Changes in API RP19B and How This Can Improve Performance

CIPS 14-004

October 2014

Presented by

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Shell
Chair API SC19B

1. Contents

Mark Brinsden
API SC 19B

2. Review of API testing for charge performance

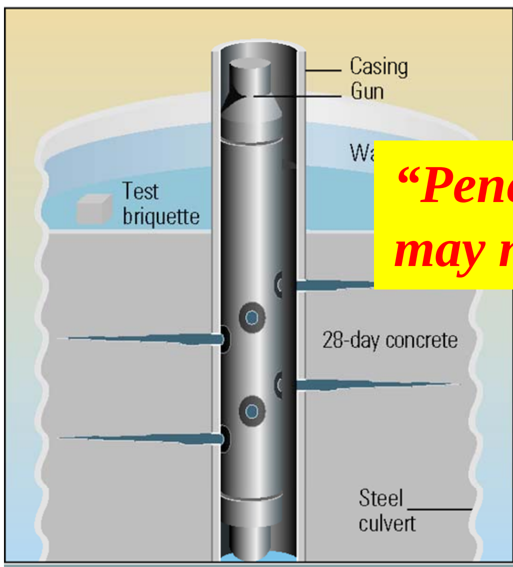
API RP19B is currently being rewritten to bring it up to date.

One of the key drivers, is about making it clear that you need to use the right kind of testing to really understand how your gun and charge are going to behave in your reservoir.

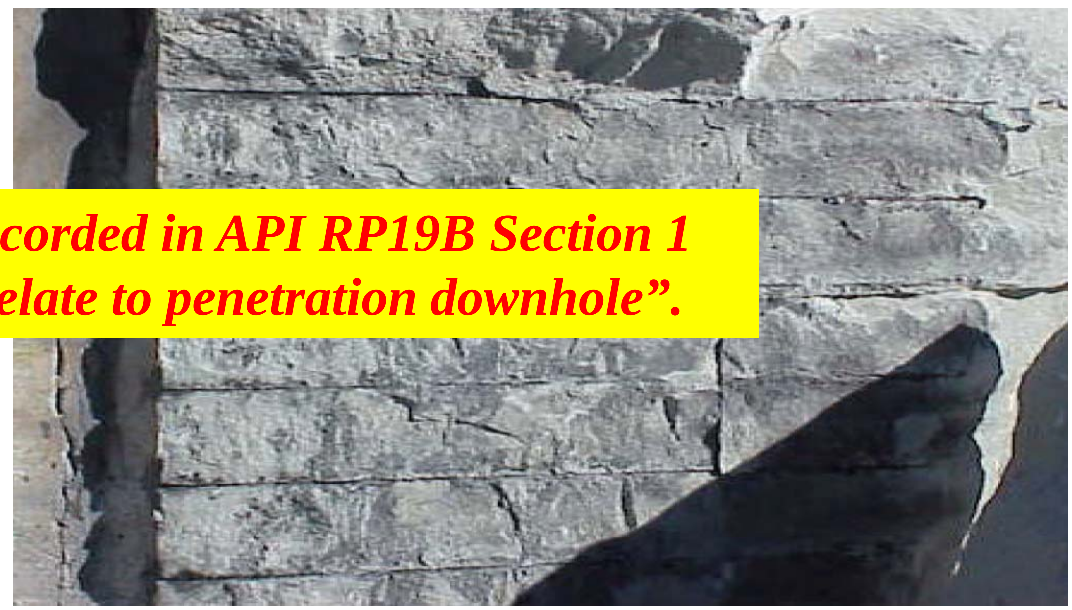
2. Review of API testing for charge performance

Section 1: Evaluation under surface conditions in concrete targets

- Provides a fit-for-purpose method of identifying – variability in charge data (LP & EHD) – charge interference – verified QC test – but also used as benchmark for charge penetration.
- Although designed to be consistent and arguably an improvement on API RP 43 Section 1 target – is know to be inconsistent and unsuitable reference for reservoir penetration benchmark.
- *A new data sheet has been drafted including disclaimer...*
- *A new addendum has been drafted for Sect 1 testing with mixed charges along with a new test sheet*



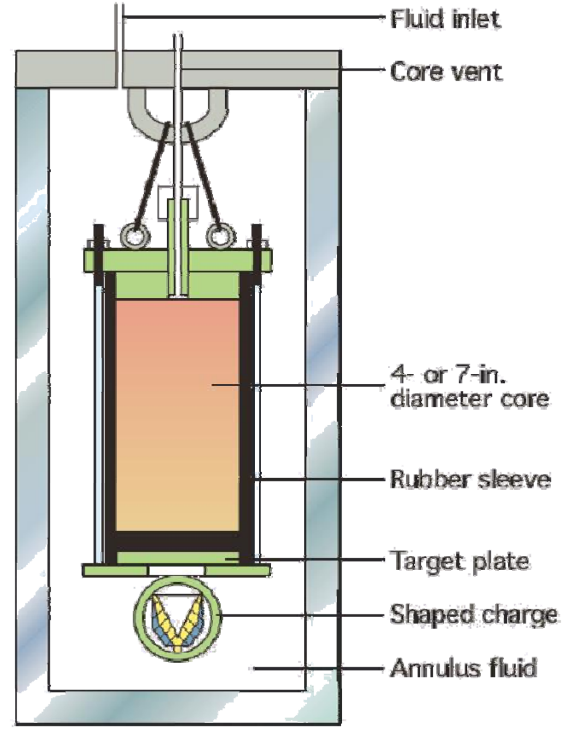
"Penetration Data recorded in API RP19B Section 1 may not directly correlate to penetration downhole".

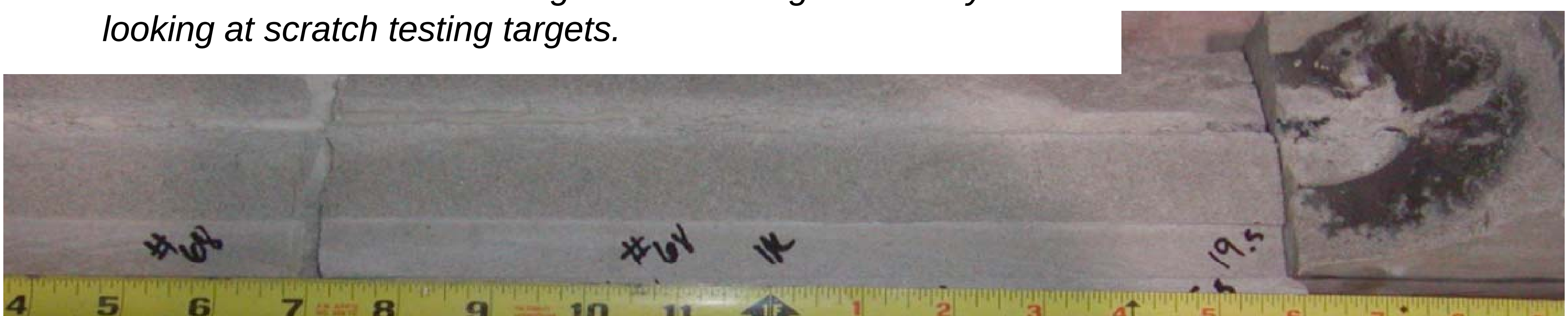


2. Review of API testing for charge performance

Section 2: Evaluation under stress conditions in rock targets

- Basic test to measure stressed rock penetration profile and performance.
- Can be expanded to different rocks, diameters and stress conditions.
- *Could also be used as one of the standards for improved charge performance testing using a selection of outcrop rock or synthetic rock targets.*
- *Committee agreed to carry out a witnessed comparative testing program for Sect 2. Letters have been sent out and all companies with Sect 2 facilities engaged.*
- *Work also been done on target UCS testing – currently looking at scratch testing targets.*





API RP19B 1. Current API RPs Overview

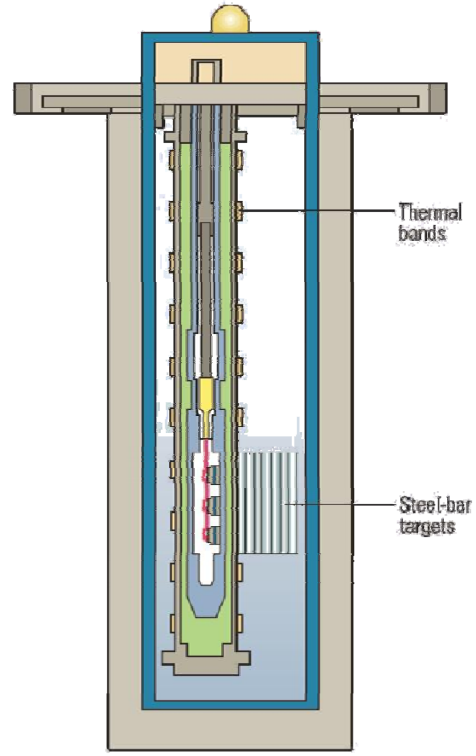
Section 3: Evaluation under elevated temperatures

- Tests charge performance due to temperature
- But target is not corrected for temperature and test is expensive
- *Committee has looked at a two tier test to prove reliability as well as performance at elevated temperature.*
- *Should include consideration for extended lenght jobs as well as CT conveyance.*
- *An additional safety section is being considered to include*

(1) heated guns,

(2) misfired guns, and

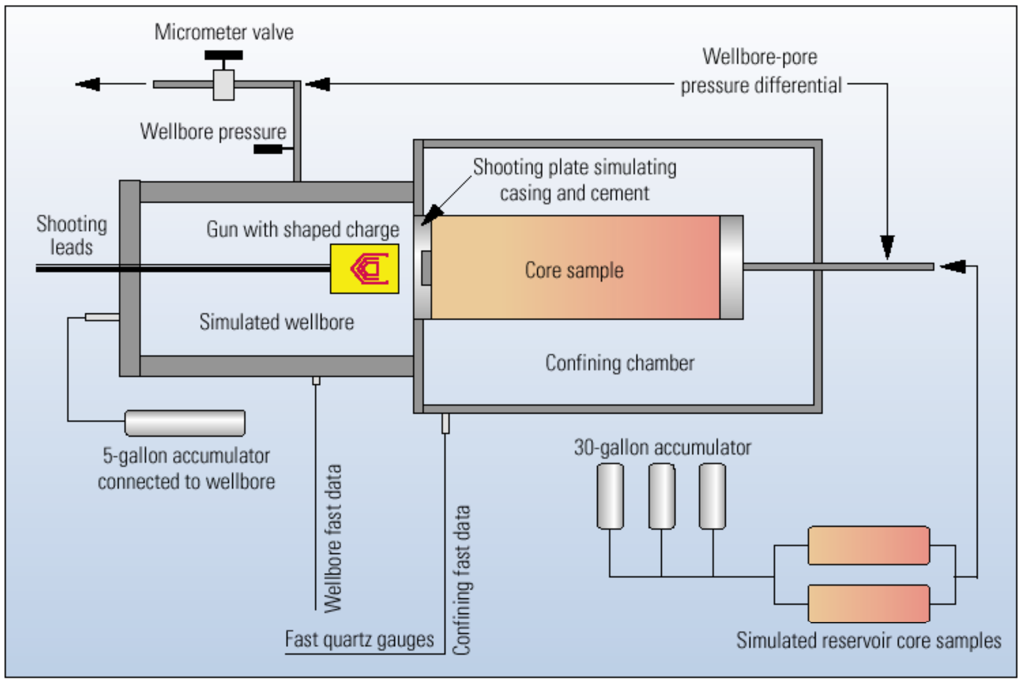
(3) guns intentionally allowed to cool before shooting.



2. Review of API testing for charge performance

Section 4: Evaluation of flow performance under simulated downhole conditions

- Suitable for evaluating flow, penetration and dynamic perforating event under simulated wellbore and reservoir conditions.
- *Section 4 has been rewritten due to need to improve the correlation in performance between the different test cells in the market and has been submitted to vote, has passed for issuing.*



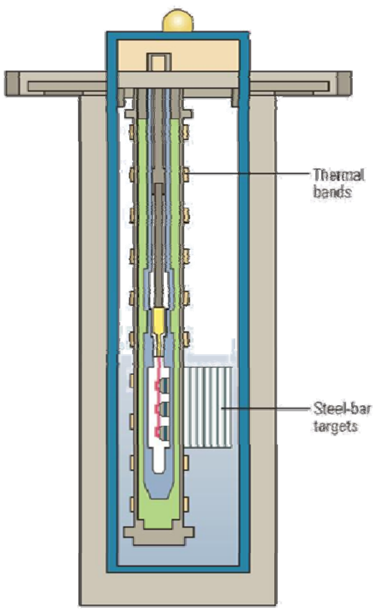
2. Review of API testing for charge performance

Section 5: Debris Evaluation

Section 6: Gun Swell – (New)

Both of these also have a great deal of relevance in understanding how well charges and guns perform under reservoir conditions.

Committee work has also progress almost to completion.



3. Using API testing – Charge consistency

American Petroleum Institute

REGISTERED DATA SHEET PERFORATING SYSTEM EVALUATION, API RP 19B SECTION 1

Service Company: Schlumberger.
Gun OD & Trade Name: 3.50-in. High Shot Density
Charge Name: [redacted]
Manufacturer Charge Part No.: 100019953 Date of Manufacture: 06/28/04
Gun Type: TCP and Wireline Hollow Carrier, Non Reusable
Phasing Tested: 72 degrees, Firing Order: X Top down X Bottom up
Debris Description: Small steel chips.

Explosive weight: 27.0 gm, HMX Powder, Case Material: Steel
Max Temp, °F: 400 1 hr ___ 3 hr ___ 24 hr 300 100 hr ___ 200 hr
Maximum Pressure Rating: 25,000 psi, Carrier Material: Steel
Shot Density Tested: 6 Shots/ft
Recommended Minimum ID for Running: See Remarks in.
Available Firing Mode: X Selective X Simultaneous
Debris Weight: n/a gm/charge, Debris: n/a in^3/charge

Remarks: Maximum gun diameter after shooting in liquid is 3.72 in.

SECTION 1 - CONCRETE TARGET

Casing Data: 5 OD, Weight: 15.0 lb/ft, API Grade: L-80 Date of Section 1 Test: 08/18/04
Target Data: 120 OD, Amount of Cement: 15,600 lb, Amount of Sand: 31,200 lb, Amount of Water: 8,105 lb.
Date of Compressive Strength Test: 08/18/04 Briquette Compressive Strength: 6,155 psi, Age of Target: 28 days

Shot No.	No 1	No 2	No 3	No 4	No 5	No 6	No 7	No 8	No 9	No 10	No 11
Clearance, in.	0.27	0.81	0.81	0.27	0.00	0.27	0.81	0.81	0.27	0.00	0.27
Casing Hole Diameter, Short Axis, in	0.45	0.32	0.39	0.36	0.51	0.47	0.38	0.41	0.48	0.49	0.47
Casing Hole Diameter, Long Axis, in	0.46	0.32	0.42	0.37	0.53	0.48	0.41	0.43	0.50	0.52	0.47
Average Casing Hole Diameter, in.	0.46	0.32	0.41	0.37	0.52	0.48	0.40	0.42	0.49	0.51	0.47
Total Depth, in.	46.8	45.6	40.1	45.7	49.9	33.7	52.8	44.5	42.1	48.6	50.7
Burr Height, in.	0.08	0.01	0.03	0.05	0.12	0.03	0.03	0.05	0.06	0.13	0.01

Shot No.	No 12	No 13	No 14	No 15	No 16	No 17	No 18	No 19	No 20	No 21	No 22	Average
Clearance, in.	0.81	0.81	0.27	0.00								xxxx
Casing Hole Diameter, Short Axis, in	0.32	0.36	0.49	0.51								0.43
Casing Hole Diameter, Long Axis, in	0.32	0.37	0.51	0.51								0.44
Average Casing Hole Diameter, in.	0.32	0.37	0.50	0.51								0.44
Total Depth, in.	48.1	45.0	24.6	44.5								44.2
Burr Height, in.	0.01	0.02	0.09	0.14								0.06

Remarks

WITNESSING INFORMATION

Date of Notice of Intent to Test: 07/19/04 Witnessed by: Truda Stevens - Quality Systems Management
Other Activities Witnessed: Target Pouring ___ Briquette: Preparation ___ Testing ___ Burr Height Measurements ___ Samples Taken: Concrete X Casing X

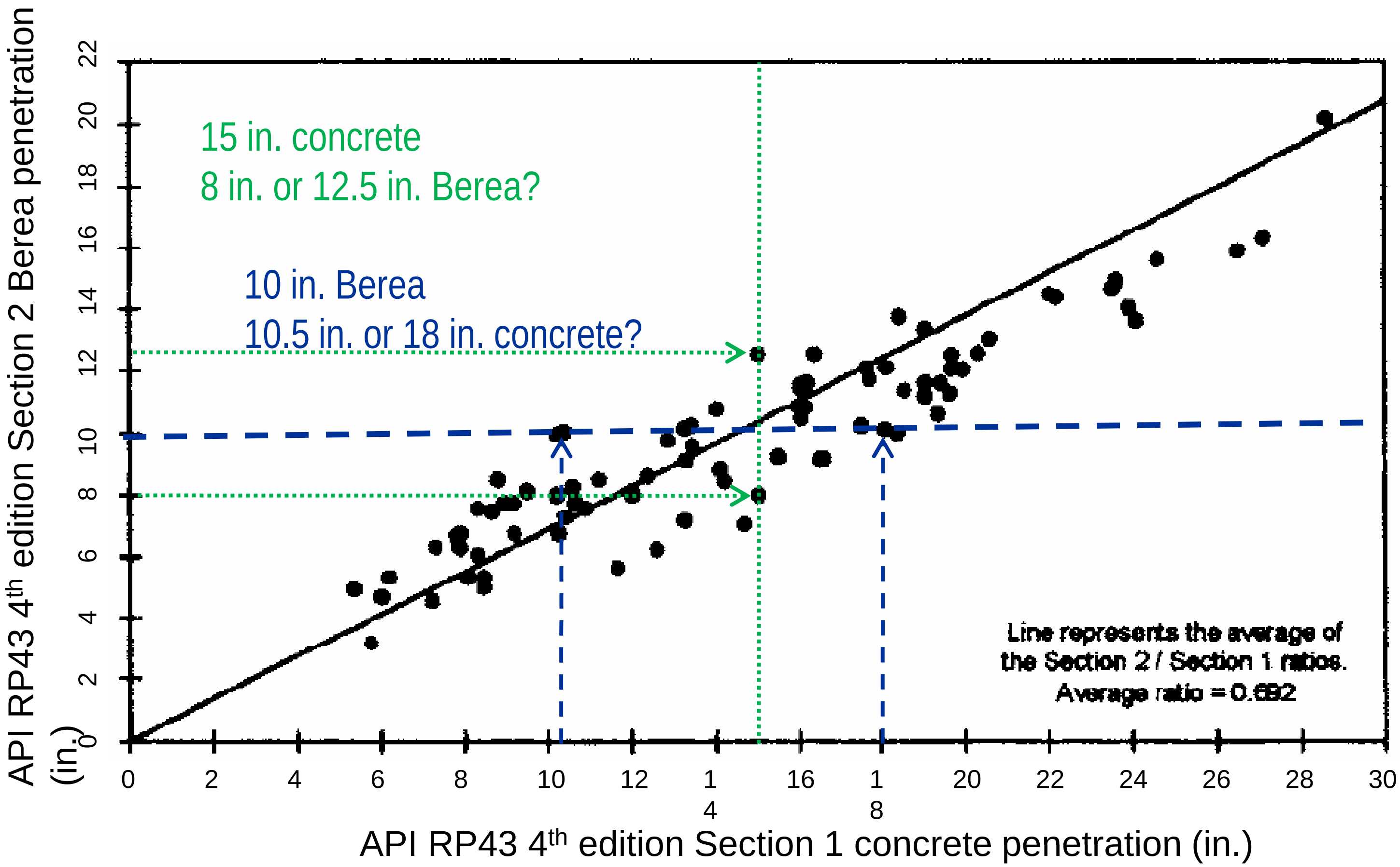
CERTIFICATION

I certify that these tests were made according to the procedures as outlined in API RP 19B: Recommended Practices for Evaluation of Well Perforators, First Edition, November 2000. All of the equipment used in these tests, such as the guns, jet charges, detonator cord, etc., was standard equipment with our company for the use in the gun being tested and was not changed in any manner for the test. Furthermore, the equipment was chosen at random from stock and therefore will be substantially the same as the equipment, which would be furnished to perforate a well for any operator. The American Petroleum Institute neither endorses these test results nor recommends the use of the perforator system described.

x CERTIFIED BY ___ Perforating Prod. Dev. Mgr. Oct 12 2004 Schlumberger 14910 Airline Road Rosharon, TX 77583
RECERTIFIED (Company Official) (Title) (Date) (Company) (Address)

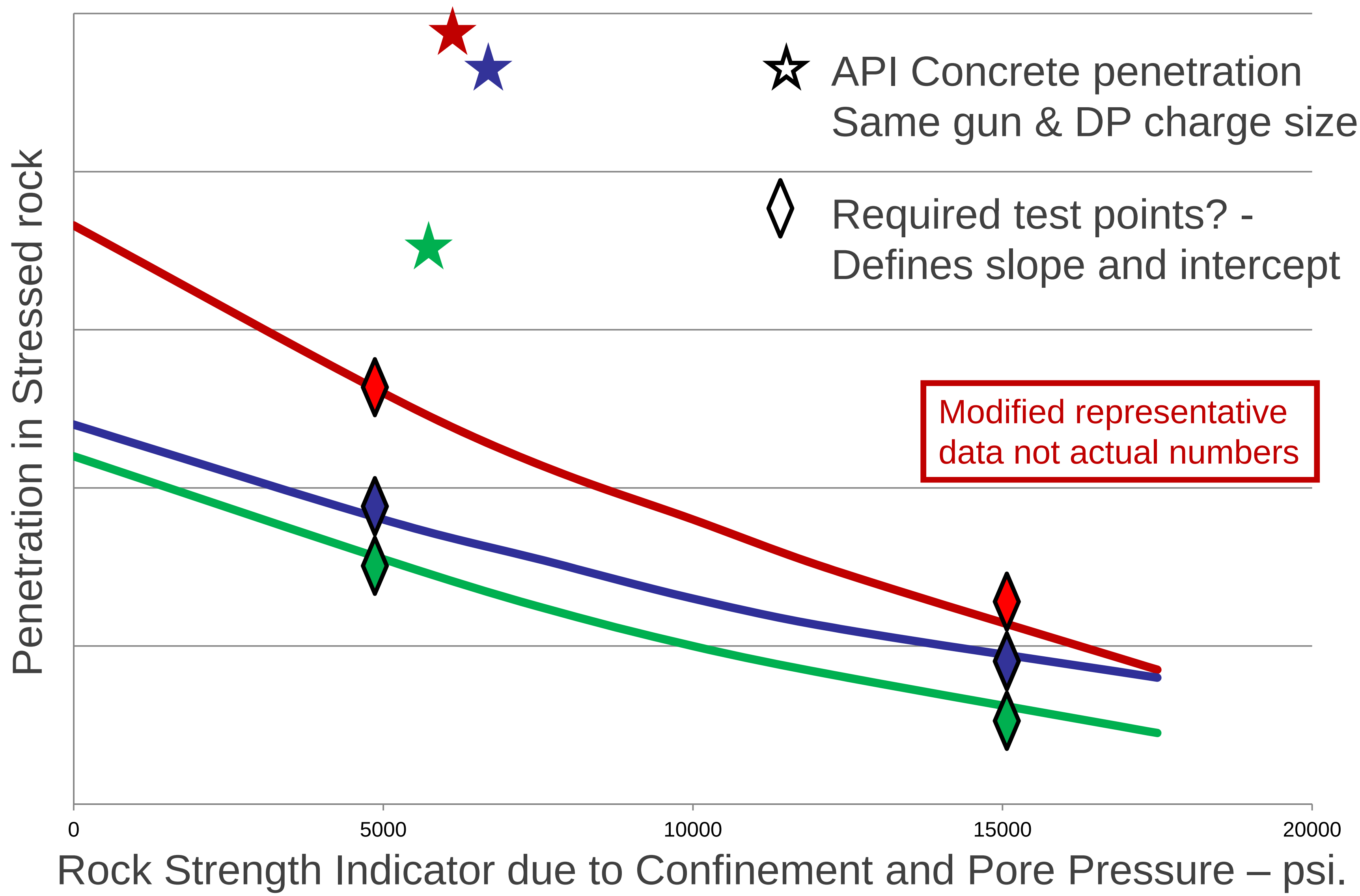
API Form 19R-A Page 1 of 1 04-048 5308 PJOmega3505_HMX_ Witnessed.xls

3. Using API testing – Relative Penetration



- Unstressed Section 1 concrete data provides no strong correllation to stressed rock penetration or in-situ reservoir rock penetration – this has been known for years.

3. Using API testing – Relative Penetration



3. Using API testing

So we understand from this that :-

1. There is no general correllation between surface concrete penetration and down hole
2. We need to select charges for specific reservoir type
3. Relying on concrete penetration is only suitable for very simple operations
4. A charge can be great for certain reservoir conditions but relatively less useful for others

4. Selecting Charges and Guns for well performance

What are the kind of things we need to think about when selecting a gun and charge for a reservoir :-

1. How is gun to casing clearance going to effect performance.

Testing the charge under simulated downhole conditions gives us actual penetration and casing hole diameter.

Actual Example:-

2-7/8in Premium Gun penetrating 9-5/8in casing into 6000psi UCS Stressed Target

Gun Clearance	Target Penetration	Casing Entrance Hole
0.5	10.3	0.25
5.0	3.9	0.15

4. Selecting Charges and Guns for well performance

What are the kind of things we need to think about when selecting a gun and charge for a reservoir :-

2. How is penetrating double casing going to effect performance.

Actual Example:-

2-7/8in Premium Gun penetrating 5-1/2in casing cemented in 9-5/8in casing into 6000psi UCS Stressed Target

Gun Clearance	Target Penetration	Casing 1 Entrance Hole	Casing 2 Entrance Hole
0.5	10.3	0.25	NA
0.5	7.1	0.25	0.15

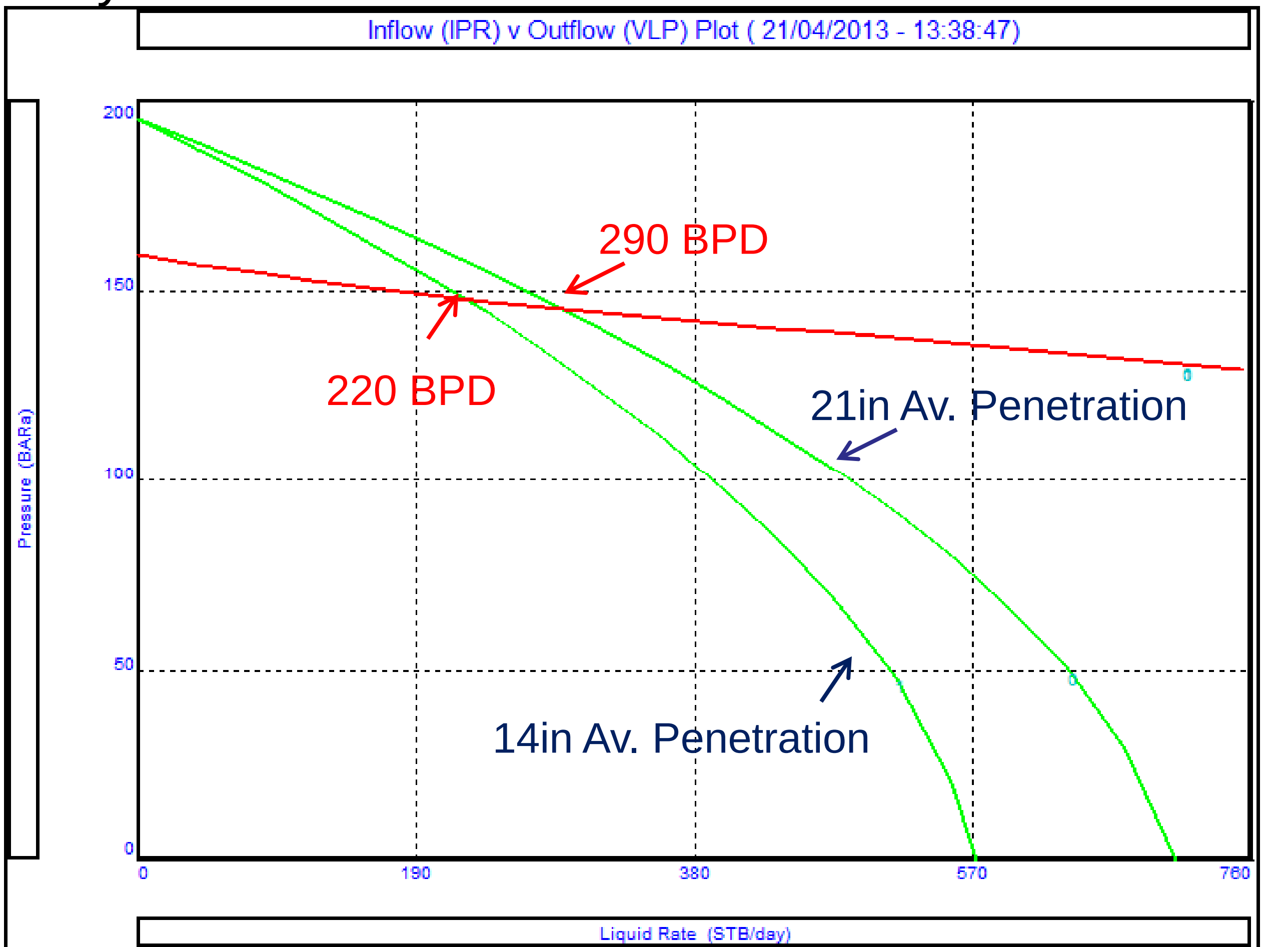
4. Selecting Charges and Guns for well performance

What are the kind of things we need to think about when selecting a gun and charge for a reservoir :-

3. Is there poor Vert. Perm., is the reservoir interbedded with impermeable Layers. Look at relative performance of higher shot density guns – lower penetration, but access every layer.
4. Reservoir temperature – is the gun suitable for your operating temperature, can you safely use an HNS charge at borderline temperatures. Use temp charts – but what about the change in charge performance with temperature – use section 3.
5. Is gun debris an issue and if so is the data in Sect 5 good enough for you to work out if a gun is suitable?
6. Will the gun operate in your downhole conditions, is gas flowing past your gun, is the gun capable of being shot in gas. Will the gun swell be an issue – we want the largest gun probably for clearance and penetration – but will it come out – Sect 6.

5. Modelling for Performance

How important is modelling for performance – given that we can't test every downhole condition in the lab?



Difference between an optimistic model and model based on stressed rock data similar to reservoir.

Example:

2-7/8in Premium Gun in 7in casing,

No Gun Clearance.

12 in Mud filtrate invasion.

5. Modelling for Performance

Most current models rely on Sect 1 penetration and apply a correlation for rock strength, stress (in some models), casing, cement and gun clearance.

Shell has 2 correlations and can use Sect 2/4 testing (as used in previous example), but still relies on converting the results back into Sect 1 penetration before predicting modelled penetration, good but not charge specific enough.

One contractor has a model and correlation based on a large number of stressed rock shots. With well documented and charge specific correlations.
This type of model is being considered by other contractors.

But all premium charges will need to be shot under various rock strength and stress conditions to make this work.

5. Modelling for Performance

Ref – EWAPS-12-18

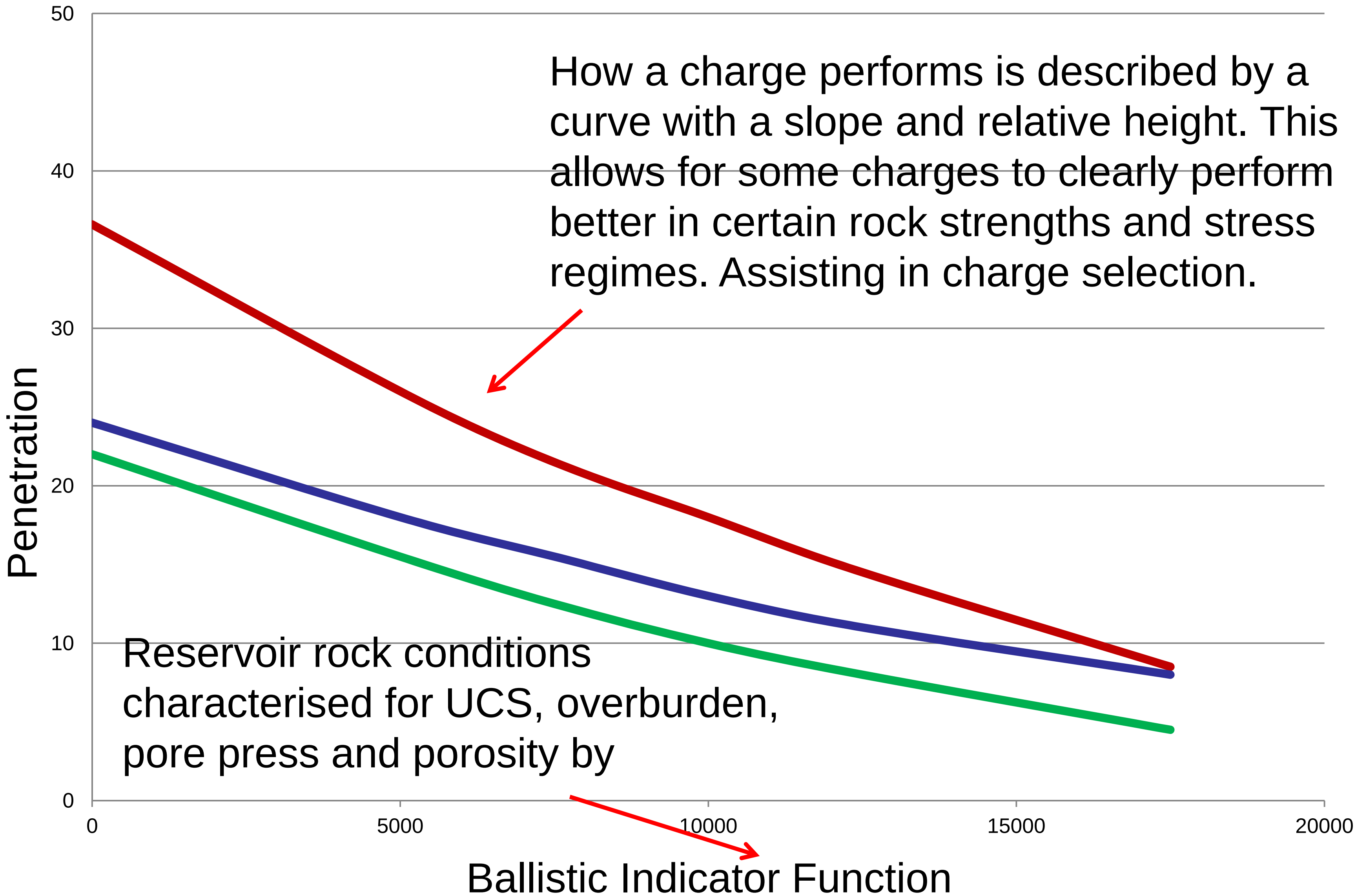
Detailed review of hundreds of shots under stressed conditions into different rock types with different charges.

It is suggested that each charge can be characterised by a combination of factors which identify a relative slope/curve and height for penetration.

In addition each rock, pore pressure and confinement condition, can also be characterised by a single term – the Ballistic Indicator Function.

So going back to my earlier slide showing the performance of 3 similar charges :-

5. Modelling for Performance



6. Conclusions and Way Forward

Is penetration consistency in outcrop rock an issue?

Are we shooting the target material in the right plane – perpendicular or parallel to bedding and in the right medium OMS, KCl Brine etc?

We are still getting significant variations in charge performance, is this due to target or charge consistency?

Should we continue to look at synthetic target development?

Should we look at a consistent way of modelling charge performance in stressed rock – if so what model?

Some possible ways forward –

6. Conclusions and Way Forward

Some possible ways forward –

Is penetration consistency in outcrop rock is an issue? Even though Berea is now more consistent – we still have significant variation.

Are we shooting the target material in the right plane – perpendicular or parallel to bedding? Consistency is the main thing in comparative testing of rock, as with pore fluid

We are still getting significant variations in charge performance, is this due to target or charge consistency? Some recent tests on commodity charges have shown some significant loading inconsistency, also charge casing manufacture inconsistency.

Should we continue to look at synthetic target development? Ideally, a joint industry effort is worth the effort for price and consistency.

Should we look at a consistent way of modelling charge performance in stressed rock – if so what model? Ideally we need an industry agreed and tested model that can be used in all penetration models.

The Importance of Charge Testing in Delivering Well Performance

Thank You

Presented by
Mark S Brinsden
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