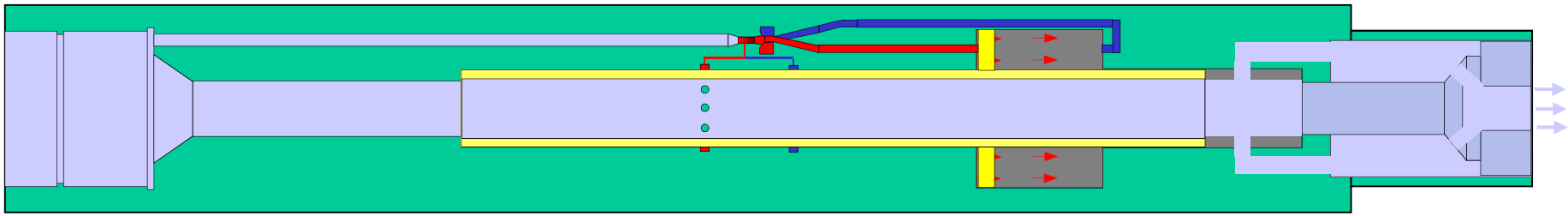

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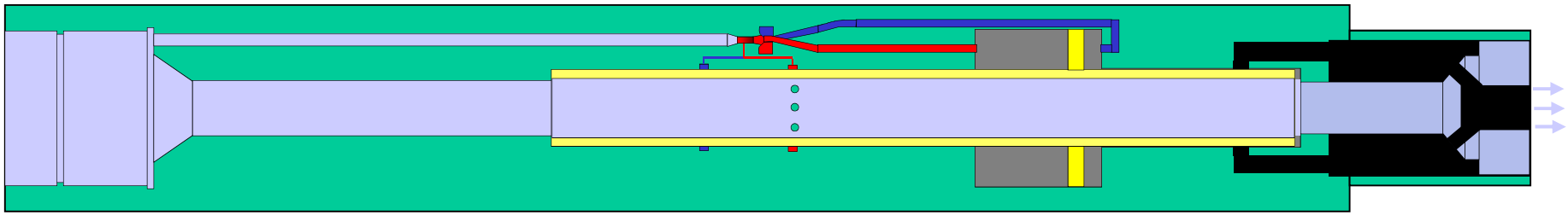

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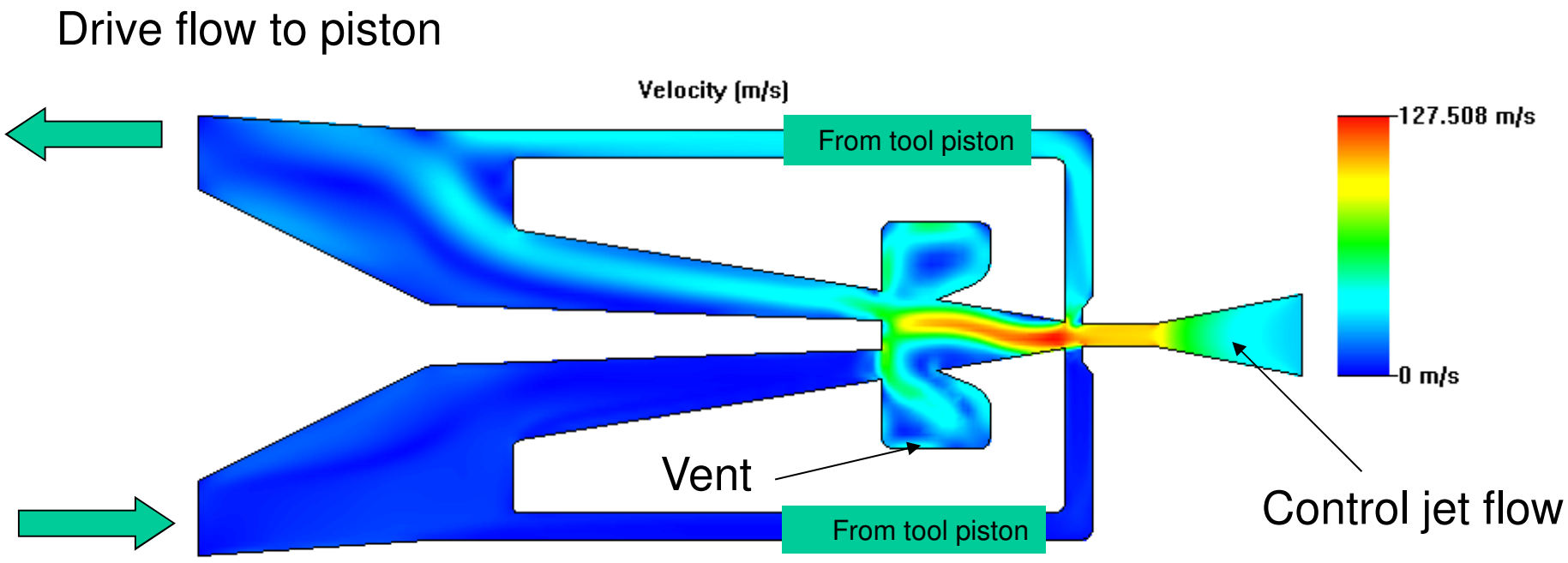
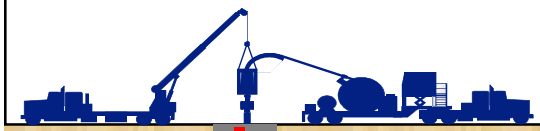
Fluidic switch

Snapshot simulation of jet switching



2” CT Simulated Plug Mill out w/Square Wave Water Hammer Tool



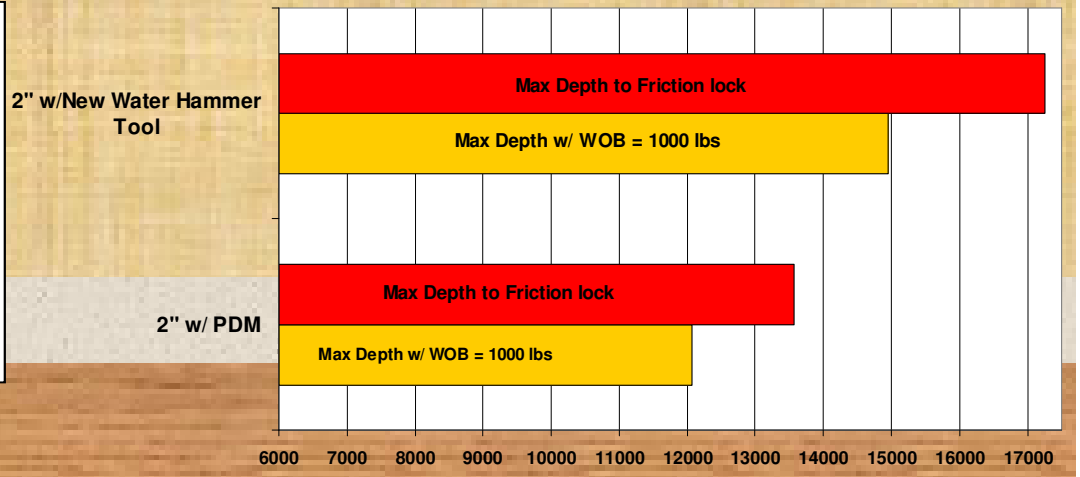
5 ½” Casing, (4.892 ID)

KOP = 6,800 ft

Hz Length = 10,000 ft

Plugs = 8

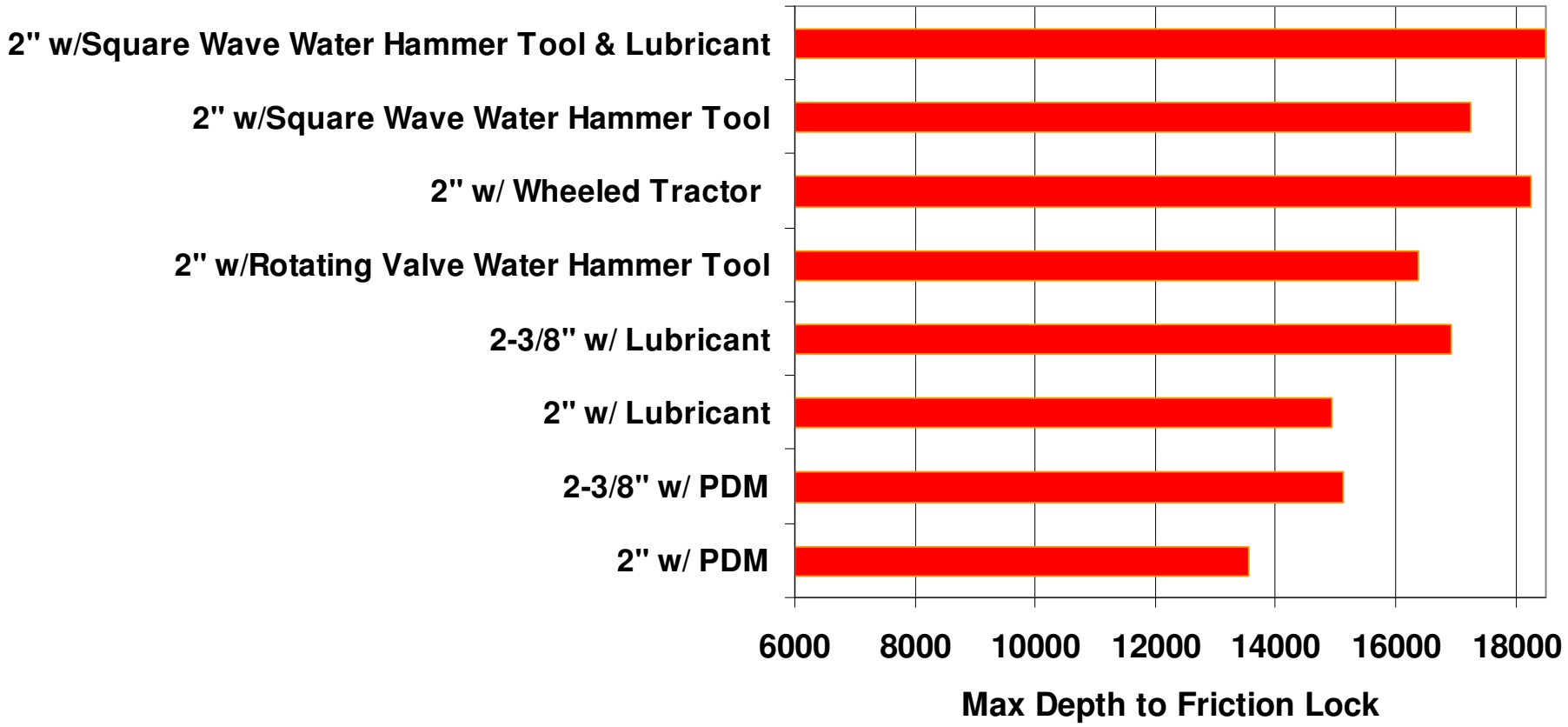
Fric. Coefficient = 0.24



2” w/ PDM Max Depth: Fric. Lock = 13,565 ft, 1,000 lb WOB = 12,065 ft

2” w/ PDM Max Depth w/Square Wave Water Hammer Tool: Fric. Lock = 17,253 ft, 1,000 lb WOB = 14,957 ft

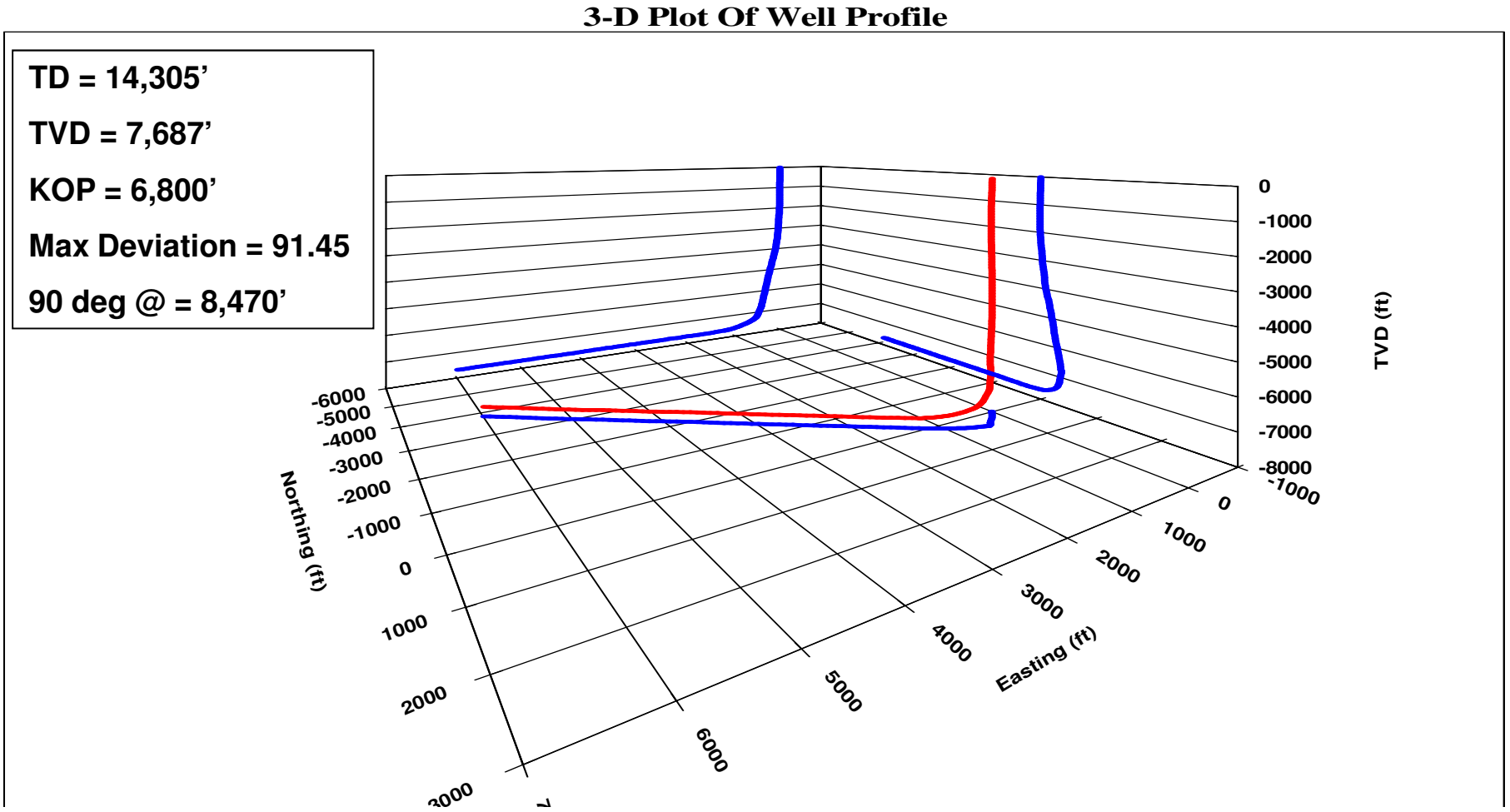
Reach Simulation Summary



Milling Field Case

- Barnett Shale Area
- 5-1/2”, 17# Casing, 14,305 ft
- BHP = 4,000 psi
- KOP 6,800 ft (7,000 ft Hz section)
- 17 plugs
- 2” CT
- Work over fluid: recycled fresh water
- 3 1/2 Motor
- Pre Job computer simulation indicated less than 1,000 lbs WOB at 12,800 ft w/ lubricant

Completion Profile



BHA Configuration

- 2” CT end connector
- 2-7/8” Check Valve
- 2-7/8” Disconnect
- X-over (PAC to Stub ACME)
- 2-7/8” Downhole filter
- 2-7/8” Square Wave Water Hammer Tool
- X-over (Stub ACME to PAC)
- 3-1/2” Positive displacement motor
- 4-5/8” 5 bladed junk mill

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Field Case Milling Comparison

2” CT no Extended Reach Tool

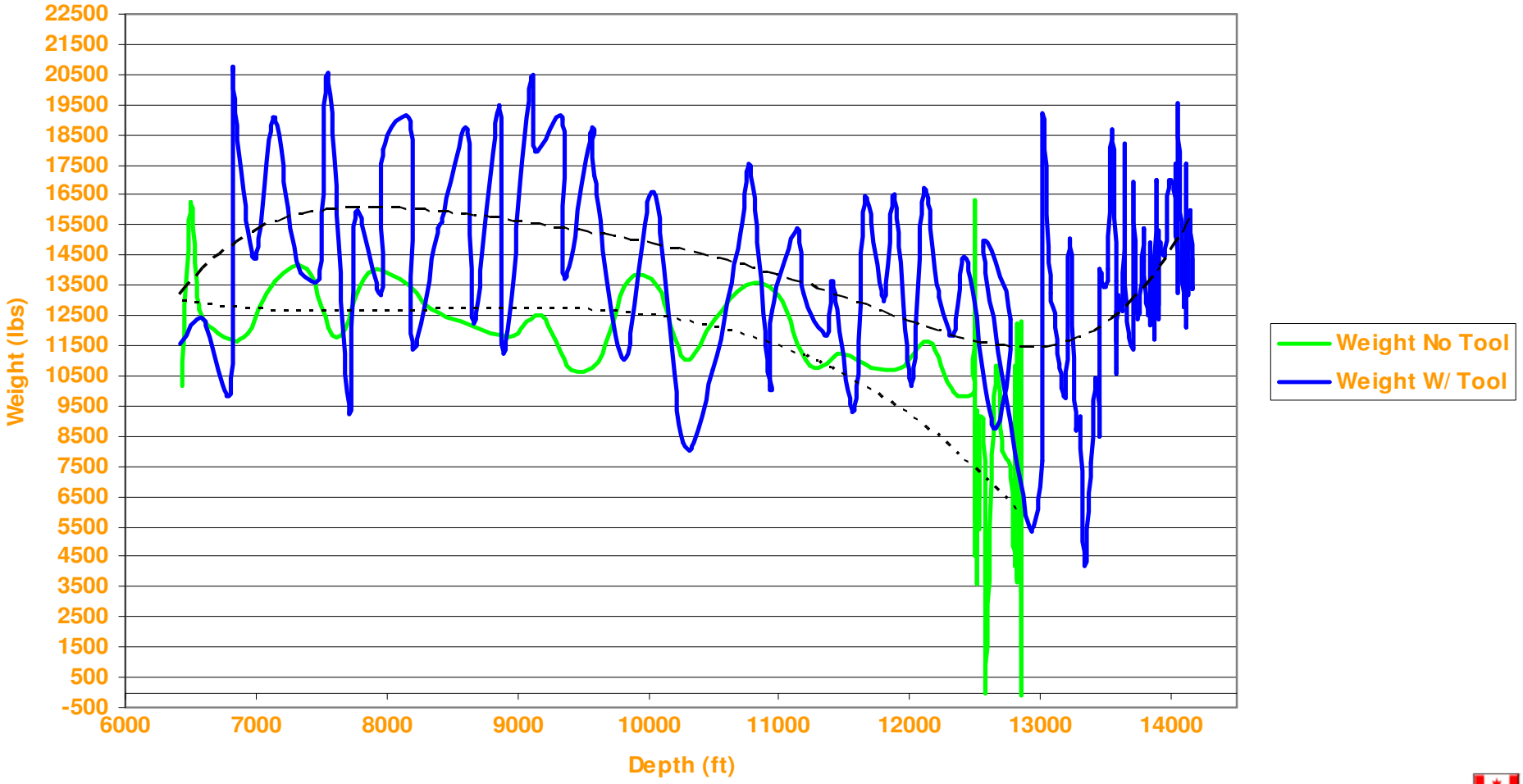
- Total plugs = 13
- Avg. active milling time plugs 1-9 = 38 mins
- Avg. active milling time plugs 10-13 = 89 mins
- Avg. pick ups = 3
- Max depth = 12,956 ft
- Lubricant utilized
- 4 ½” Tri-cone

2” CT w/New Water Hammer Tool

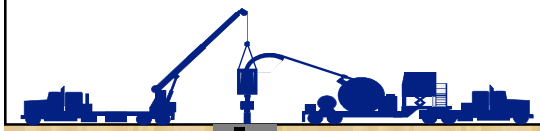
- Total plugs = 4
- Avg. active milling time plugs 14 -17 = 16 mins
- Avg. pick ups = 0
- Max depth = PBTD
- No lubricant utilized
- 4-5/8” 5 bladed junk mill

Field Case Comparison

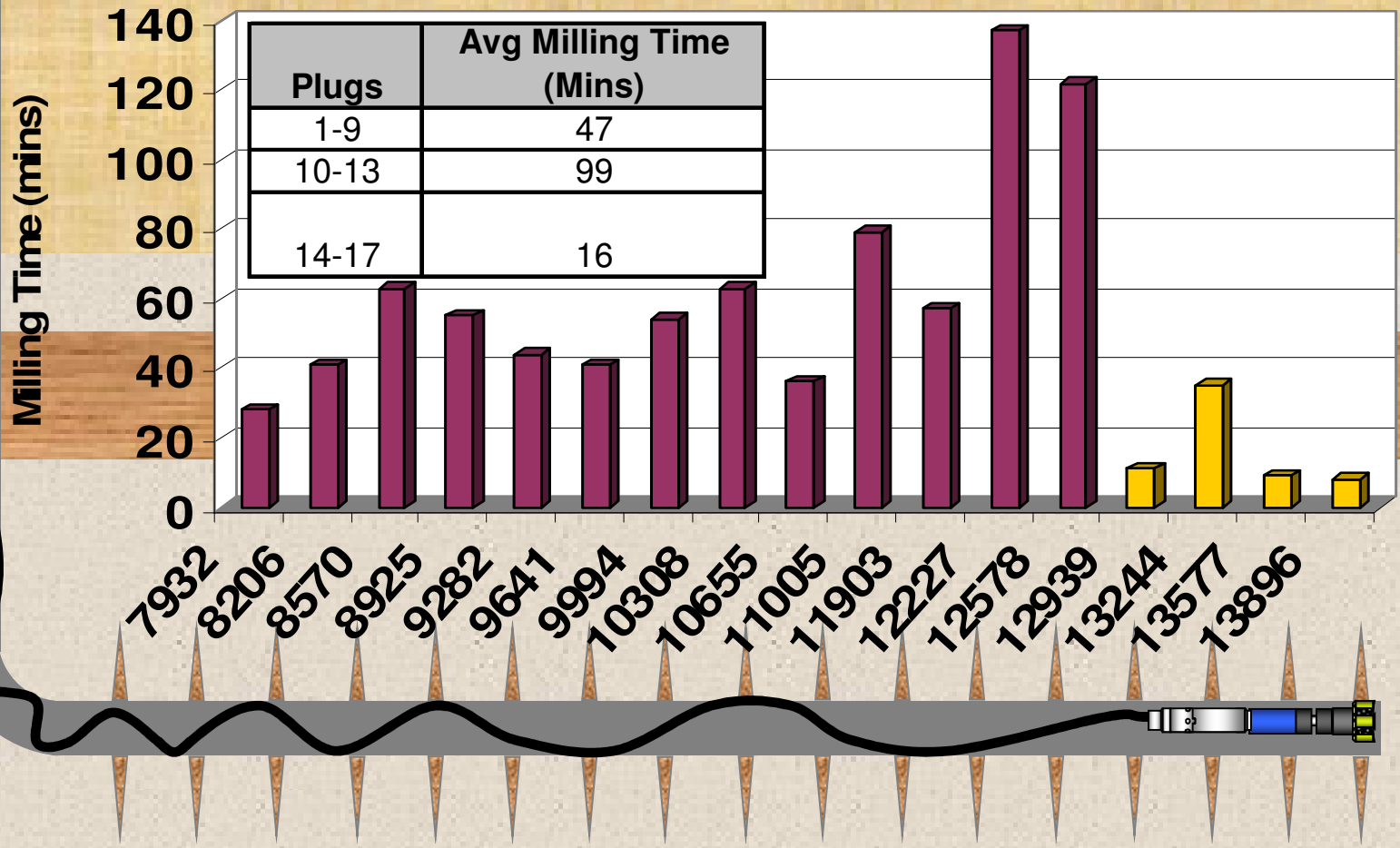
2" Actual Comparison



2” CT Field mill out w/New Water Hammer Tool



Plugs	Avg Milling Time (Mins)
1-9	47
10-13	99
14-17	16



Plugs 14-17 were milled using the 2-7/8” New Water Hammer tool.

Square Wave Tool Summary

- Extended reach / weight on bit applications
  - Water hammer creates vibrations along length of CT, decreasing friction
  - Water hammer force is adjustable
  - Wide range of flow rates allowed
  - Cost effective over utilizing larger CT
- Field results
  - Square wave water hammer tool improved milling performance and extended reach
  - Weight on bit better than larger CT

Questions?