Distinguished Lecturer Program

Primary funding is provided by

The SPE Foundation through member donations and a contribution from Offshore Europe

The Society is grateful to those companies that allow their professionals to serve as lecturers

Additional support provided by AIME

Society of Petroleum Engineers
Distinguished Lecturer Program
www.spe.org/dl

Distinguished Lecturer Program

PERFORATING FOR INFLOW PERFORMANCE IN NATURAL COMPLETIONS

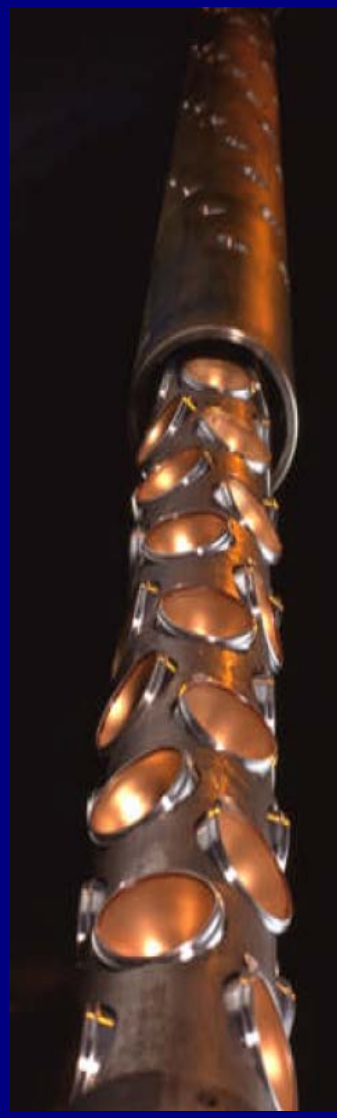
Mark S Brinsden

Shell

Society of Petroleum Engineers
Distinguished Lecturer Program
www.spe.org/dl

OUTLINE OF PRESENTATION

- INTRODUCTION
- THE TRADITIONAL APPROACH TO PERFORATING
- MEASURING PERFORATOR PERFORMANCE
- MODELING PERFORATORS FOR WELL PERFORMANCE
- CASE HISTORY
- RECENT ADVANCES IN PERFORATING TECHNOLOGY
- IMPLEMENTING WHAT WE HAVE LEARNED



THE TRADITIONAL APPROACH TO PERFORATING

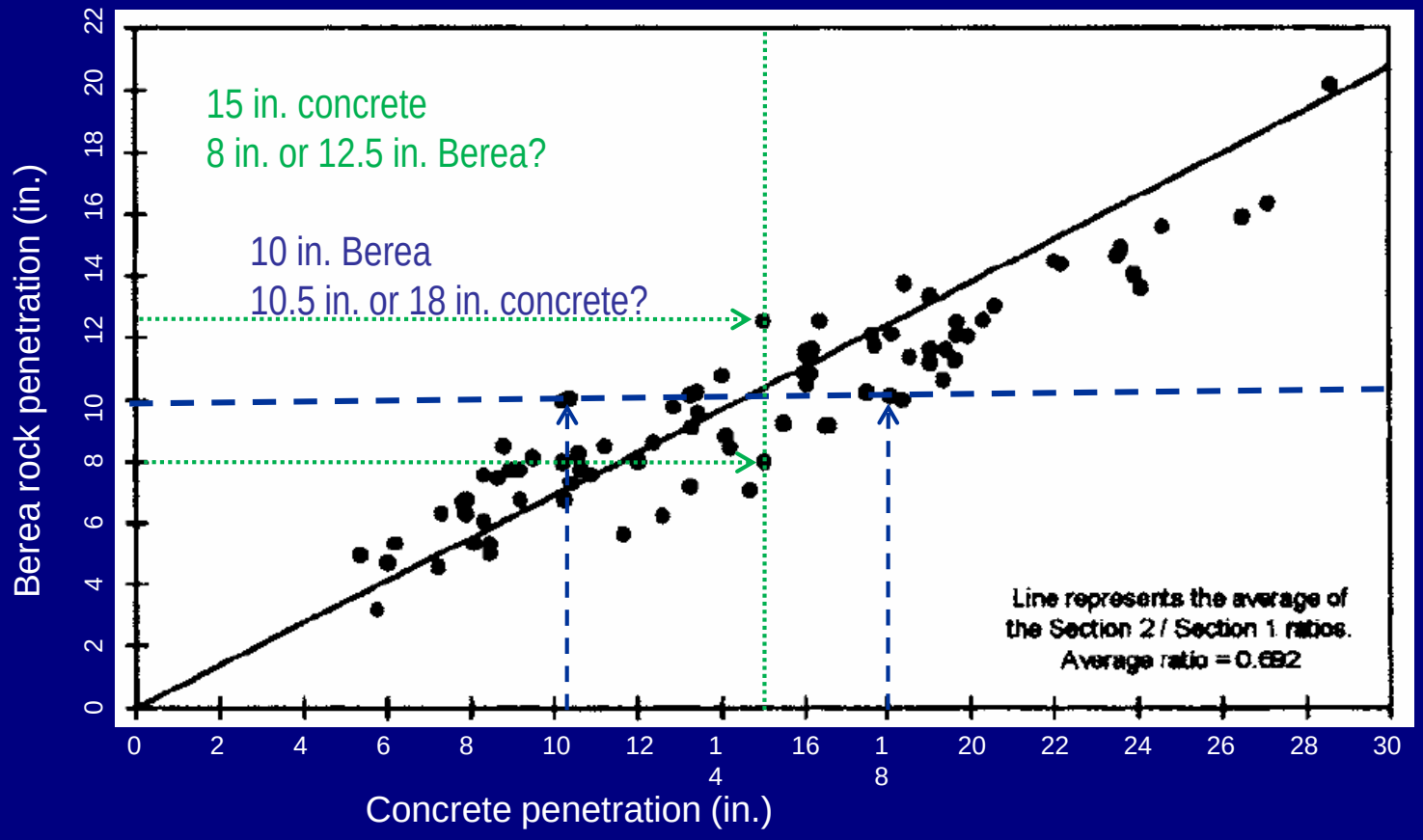
- For most wells, perforating is the only connection to the reservoir.
- Getting this right is essential to well performance.
- But what do we normally do?
- Use API RP Sect 1 concrete performance
- But....

"Penetration Data recorded in API RP19B Section 1 may not directly correlate to penetration downhole".

- From API RP 19B under revision

THE TRADITIONAL APPROACH TO PERFORATING

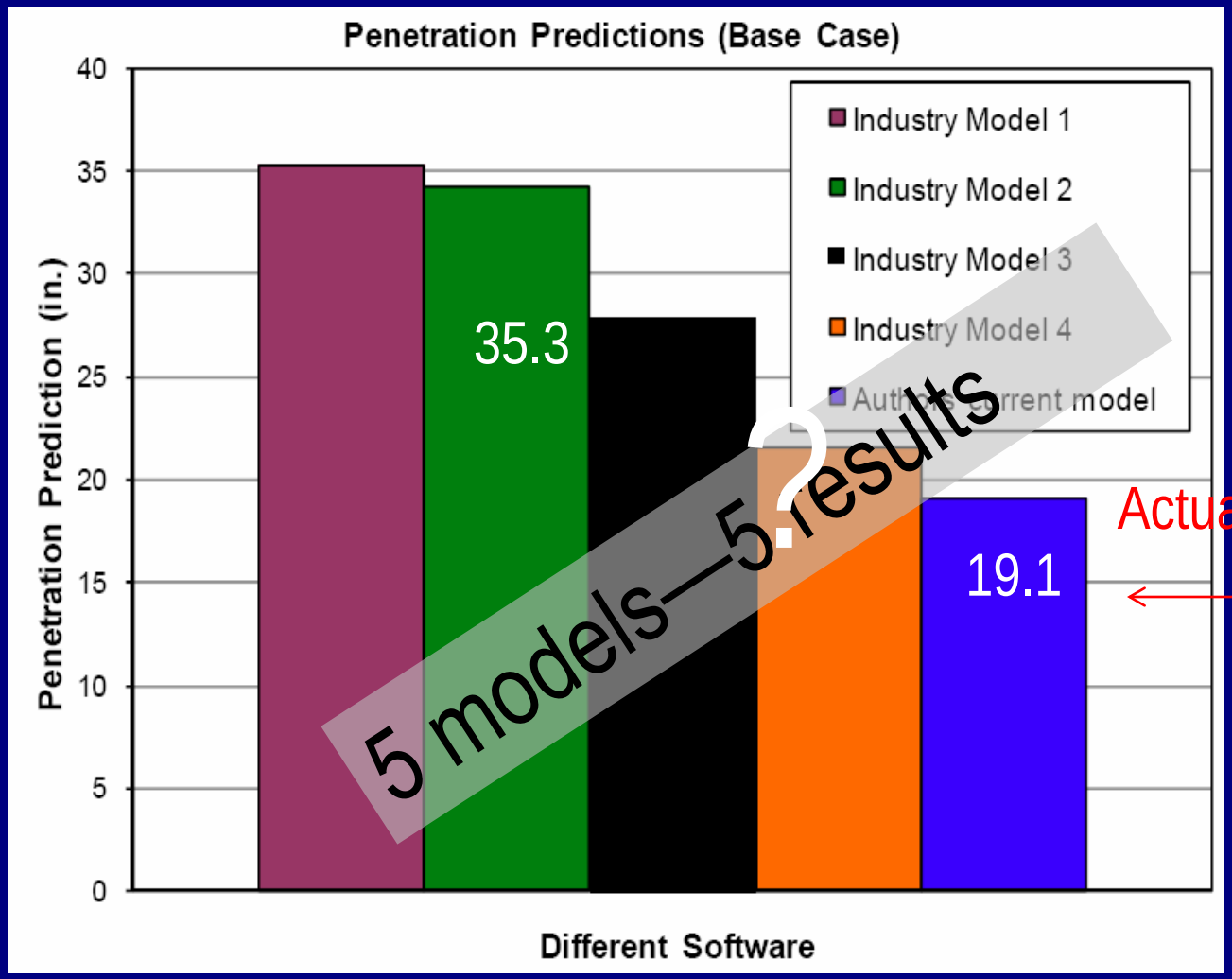
- Sect. 1 concrete data correlation to Sect. 2 rock penetration



This is old published data and has been known for years.

THE TRADITIONAL APPROACH TO PERFORATING

- Modeled penetration

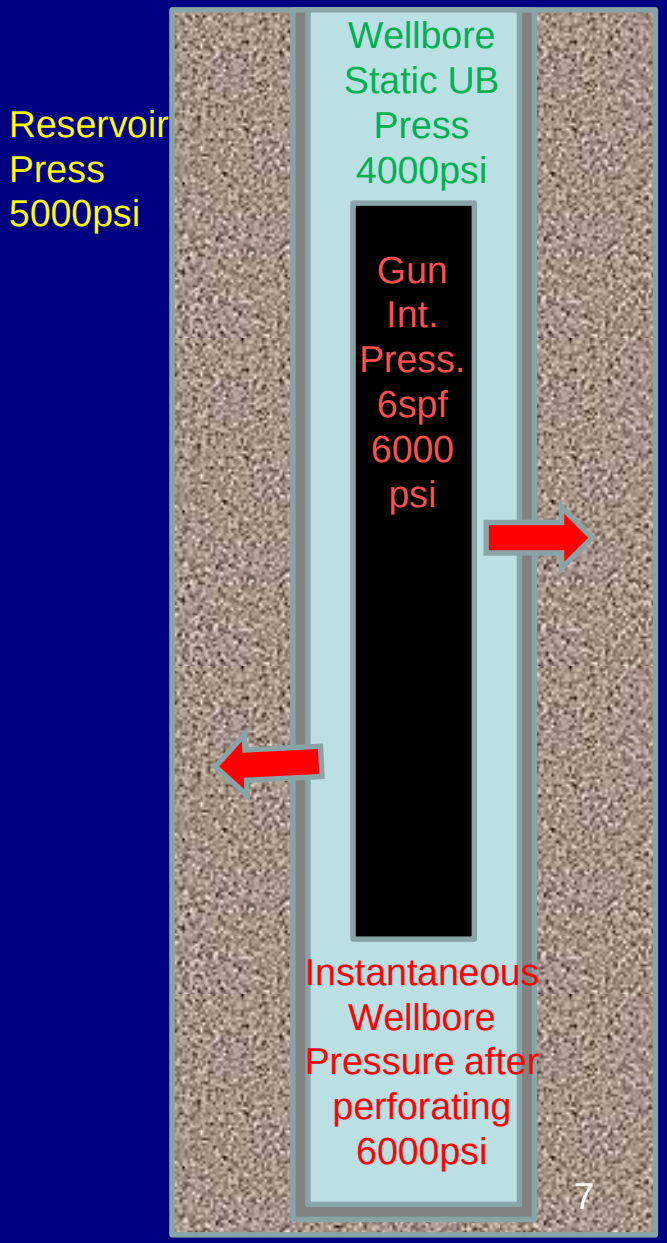


SPE 125020

Actual Stressed Rock
14.4

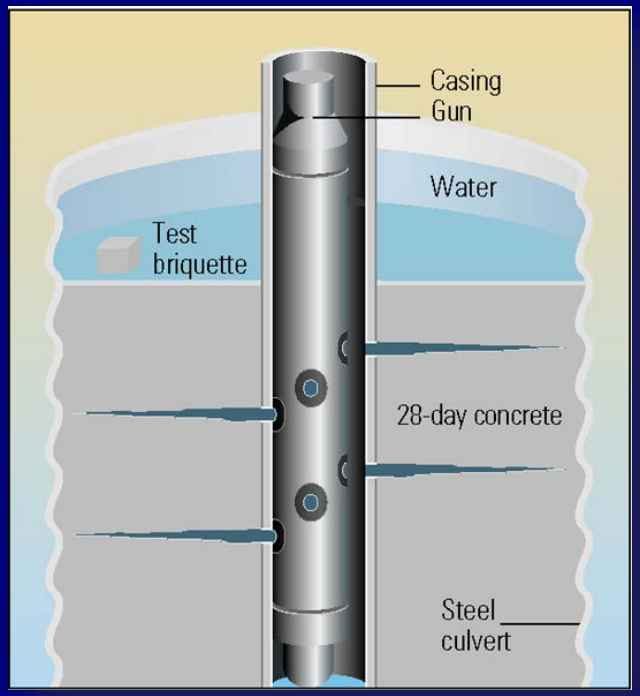
THE TRADITIONAL APPROACH TO PERFORATING

- Use a static underbalance to clean up the perforations and the well
  - But - if the gun pressure is higher than the reservoir pressure – then the well will be instantaneously overbalanced during perforating
  - Perforations do not clean up immediately
  - In some reservoirs few perfs will clean up at all, as they were not actually shot underbalanced
  - Unexpected poor well performance – from poor perforating design



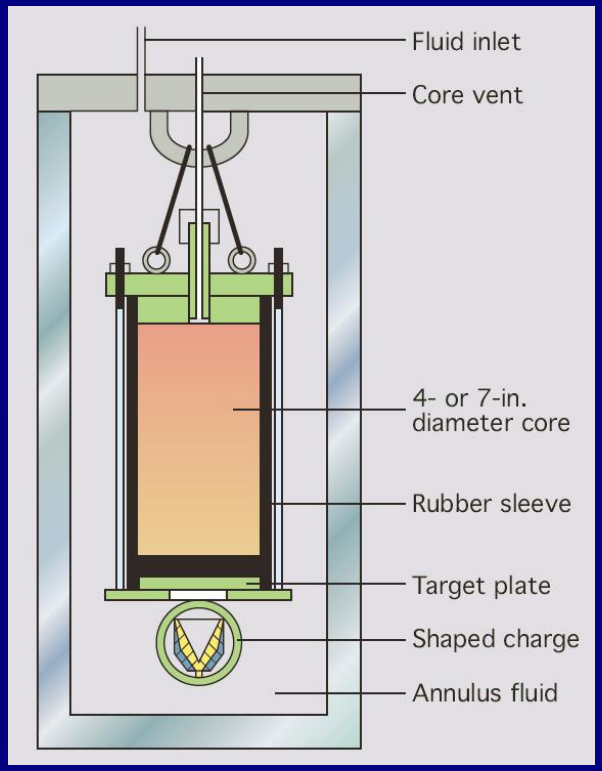
MEASURING PERFORATOR PERFORMANCE

- Perforator performance is generally measured using API Recommended Practice 19B (currently being revised)
  - Charge and gun performance are currently identified by Section 1
  - Section 1 provides a good overall indicator of gun interference and range of perforator penetration
  - Does not provide useful measure of rock penetration

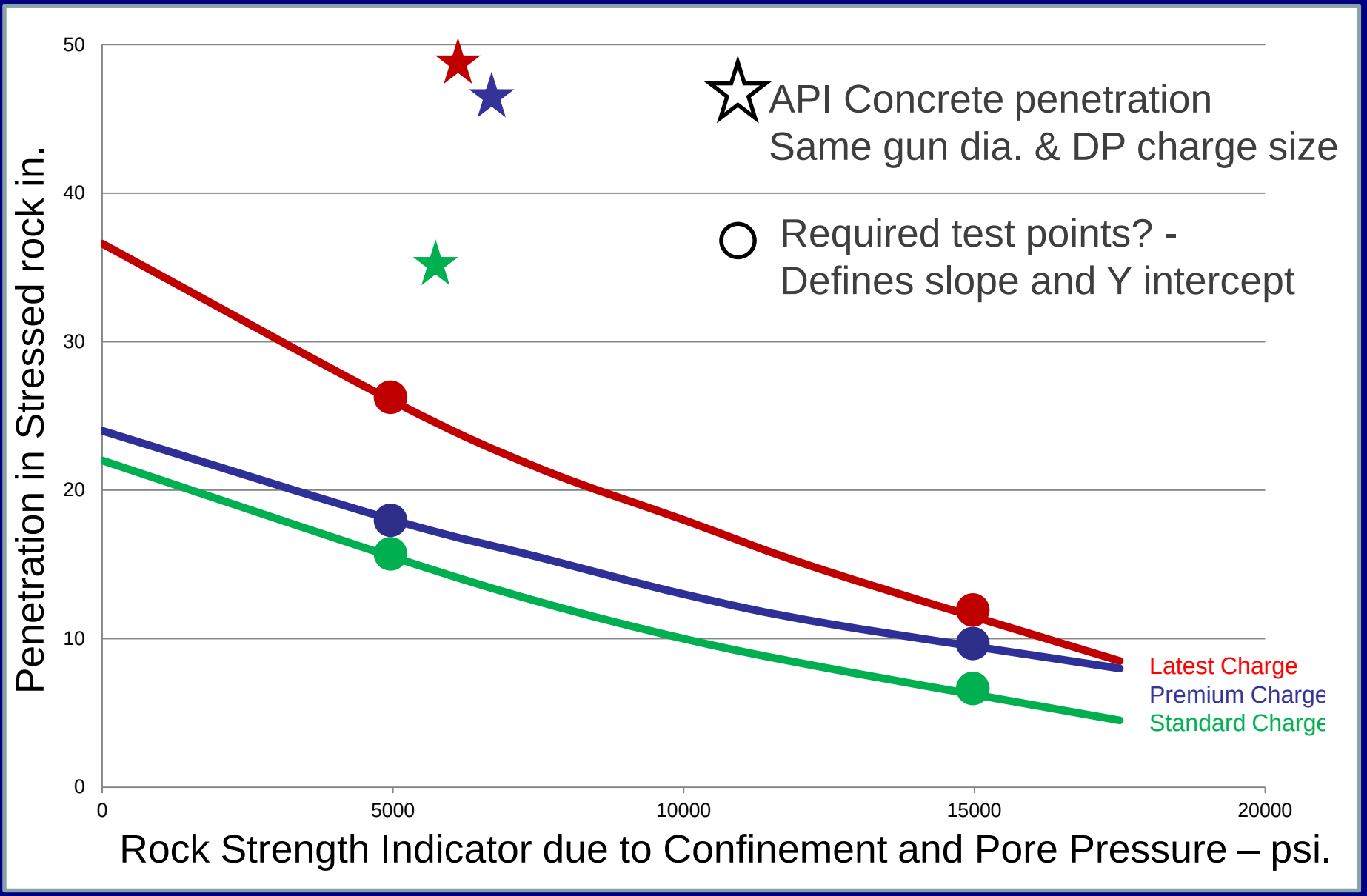


MEASURING PERFORATOR PERFORMANCE

- To partially simulate downhole conditions charges are tested in stressed rock using Section 2 testing
- A good estimate of charge penetration can be achieved using core material or similar outcrop rock targets

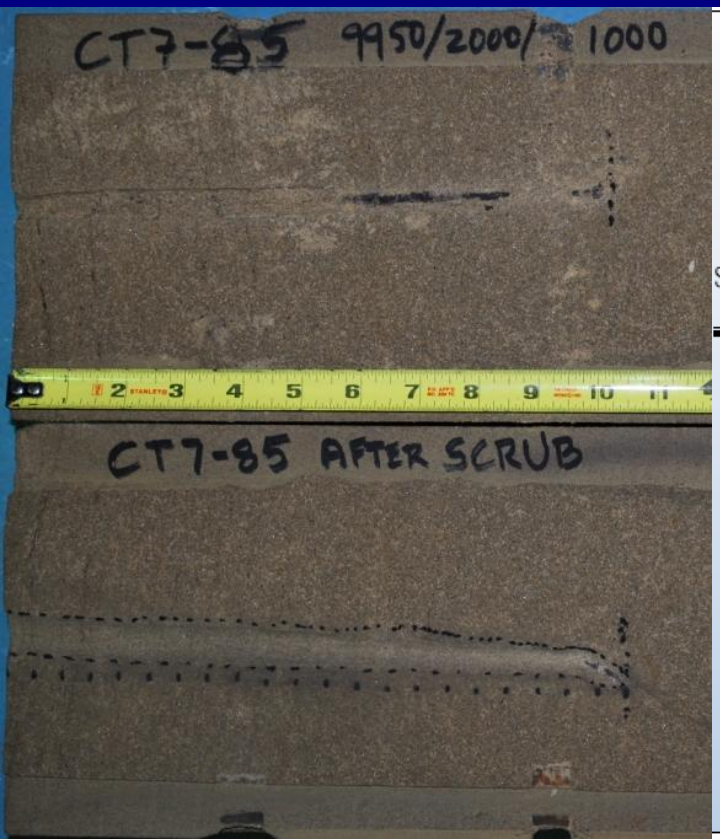


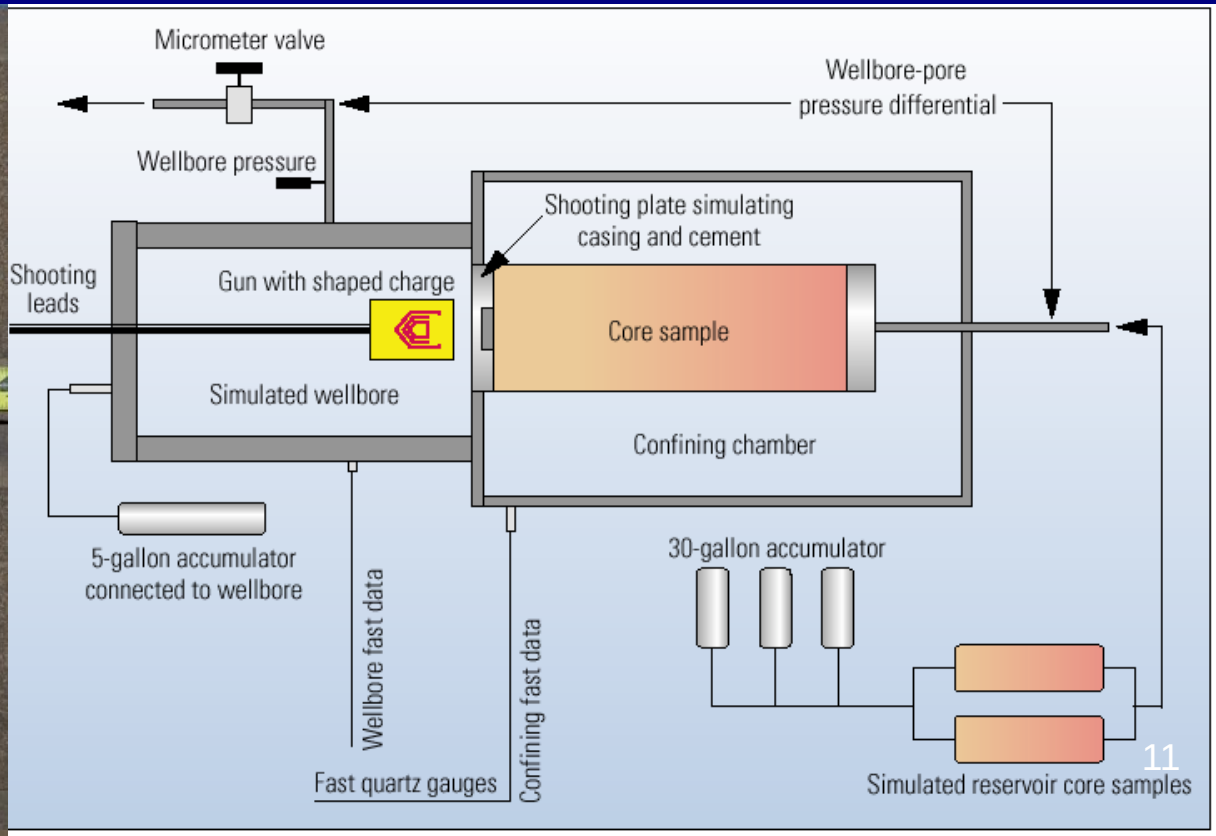
MEASURING PERFORATOR PERFORMANCE



MEASURING PERFORATOR PERFORMANCE

- Perforating tunnel dynamics can be simulated using Section IV
- Test conditions must be rigorous (charge container volume) and the test facility should simulate the reservoir conditions
- Example of actual and cleaned tunnel – how to get a clean tunnel?





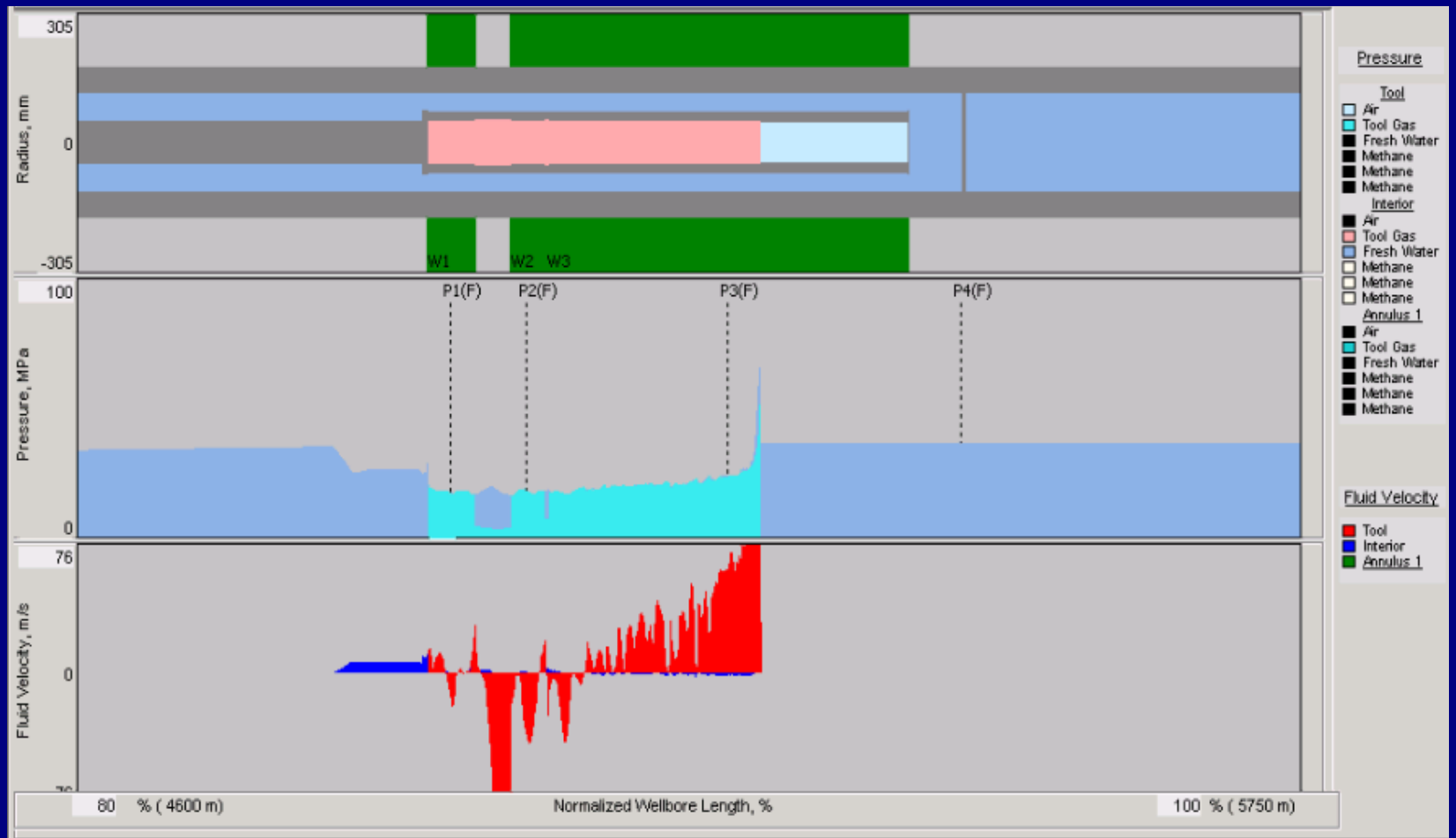
MODELING PERFORATORS FOR WELL PERFORMANCE

- Model Perforations for gun dynamics and penetration
  - Gun Dynamics –
    1. Dynamic Underbalance surge to clean tunnels and remove crush zone
    2. Identify DUB to avoid excessive sand production – stuck guns
    3. Dynamic Overbalance or Extreme OB to clean tunnels and for tip fracs
    4. Modelling propellants for propellant fracturing (not covered)
    5. Modelling gun movement to avoid fishing jobs (not covered)
  - Perforating Penetration & Inflow -
    1. Model relative penetration under reservoir conditions
    2. Model well inflow (or injection) performance

MODELING PERFORATORS FOR WELL PERFORMANCE

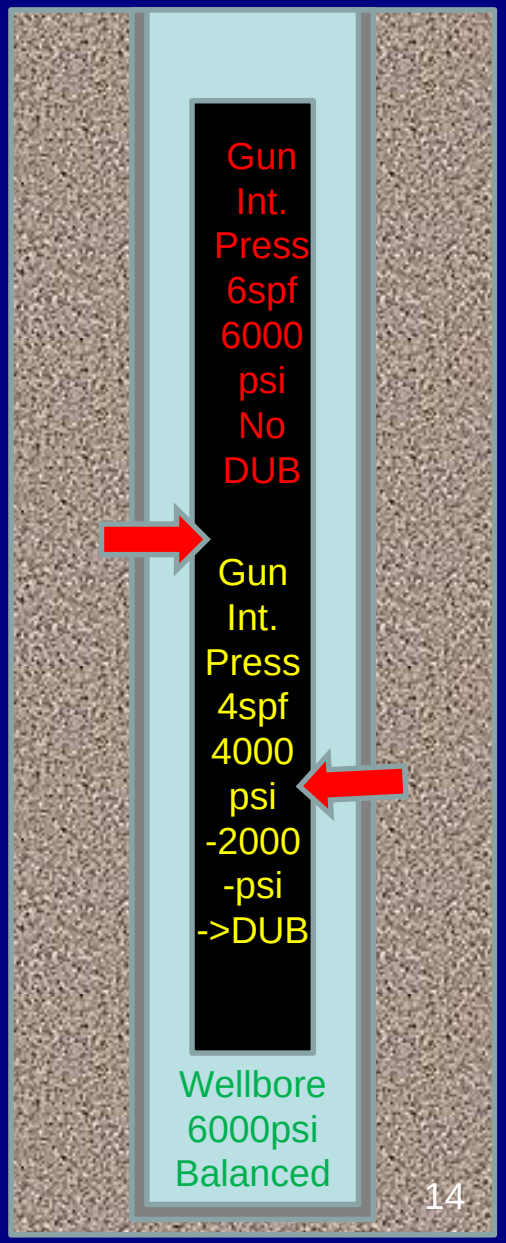
- Gun Dynamic models

  Dynamic Underbalance surge or instantaneous surge to clean tunnels and remove crush zone



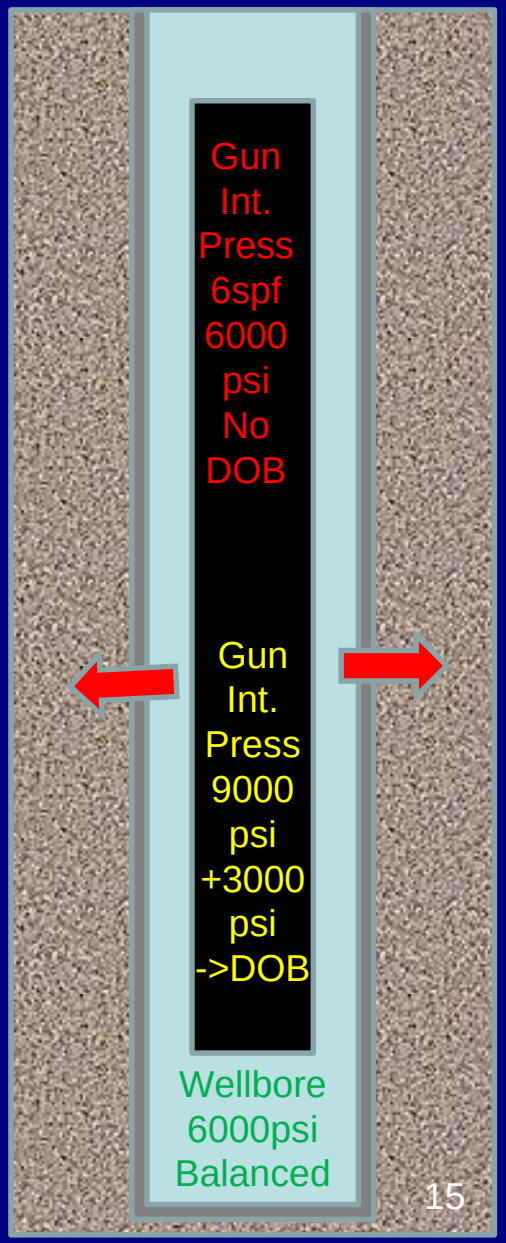
MODELING PERFORATORS FOR WELL PERFORMANCE

- Generate dynamic underbalance surge to clean perforation tunnels and remove crush zone
- Unintentional dynamic UB can draw sand from perforations
- Unwanted fill and or stuck guns can result
- Given rock properties and gun dynamics it is possible to model sand production



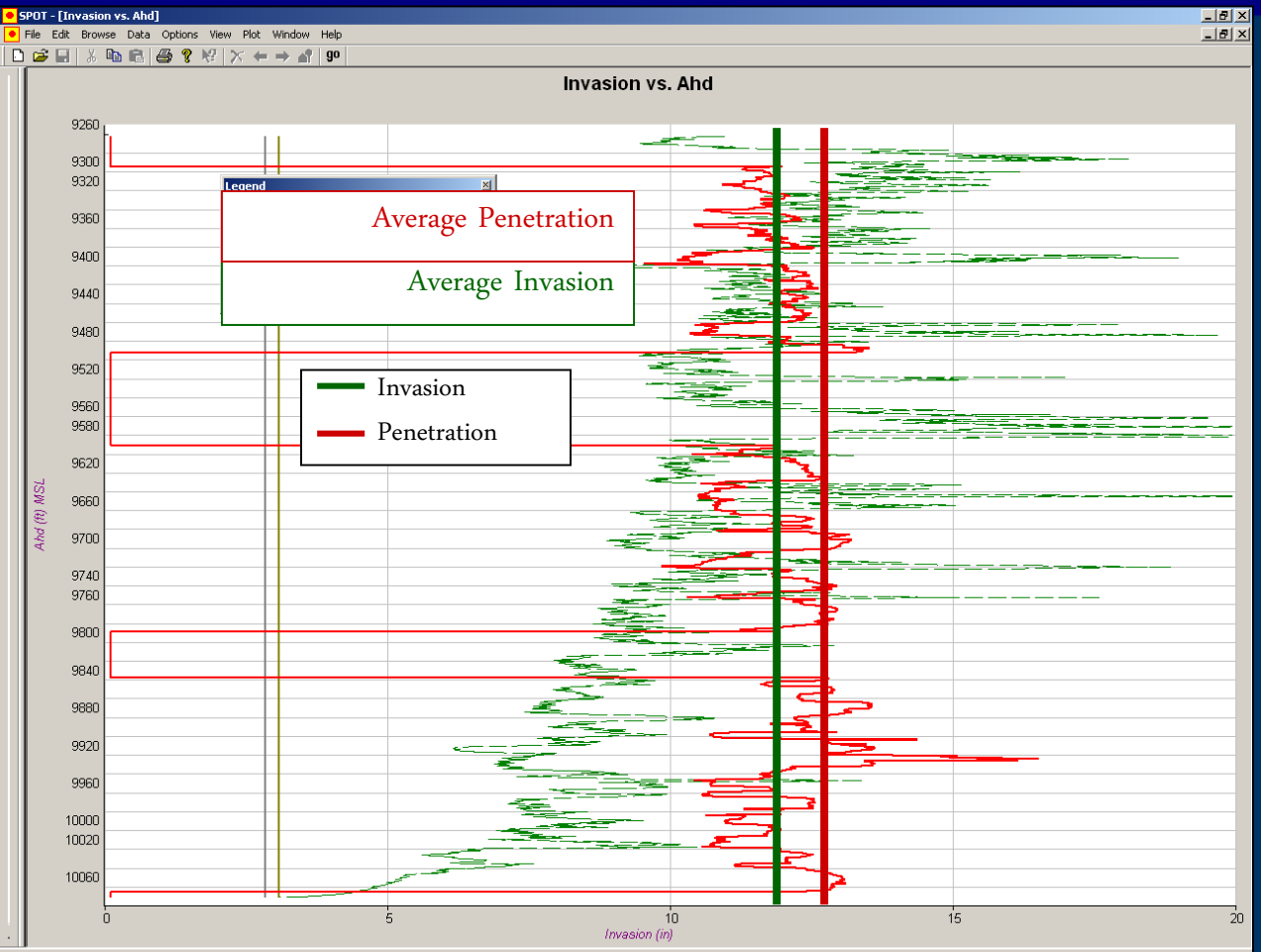
MODELING PERFORATORS FOR WELL PERFORMANCE

- Generate Dynamic Overbalance or Extreme OB to generate small fracs at the tunnel tip
- Dynamic OB difficult to achieve if :-
  - Gun internal pressure <= wellbore / reservoir pressure – overbalance can become underbalance
- Extreme OB has been successfully applied
  - As a frac alternative in shallow reservoirs
  - For pre-frac perforating to assist in reducing frac initiation pressure



MODELING PERFORATORS FOR WELL PERFORMANCE

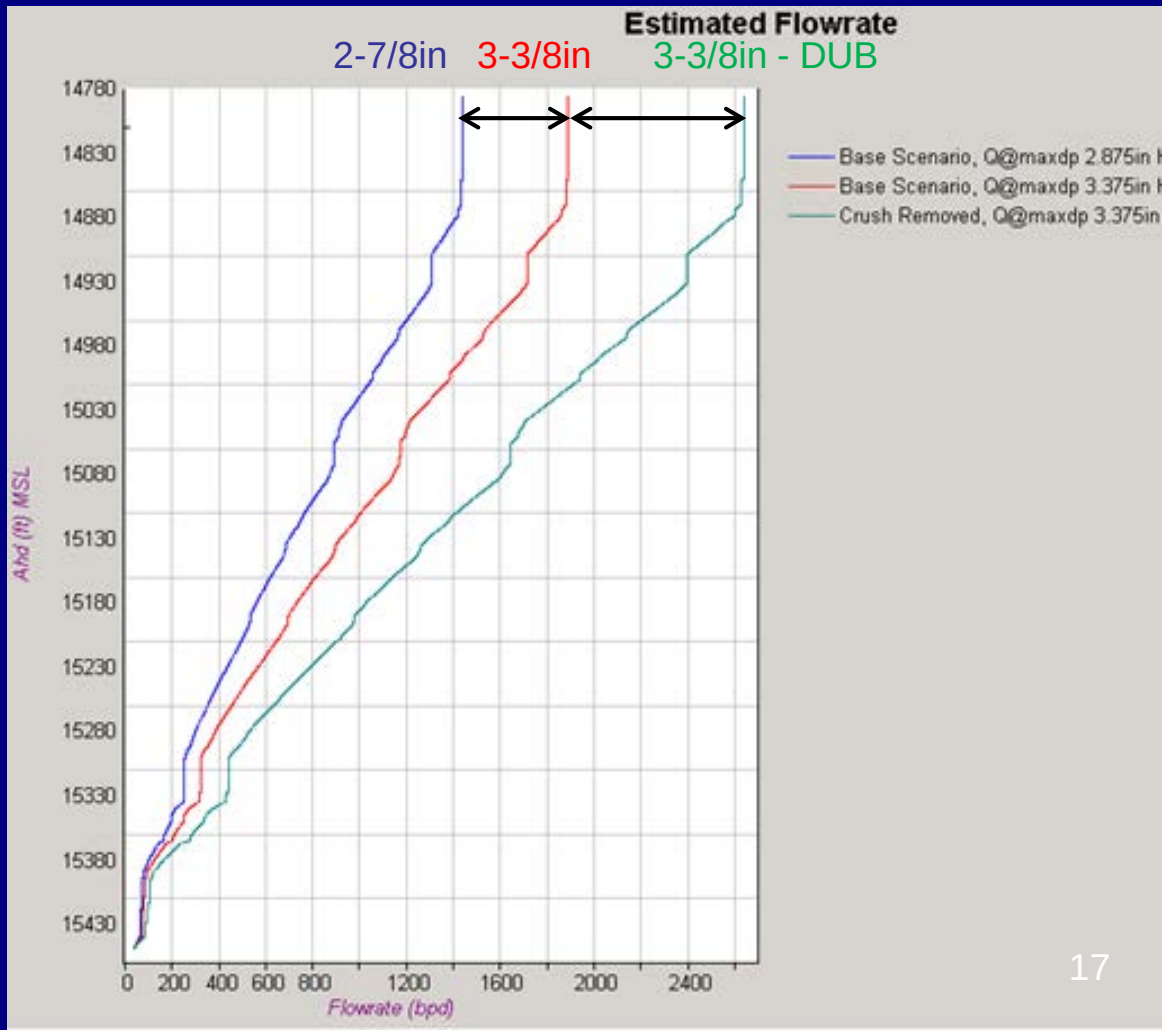
- Perforating Penetration & Inflow models should be used to model relative penetration under reservoir conditions



- Perforation penetration should be modelled at layer or petrophysics data resolution
- Average penetration data leads to very poor estimation of flow
- Detailed knowledge of penetration helps with understanding penetration versus filtrate invasion

MODELING PERFORATORS FOR WELL PERFORMANCE

- Perforating Penetration & Inflow models should be used to model well inflow (or injection) performance
  - Detailed knowledge of penetration and reservoir permeability helps identify which intervals to perforate
  - Possible to compare charges
  - Possible to identify impact of crush zone removal on flow

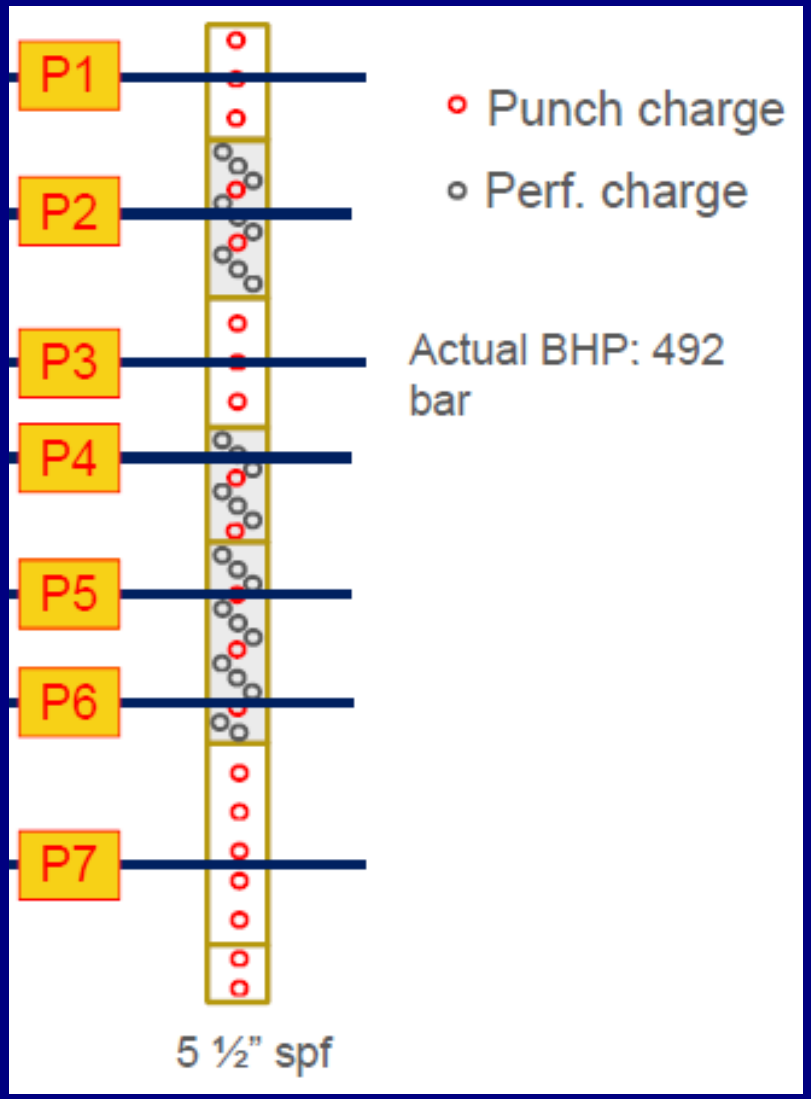


CASE HISTORY

- Apply comprehensive modelling and experience of perforating to a real well condition:-
  - Moderately tight gas well
  - Permeability sufficiently high not to require frac
  - Previous well in the same reservoir did perform well, so asset requested support to optimise perforation
  - Program developed using both dynamic perforating model and a penetration + inflow/outflow model
  - Final design combined both instantaneous gun dynamics and surge from empty gun chambers to deliver maximum shot density and perf tunnel optimisation

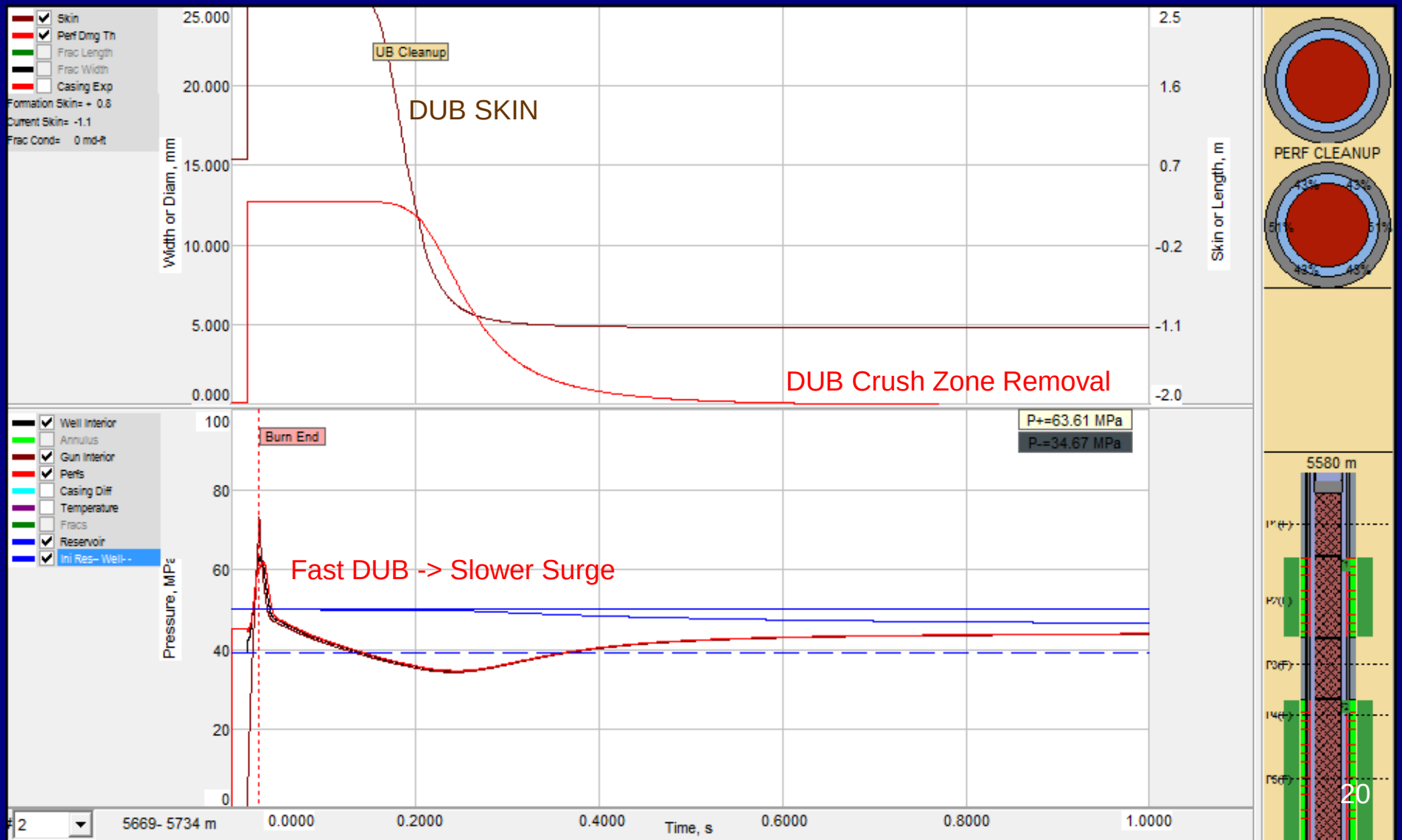
CASE HISTORY

- Case Study Well
  - Deviated well approximately 19,000ft AH, 11,000ft VD 60deg across reservoir
  - Reservoir pressure – 7,500psi
  - 1.18SG Brine with approximately 2,000psi static underbalance
  - Several units to be perforated averaging 1mD
  - Therefore possible to make use of blank gun for surge



CASE HISTORY

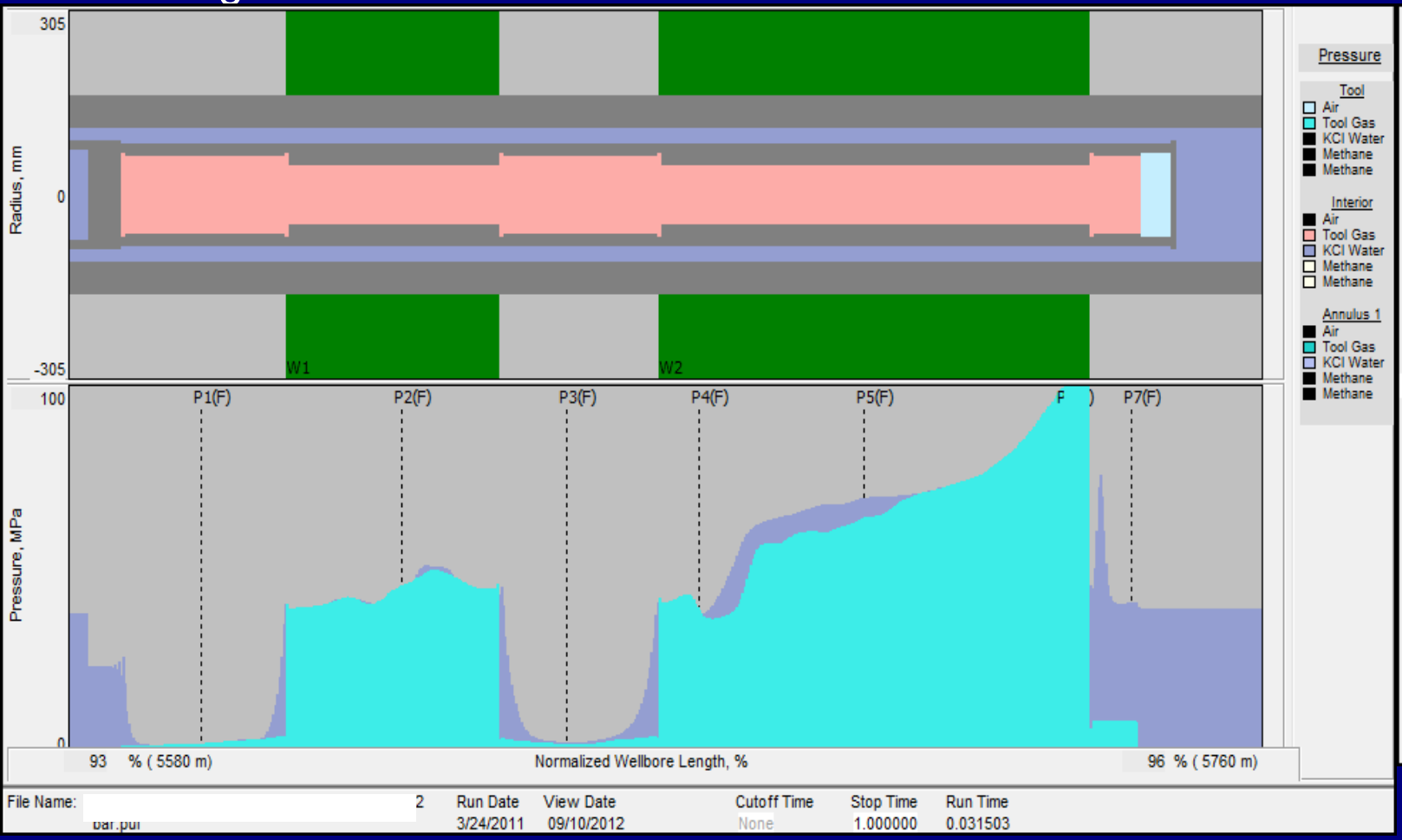
- Case Study Well - Small fast DUB followed by surge DUB

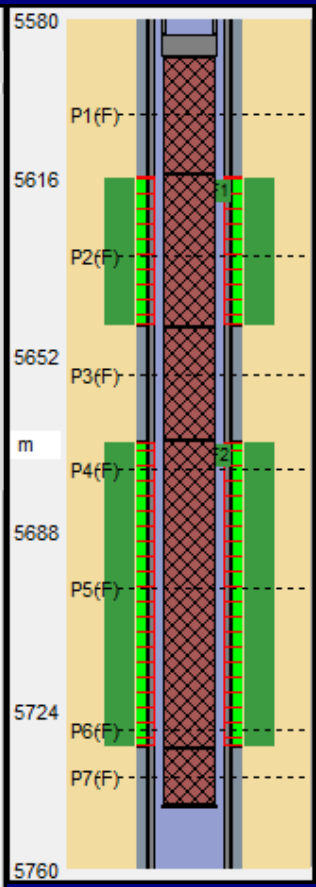


CASE HISTORY

DUB AVI

- Case Study Well
  - Surge chambers above below and in-between perforated intervals generate localised underbalance.





CASE HISTORY

- Case Study Well
  - Maintained high shot density 5.5spf – good for low Kv/Kh – gun pressure slightly less than reservoir pressure
  - Made use of blank gun above below and between perforations to provide near perf surge chambers
  - Modelled sensitivities to obtain best performance
  - Did not follow contractors own low SPF design having carried out detailed dynamic design internally
  - Resulting well performance exceeded expectations

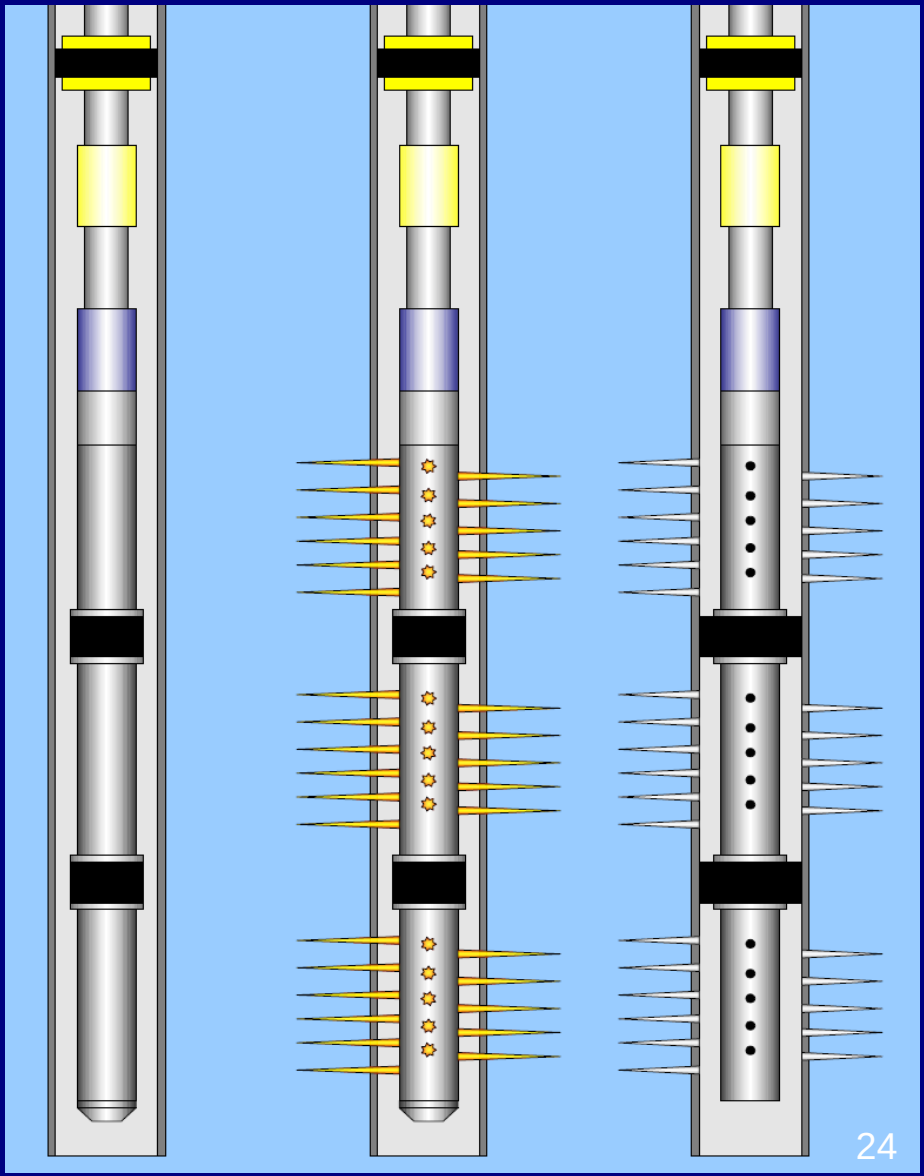
RECENT ADVANCES IN PERFORATING TECHNOLOGY

- Many recent advances in perforating – some examples:-
  - Variations on Dynamic Underbalance Perforating
  - Reactive Liner perforating, generates heat and pressure in the tunnel
  - Convergence charges – jets intersect on a plane or a point – especially for pre-frac
  - Consistent hole size charges and slot charges for frac
- Example of two technologies in development
  - Flow Thru Guns - such as the ‘Full Flow Gun System’
  - Disappearing Gun Systems

RECENT ADVANCES IN PERFORATING TECHNOLOGY

Flow Thru Gun Systems

- First designed and successfully run in N Sea wells - but not optimised
- Identified as technology for improvement
- Full Flow Thru ID in Gun
- Minimal Gun Debris
- Can be developed in different diameters, gun materials and charges
- Run as lower completion
- Run as liner in OH or inside liner
- Run with swellables for isolation
- Shoot and flow



RECENT ADVANCES IN PERFORATING TECHNOLOGY

Disappearing Gun Systems

- Many designs of Disappearing guns for different applications.
- Developing a system for perforating and propellant fracturing horizontal wells in moderately tight reservoirs
- Composite gun needs to be - horizontal capable and withstand downhole conditions
- Must disappear or fragment into light particles, which can clean-up
- Another shoot and flow technology avoiding pulling

IMPLEMENTING WHAT WE HAVE LEARNED

- Optimising Perforating is generally the lowest cost way of improving well performance
- Only the very simplest reservoir conditions do not benefit from comprehensive design and system selection
- Perforating for optimum well performance is now more effective due to –

  1. Better testing of charge performance using stressed rock penetration
  2. Advanced models
  3. Increased communication of perforating technology

THANK YOU

END