DYNAMIC BEHAVIOUR OF A BHA DURING SLEEVE SHIFTING OPERATIONS

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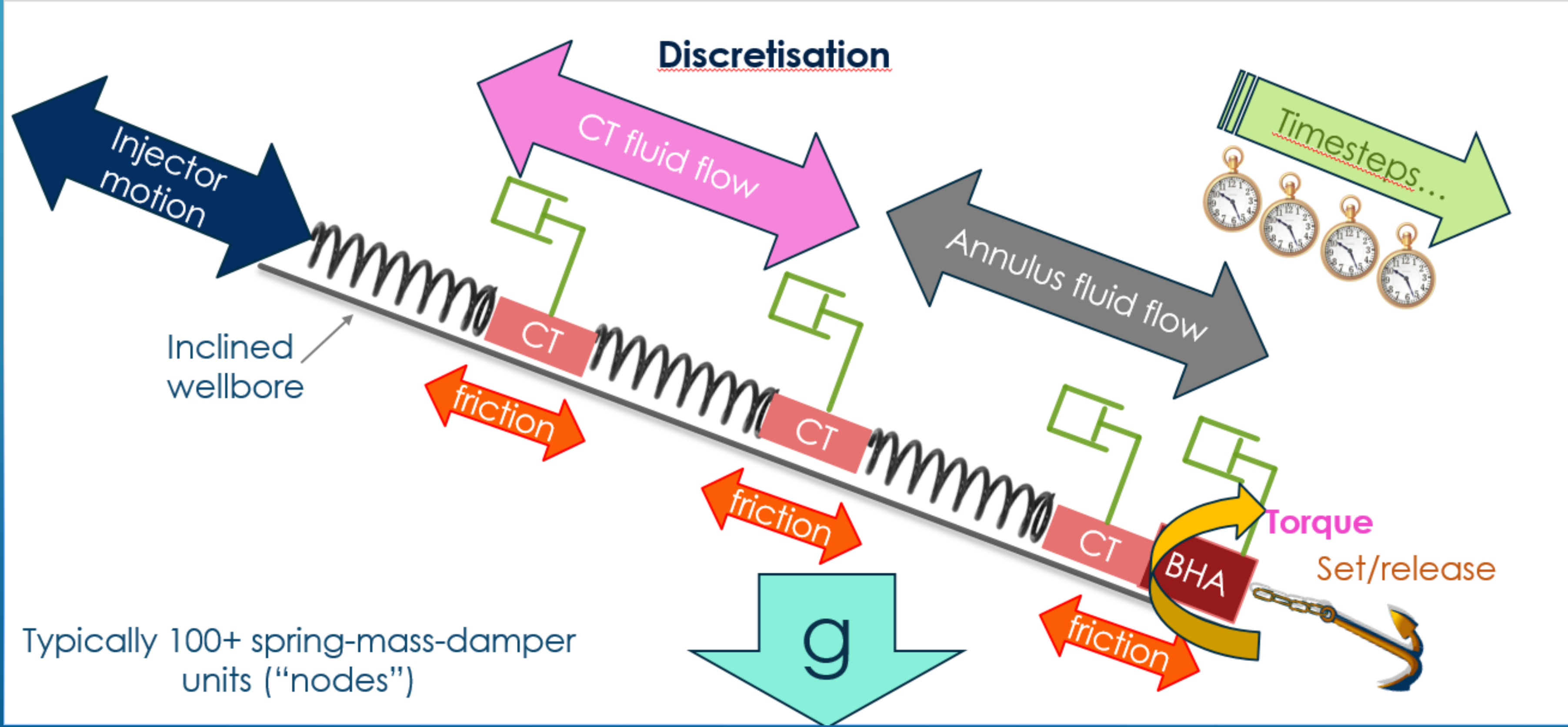
NCS Multistage

ICoTA Round Table 24th October 2018

BHA DYNAMICS 1

- 2015: presented Livesim model
  - Described validation against field data
  - Described modelling of BHA & CT stick-slip motion



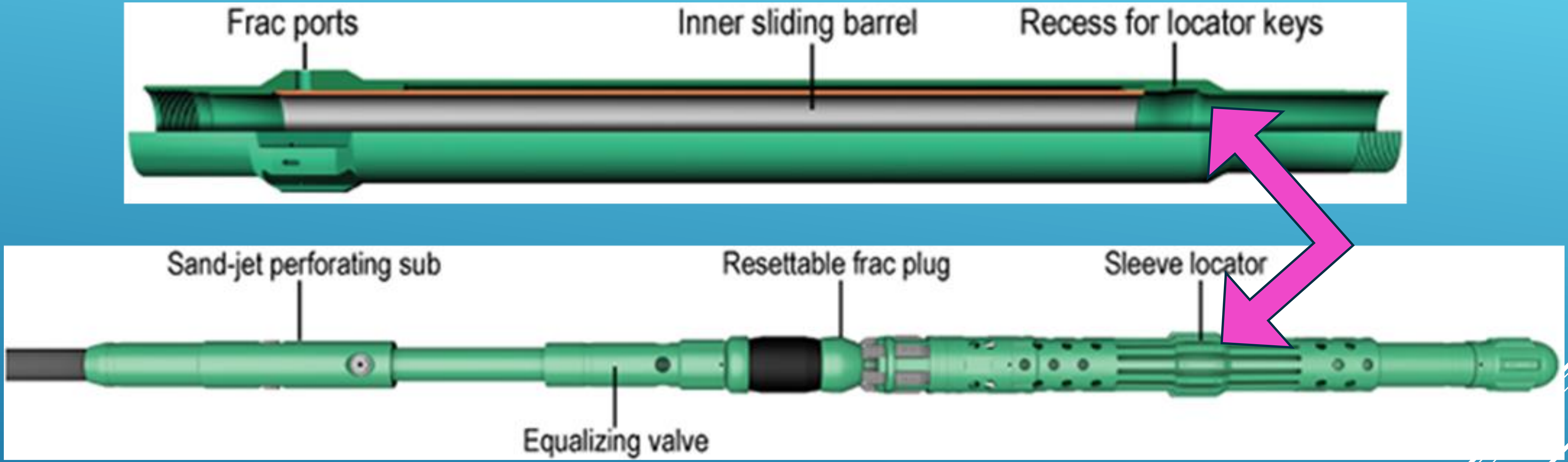
BHA DYNAMICS 2

- 2017: Juan Montero (NCS Multistage)
  - Using the model to study the connection between stick-slip and locator problems

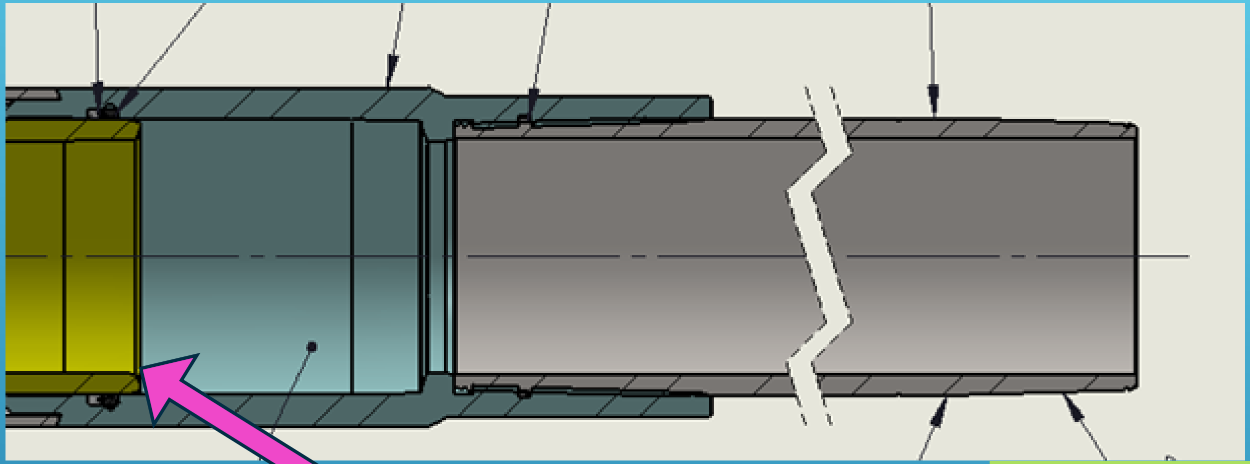
BHA DYNAMICS 3

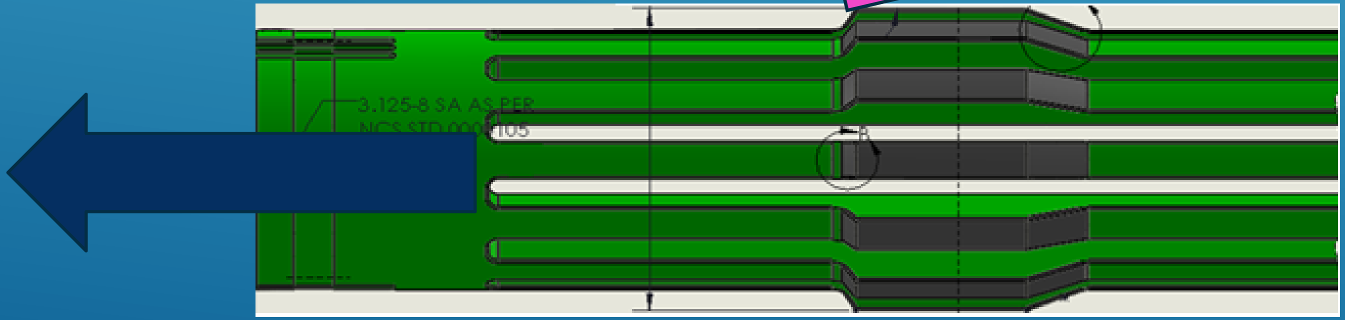
- 2018: Beyond stick-slip
  - Of interest to users of CT with sprung locators.

BHA & SLEEVE


Frac ports
Inner sliding barrel
Recess for locator keys
Sand-jet perforating sub
Resettable frac plug
Sleeve locator
Equalizing valve

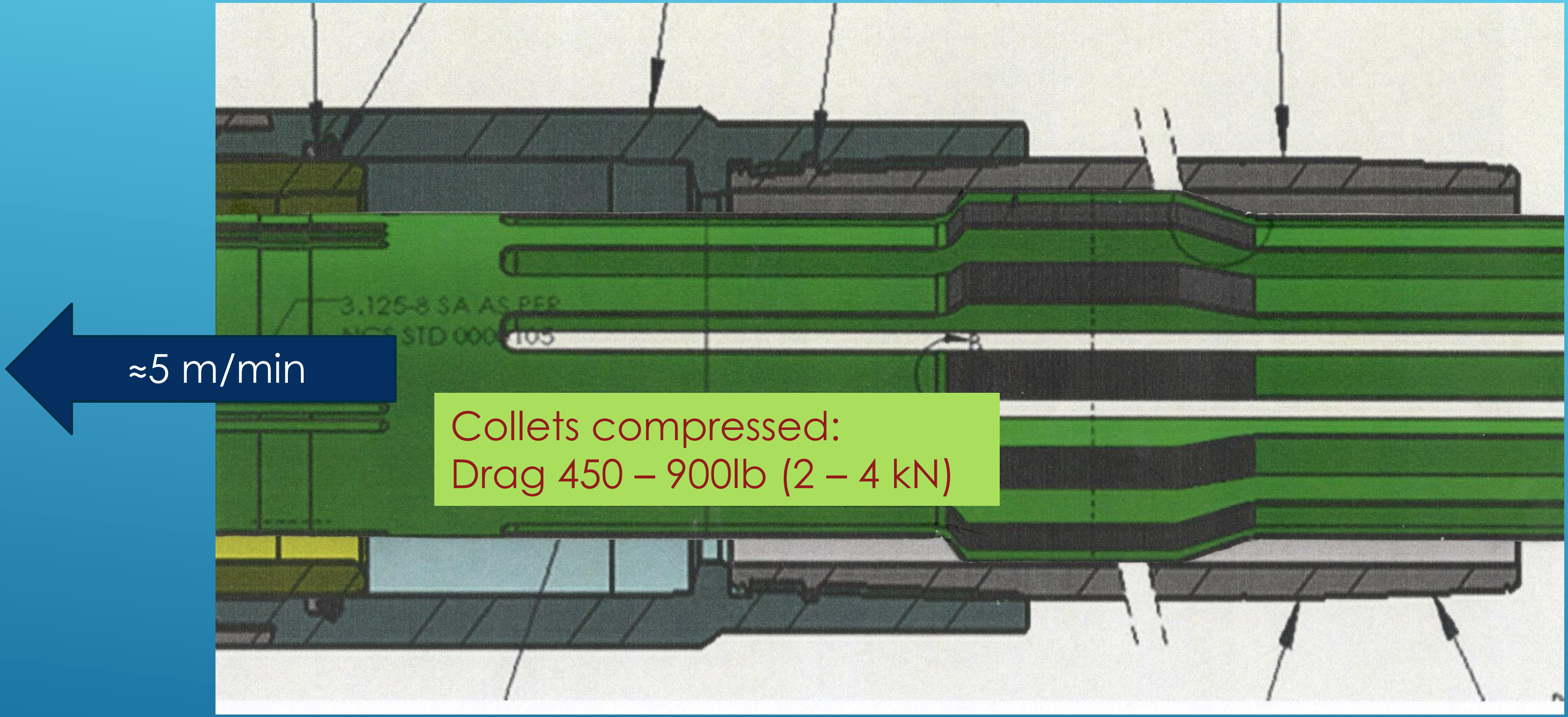
SLEEVE AND LOCATOR COLLETS





A "pop-thru" is a failure mode in which the BHA pulls past the location point and comes to rest just above it.

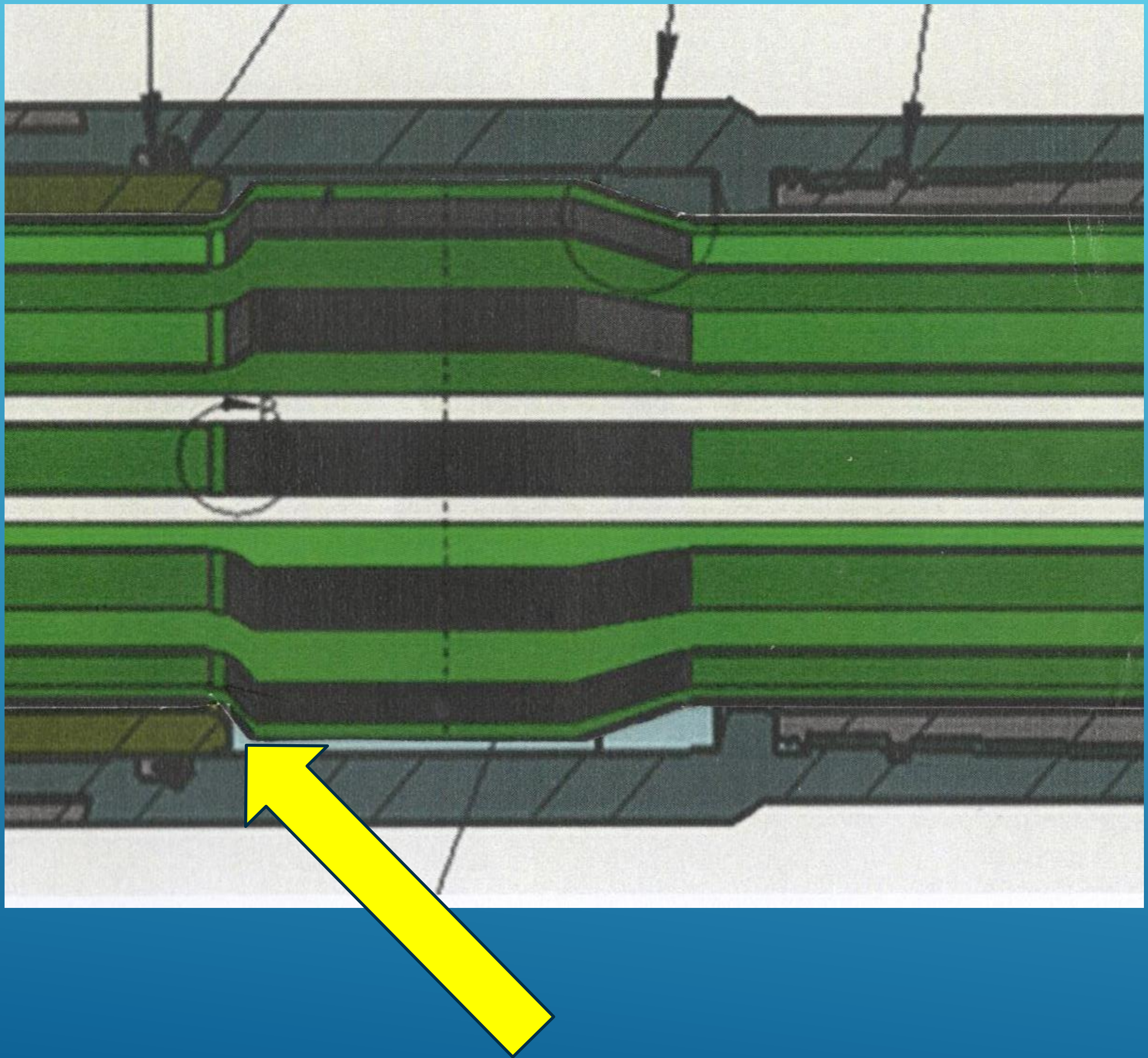
STAGE 1: APPROACH



STAGE 2: LAUNCH & TRANSIT

Collets free, drag is removed.
BHA accelerates.

STAGE 3: CONTACT



STAGE 4: LOAD BUILD-UP

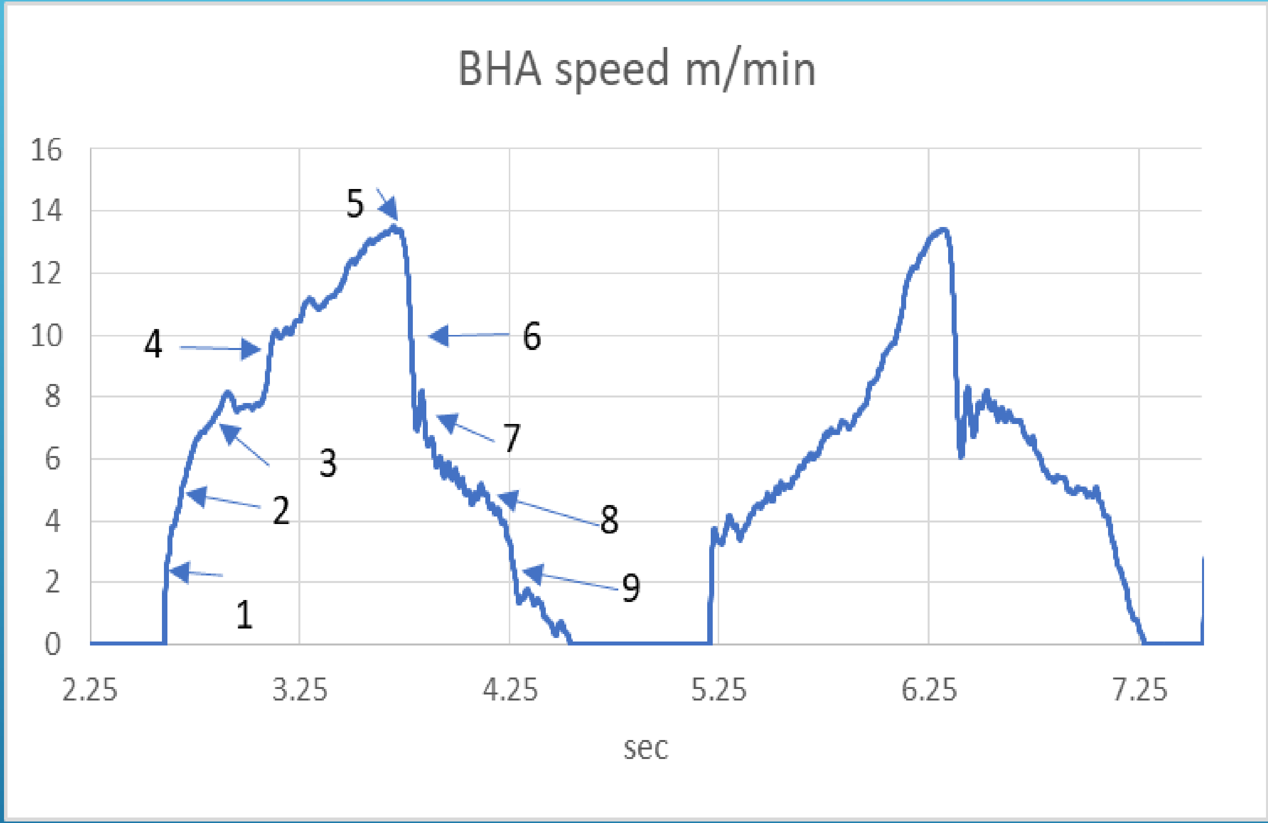
Collets compress as they are pulled against the sleeve.

Typical pull-through force is
5 – 6000 lb (22 – 27kN).

APPROACH 1

- Collet drag is necessary for the tool to switch correctly.
- Drag will in most cases cause stick-slip when approaching at 5m/min.
- How does stick/slip affect the launch into the sleeve profile?

APPROACH 2



Livesim prediction of stick-slip cycles in approach.
POH at 5m/min, surges to 13.

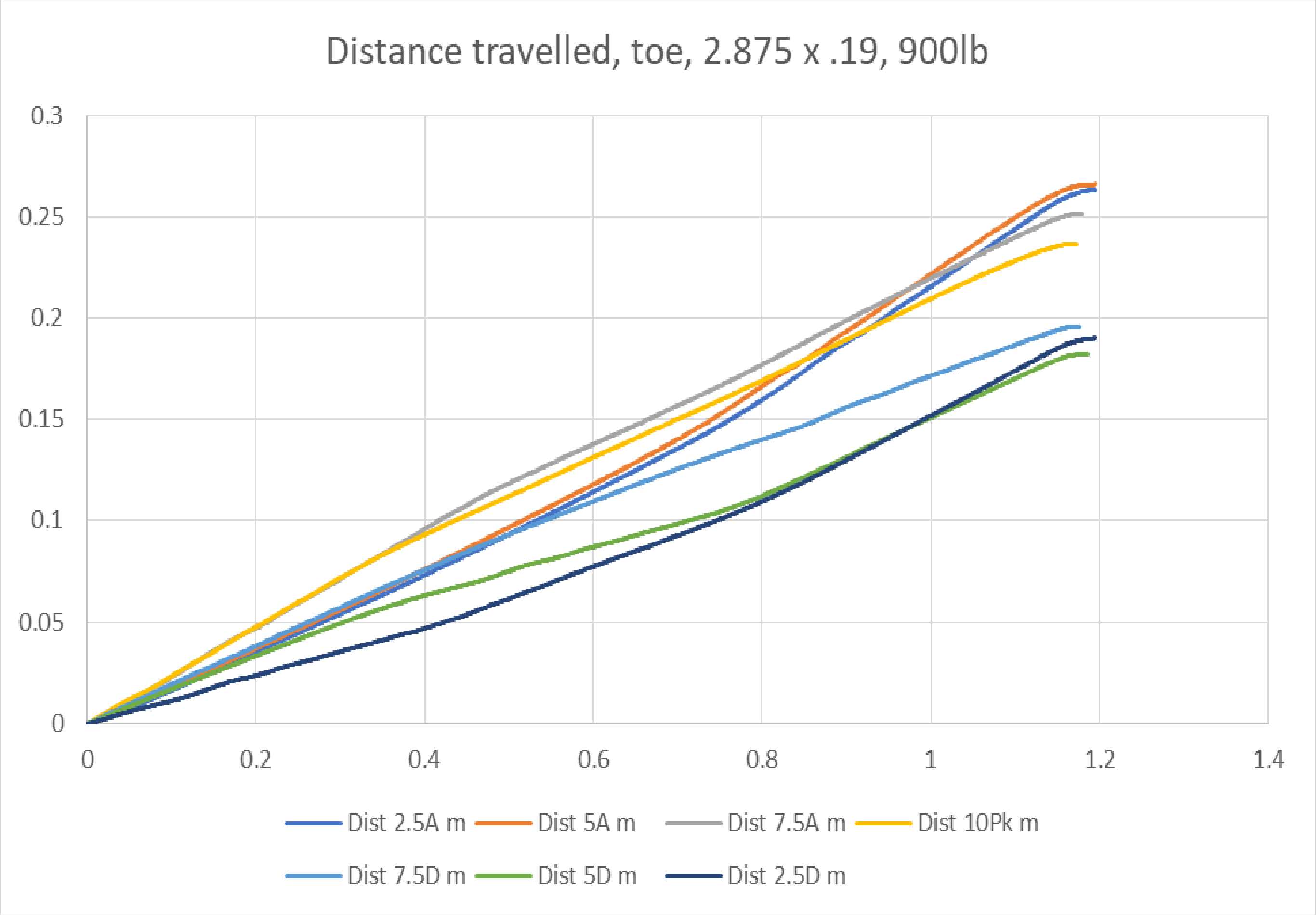
Identify 9 points in a cycle at which the BHA might launch into the profile:

1 to 4: BHA is accelerating when launched.
5 is peak speed.
6 to 9: the BHA is decelerating.

Next, modelling launches from these 9 points in the cycle.

Focus on how far the BHA would travel before coming to rest, if there were no sleeves to obstruct it.

LAUNCH & TRANSIT 1

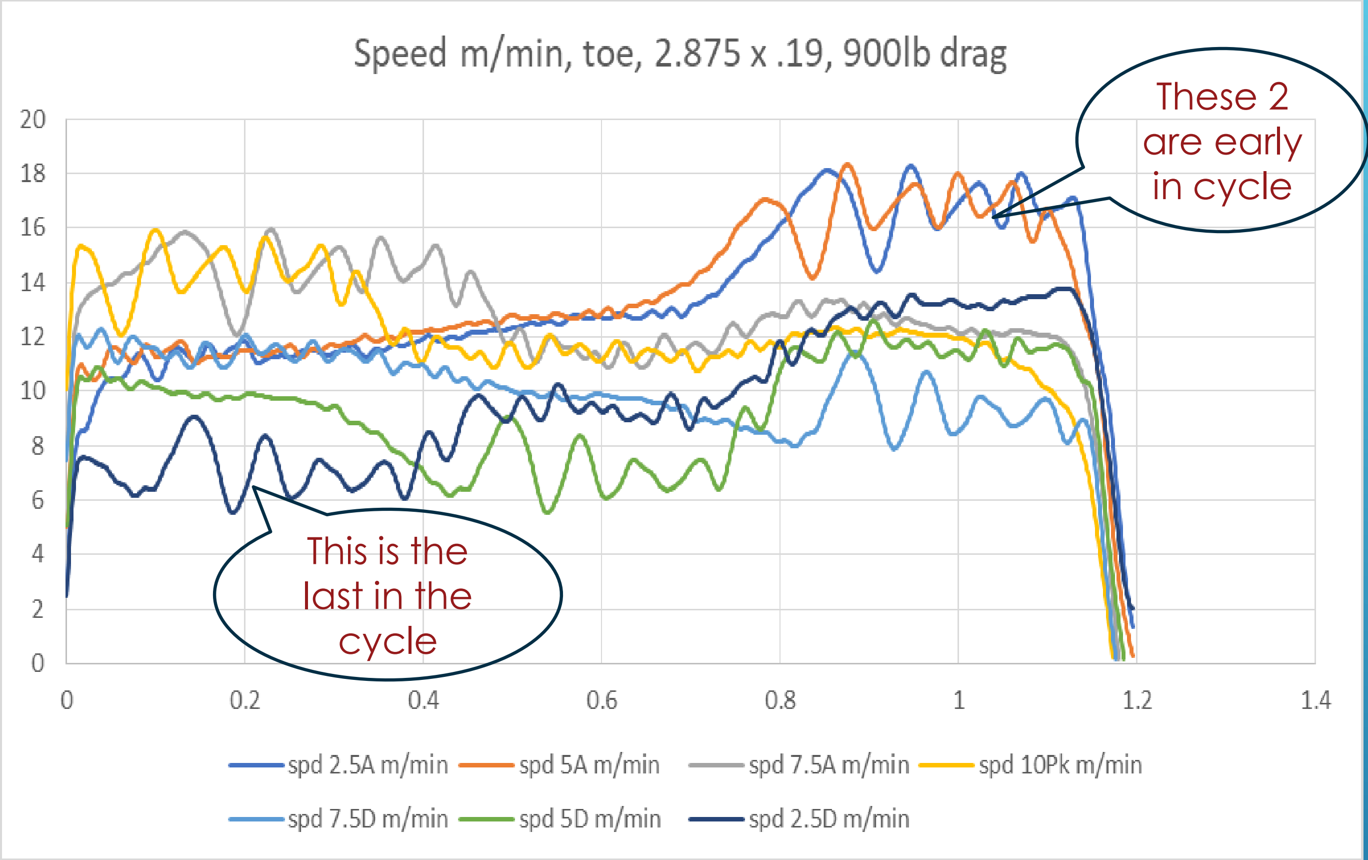


Livesim simulation of launching from 9 points in the stick-slip cycle.
Distance (m) vs time (sec).

Result: BHA travels 0.27m launched from early in the cycle vs 0.18m from late in the cycle.

Next, plotting speed vs time from the same simulations…

LAUNCH & TRANSIT 2



Livesim simulation of launching from 9 points in the stick-slip cycle.
Speed (m/min) vs time (sec).

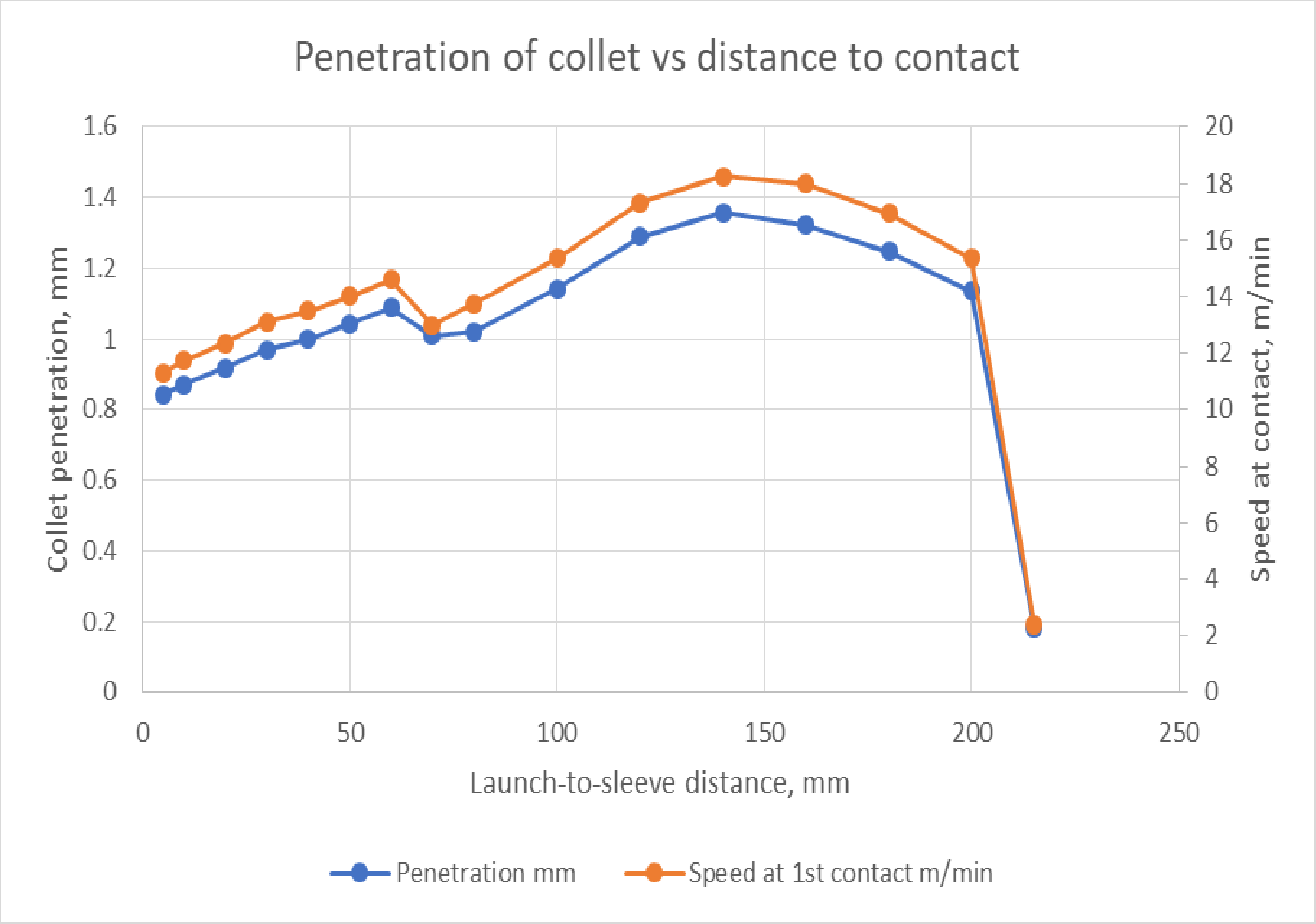
Result: wide variation in speed at any time.
Also, note that travel duration is same for all.

Next, we look at how these speed variations influence the potential for pop-thru failures.

CONTACT 1

- Simulate the collets striking a sleeve placed at a range of distances from launch.
- The spring constant of the collets is 1.25 E7 N/m (71,000 lb/in).
- Pop-thru will occur if the collets penetrate 2mm beyond the contact point.

CONTACT 2



This is from the same data set, using the #2 condition (launched early in the stick-slip cycle when accelerating from 5 m/min).

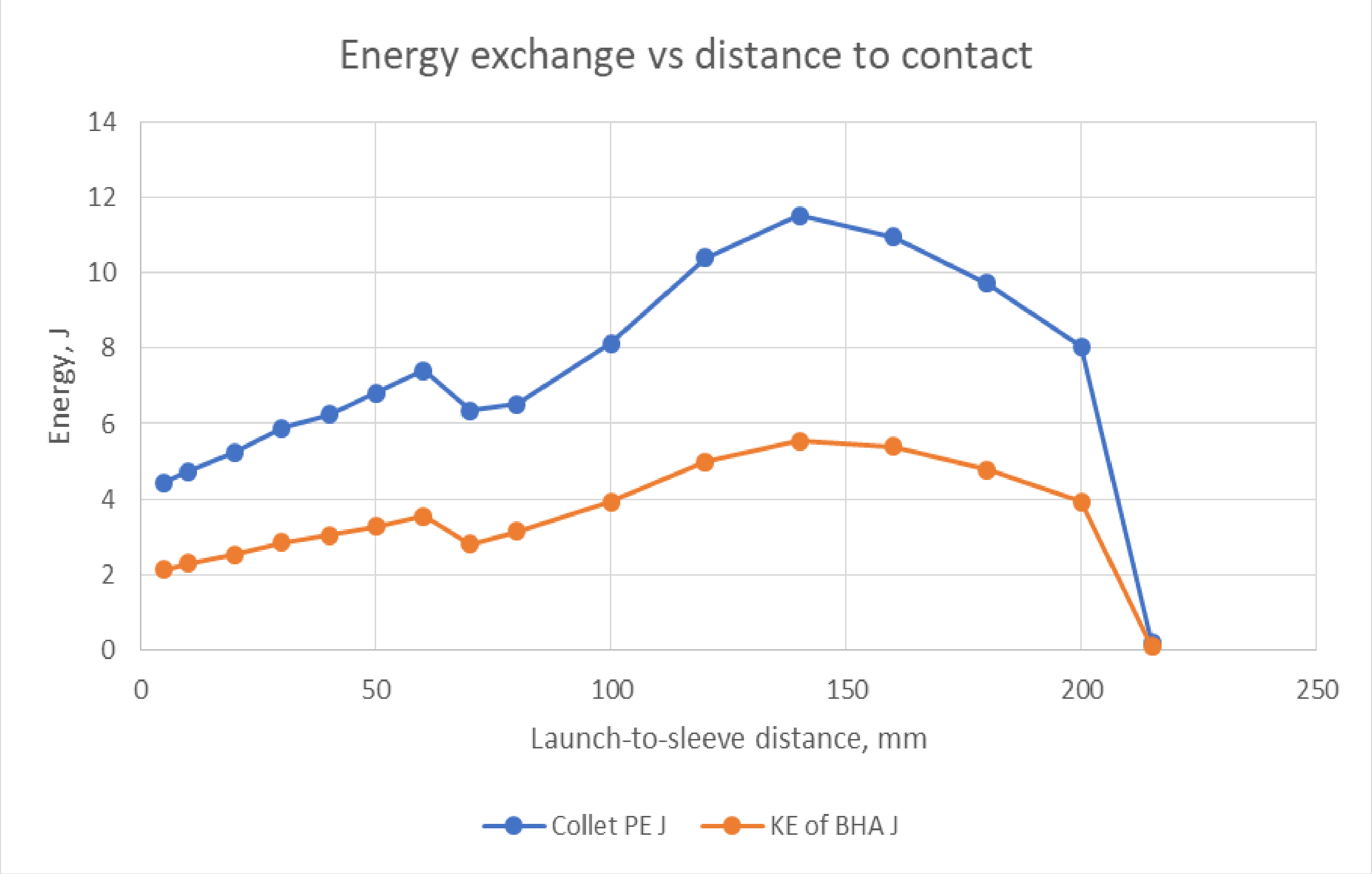
The sleeve is placed between 5 and 215mm from the launch point.

RHS scale: BHA speed at contact (orange), LHS scale: distance the BHA moves while compressing the collets.

Pop-thru would occur at 2mm.

Conclusion: there is a close linear relation between contact speed and collet penetration.

CONTACT 3



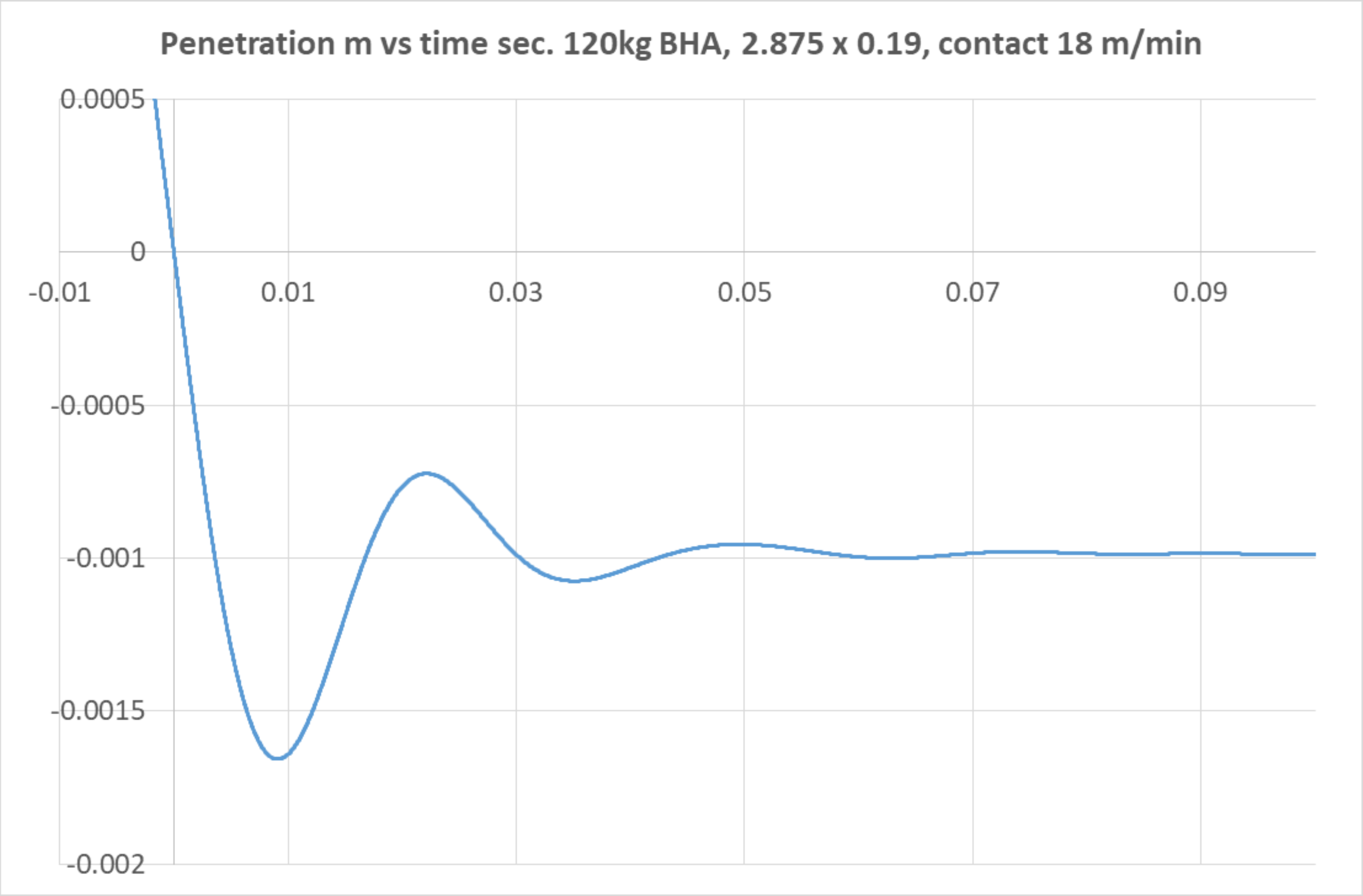
<u>Balancing the energy budget.</u>

From the previous chart, convert the BHA mass and speed to kinetic energy and convert the deflection of the collet springs into potential energy.

There was not enough KE available in the BHA to provide the PE which arrives in the collets.

The discrepancy comes from a mass which has been ignored.

CONTACT 4



This plots the penetration of the collets as a function of time.

There are two forces acting on the collets. The peak is caused by the momentum change of the BHA – acting as a point mass.

The plateau is caused by the momentum change of the CT.

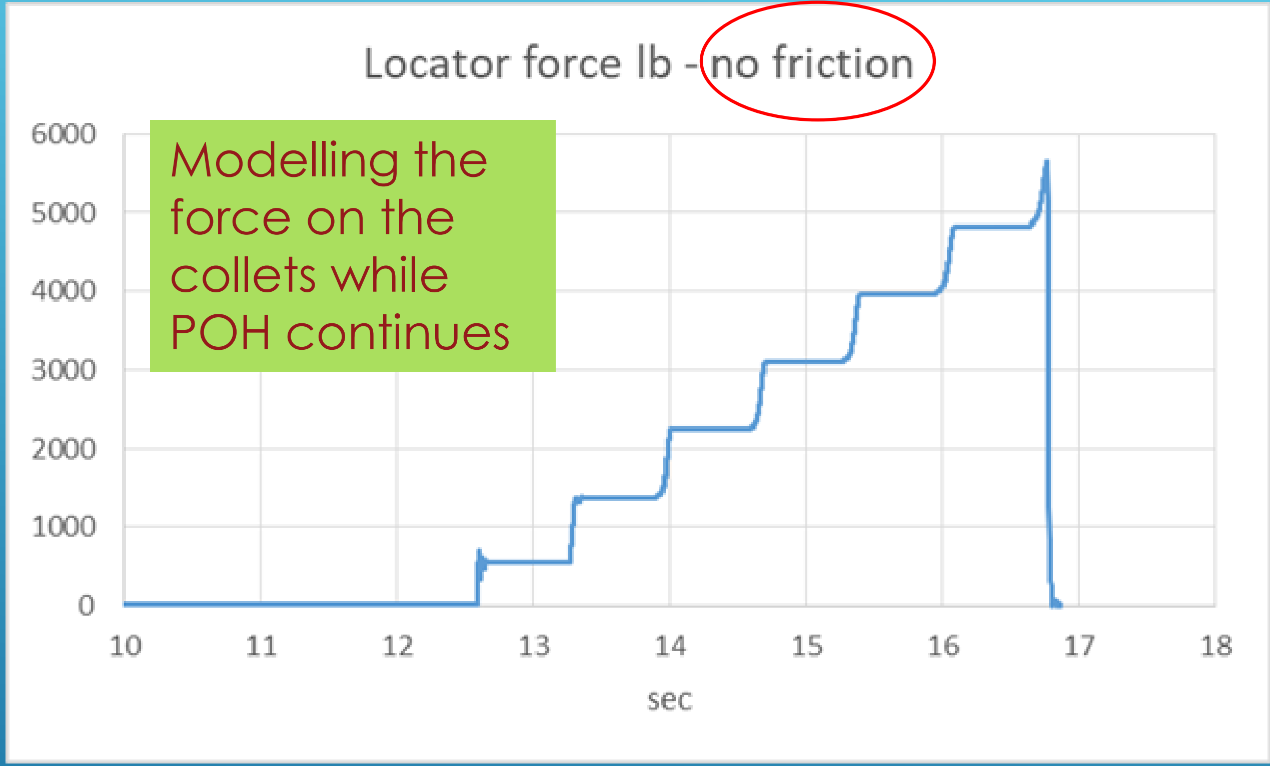
CONTACT 5

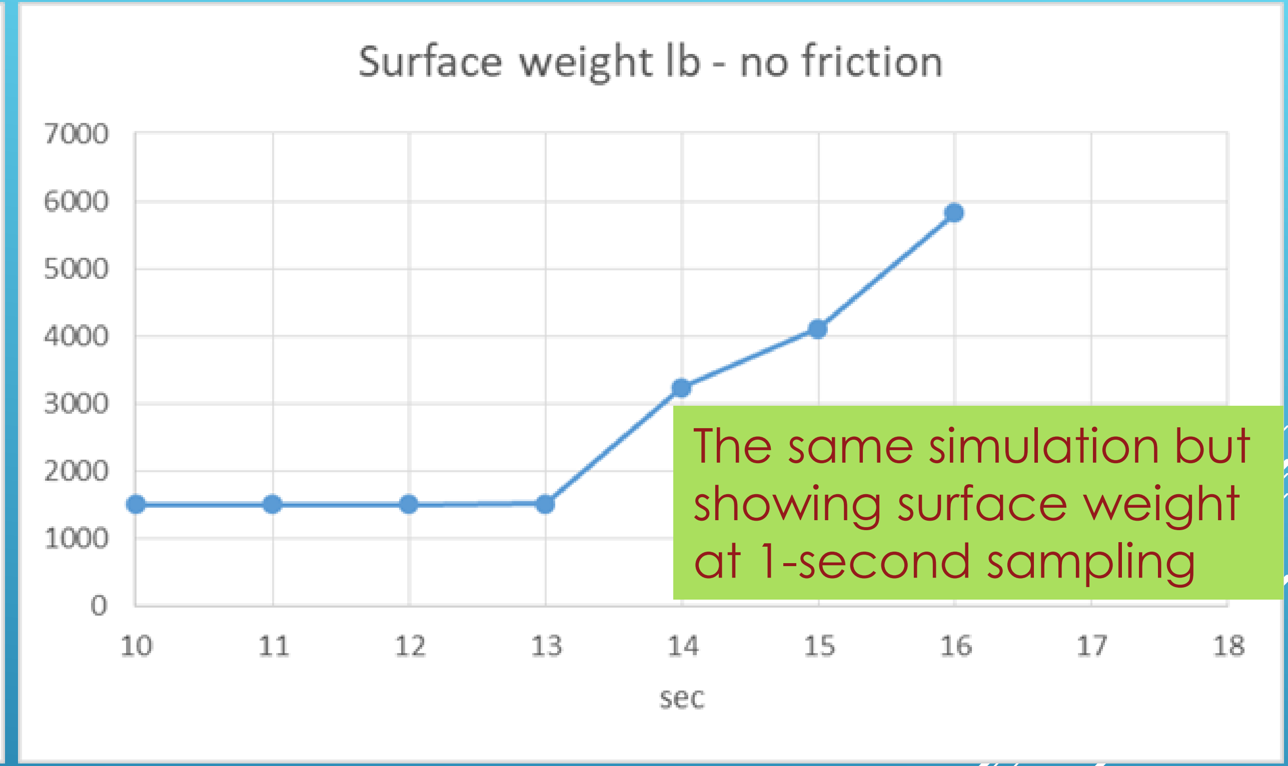
- To calculate the rate of change of momentum of CT:
- When the BHA stops, a wave of deceleration travels up the CT at the speed of sound in steel.
- The mass of the CT is 8.12 kg/m.
- Sonic velocity = 5050 m/s.
- CT is moving at 18/60 = 0.3 m/s.
- Force = 8.12 x 5050 x 0.3 = 12.3 kN
- Penetration was 0.98 mm ≡ 12.3 kN for this collet.

FORCE BUILD-UP 1

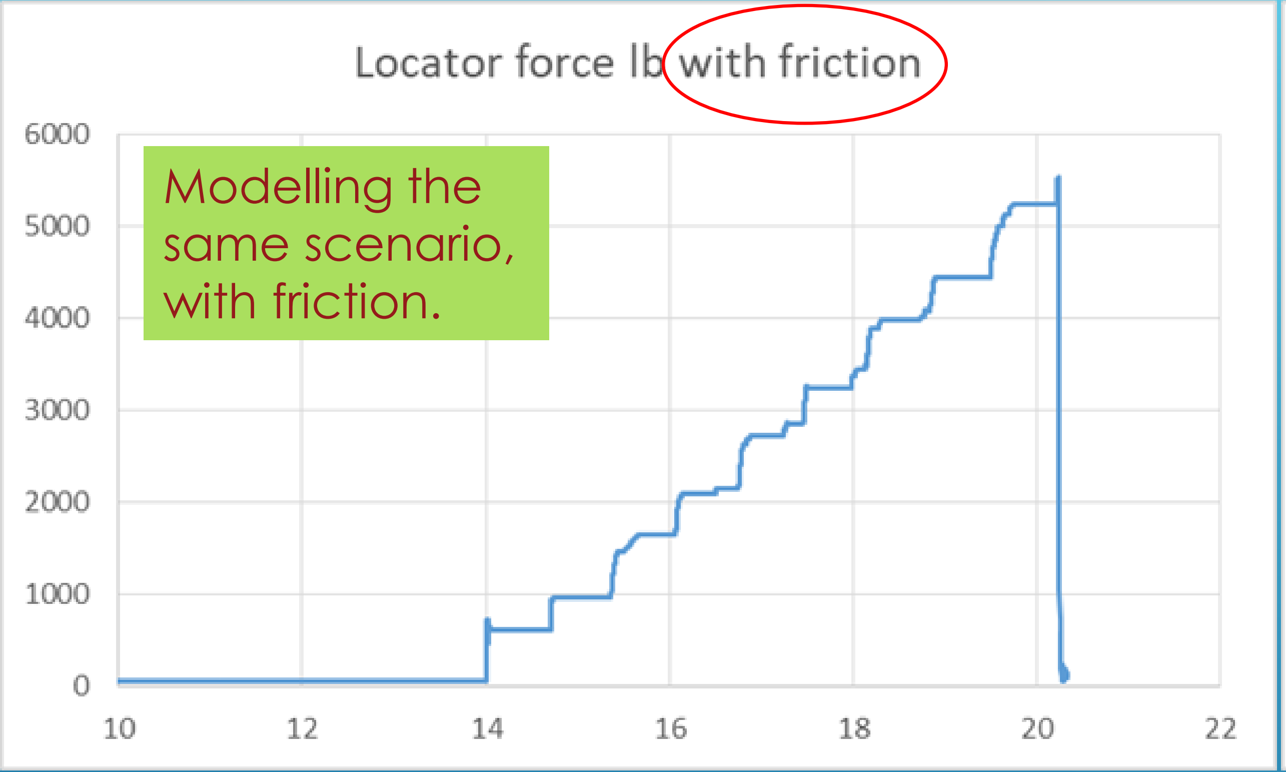
- The force on the collets is steady, once the BHA spike is damped.
- The deceleration wave travels all the way to the injector and then reflects back.
- But meanwhile the injector is still POH.
- The additional stretch of the CT is superimposed on the wave.
- It arrives at the BHA as a step-change of force and again reflects back.
- This continues until either the BHA pulls through or the injector stops.

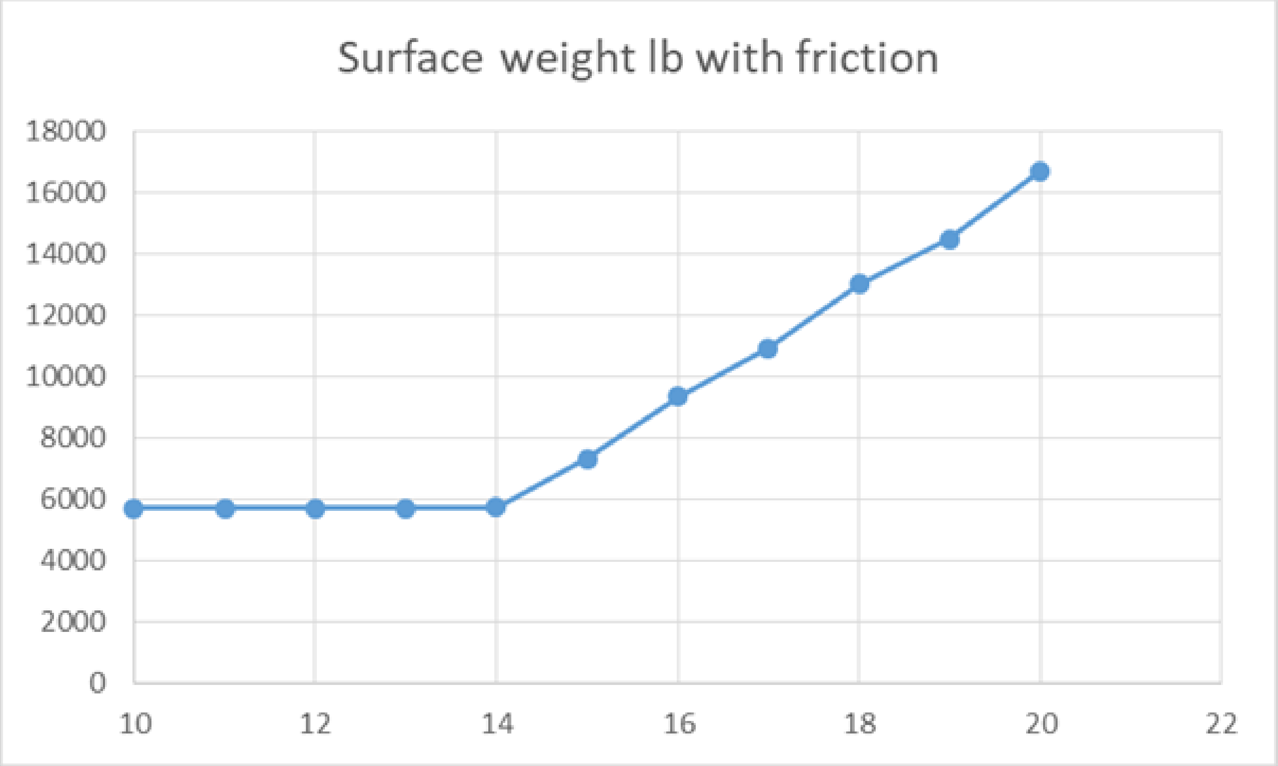
FORCE BUILD-UP 2



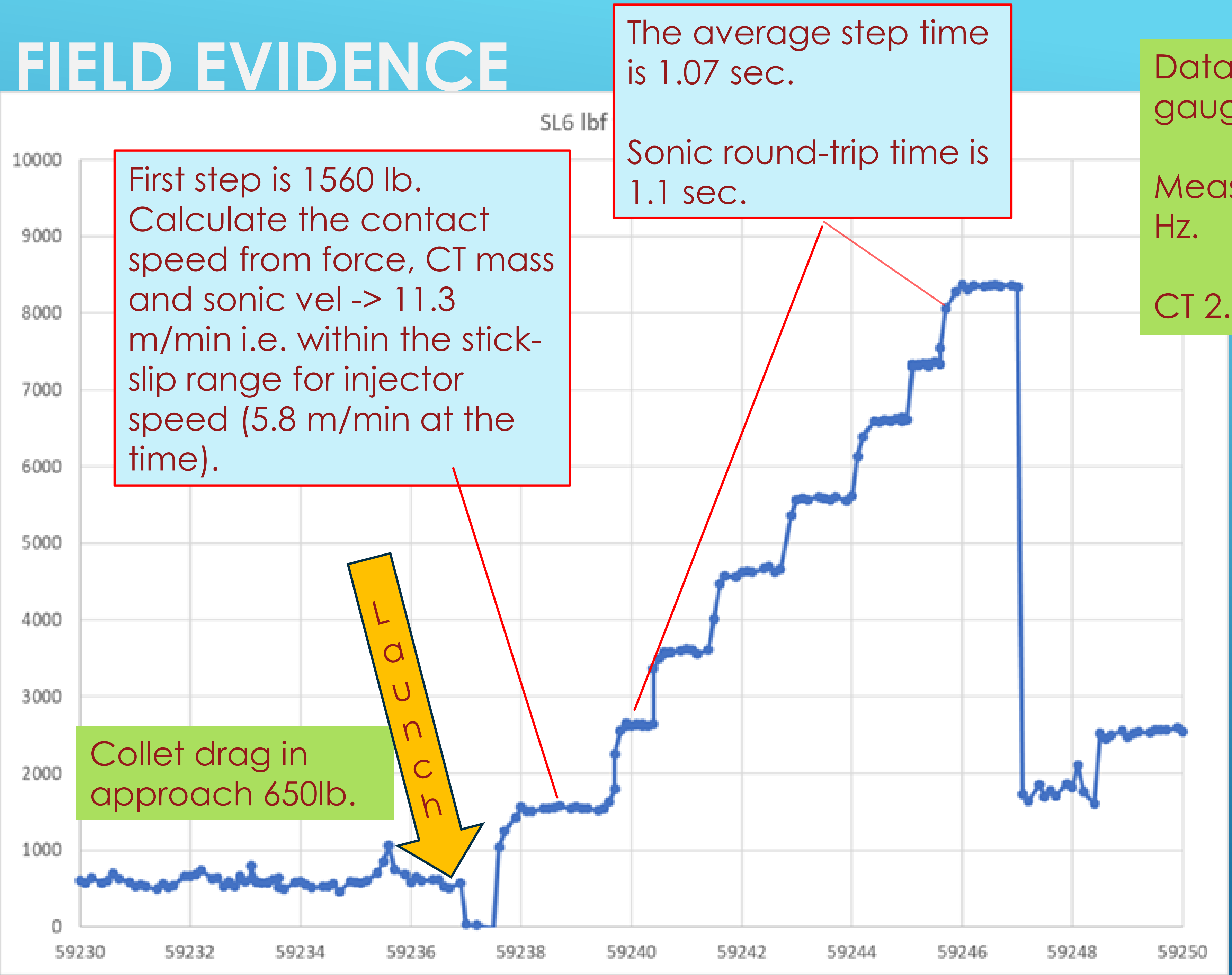


FORCE BUILD-UP 3





FIELD EVIDENCE

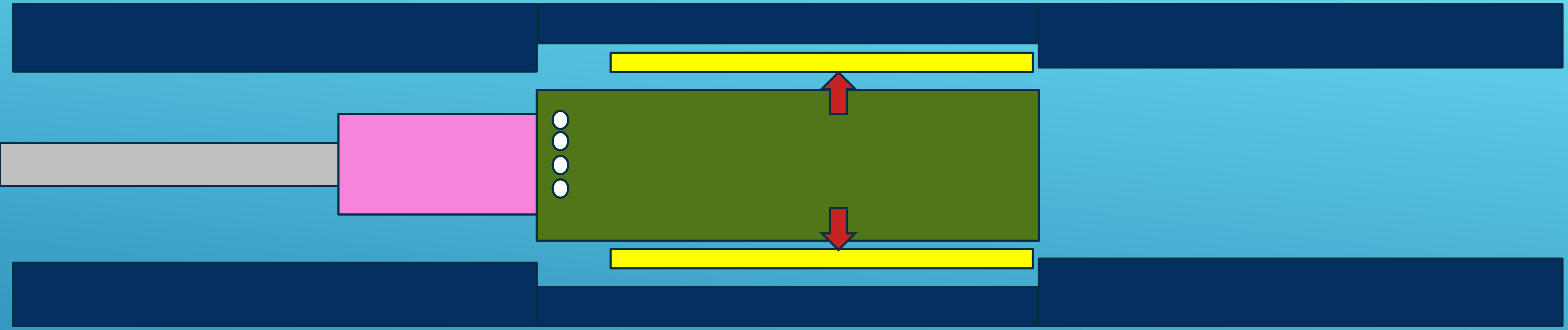


Data recorded on an NCS memory gauge in Alberta in 2017.

Measuring pull lbf in the BHA at 10 Hz.

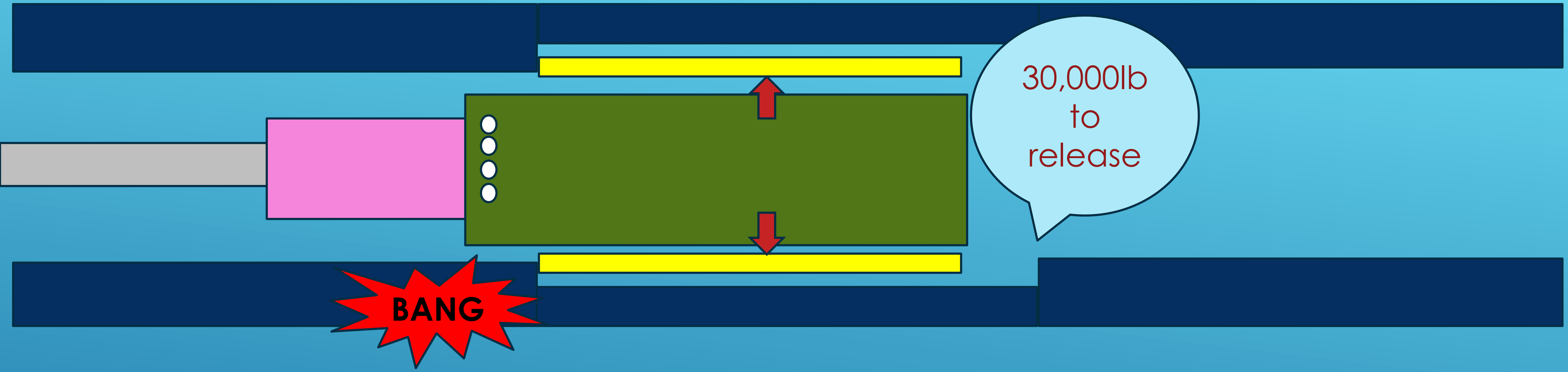
CT 2.625 x .188 at sleeve #6, 2792m.

LAUNCH WITH HIGHER FORCE 1



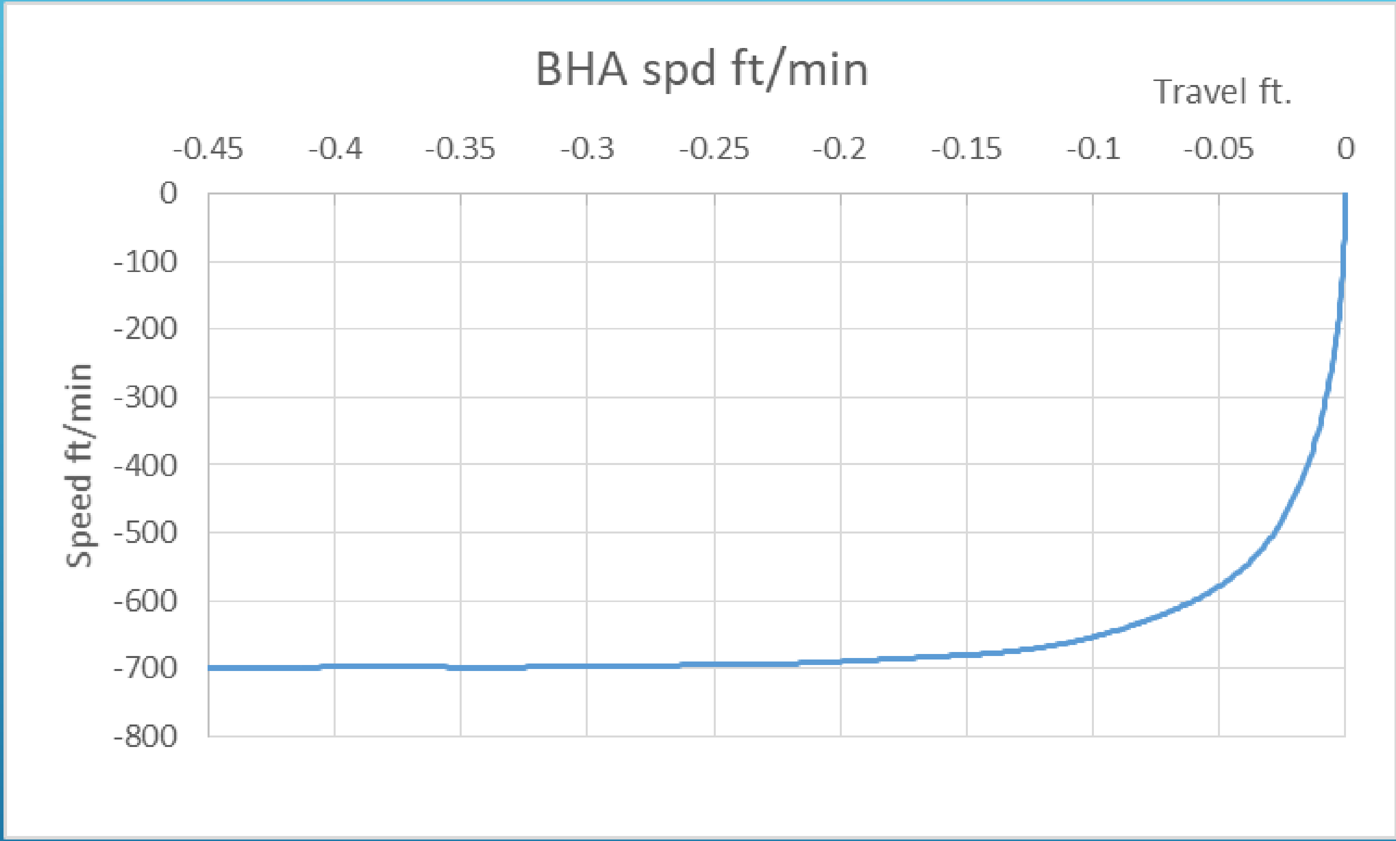
- Shifting a sleeve needs a high pull force.
- How fast will it be travelling when it hits the end stop?
- What consequences might there be for the BHA?

LAUNCH WITH HIGHER FORCE 2



- BHA + inner sleeve 275lb; shift distance 5.4”
- Multiple half-hard brass shear pins total 42,900 lb
- CT 2.875 x .175
- Shear-sub mass 20lb

LAUNCH WITH HIGHER FORCE 3



Hits the stop at 700 ft/min (3.6 m/sec)

Penetration is not involved but the calculated stable force from CT = 30,350 lb.

The total shear pin failure load is 42,900 lb but that is the ultimate load, not yield.

SHEAR PINS

- Tensile yield stress of the brass is 55,000 psi.
- The major stress on the pins is shear; shear yield of this alloy is not specified but if it is in proportion to tensile yield, the pins will start to yield at 30,400 lb.
- Other considerations:
  - The point mass of the shear sub above the pins will add KE of 63 J
  - Weakest pin will yield first.
  - Derate the material at temperature.

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Low-cycle multiaxial fatigue behaviour and fatigue life prediction for CuZn37 brass using the stress-strain models

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A B S T R A C T

The low-cycle, strain-controlled fatigue tests have been conducted on CuZn37 brass (ASTM: C27200, EN: CW508L). Machined specimens have been subjected to uniaxial, proportional and non-proportional axial-torsional loadings. The monotonic and cyclic material properties have been determined for the loadings used. The obtained fatigue lives have been analysed in reference to the total Huber-von Mises equivalent strain ranges, the hysteresis loops energy in the loading cycle and the total plastic strain energy in the fatigue test. The relations between the plastic strain energy and the total as well as the plastic strain have been described. On the basis of the obtained experimental results, the selected stress-strain multiaxial fatigue criteria have been evaluated. In the conclusion it was found that fatigue lives predicted using

SHEAR PINS

- The authors conducted tests on the European equivalent material grade.
- They found a fatigue life of 383 cycles at 0.8% strain.

ICOTA

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Calgary

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