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2016 INTERNATIONAL PERFORATING SYMPOSIUM GALVESTON

A NEW METHOD FOR PREDICTING PERFORATION ENTRANCE HOLE DIAMETER

IPS 16-37

GEODynamics®

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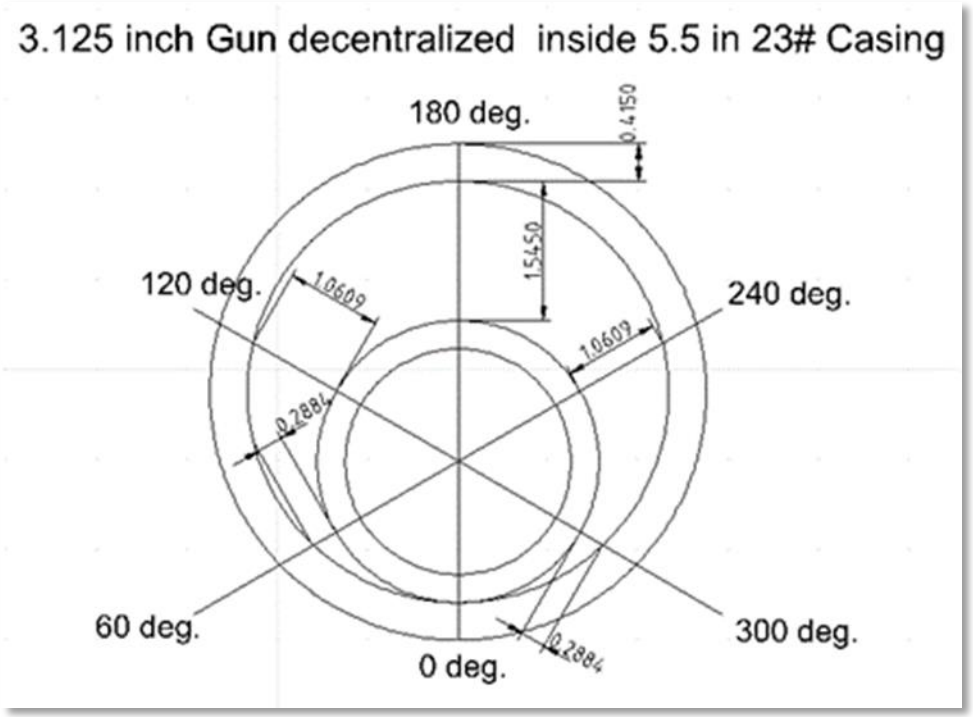
INTRODUCTION

- An accurate measurement of perforation entrance hole diameter is important when planning and executing a hydraulic fracturing operation
- Entrance hole diameter variability with phasing must be known when:
  - Selecting the proppant diameter in order to reduce bridging;
  - Estimating perforation friction, especially in limited entry applications; and
  - Using ball sealers.
- Various charges shot at a number of clearances in order to develop EHD correlation
- API 19B Section 1 data (or equivalent) used – with the forthcoming Section 7 testing the method can be further refined

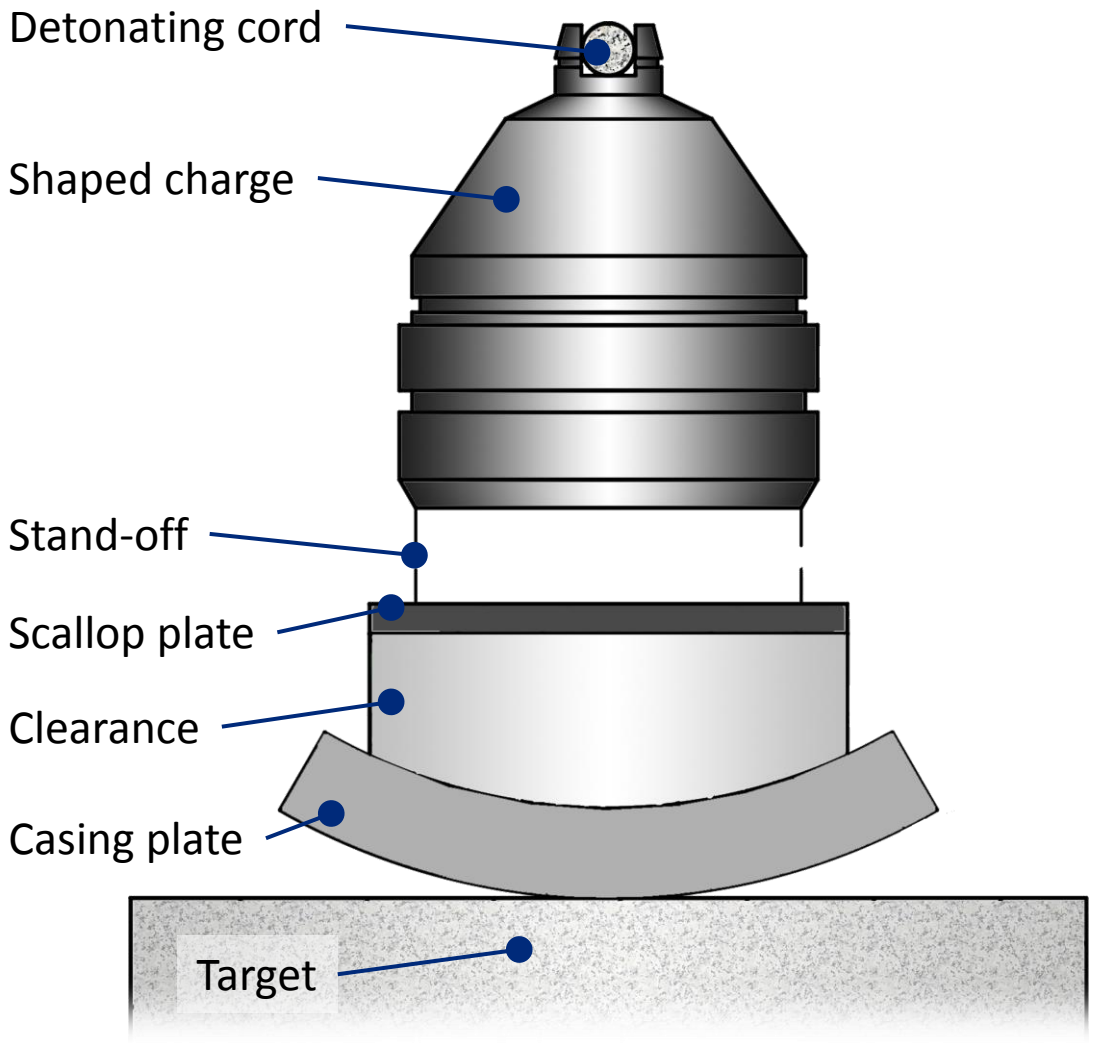
ENTRANCE HOLE VARIATION WITH CLEARANCE

- In a decentralized configuration the clearance varies around the circumference and as a result the entrance hole diameter varies (sometimes significantly)
- The variation is recorded in the API 19B Section 1 test and the resulting data can be used in situations where the same configuration will be used in a well
- But what about the situation where the same charge and carrier will be shot in a different sized casing?



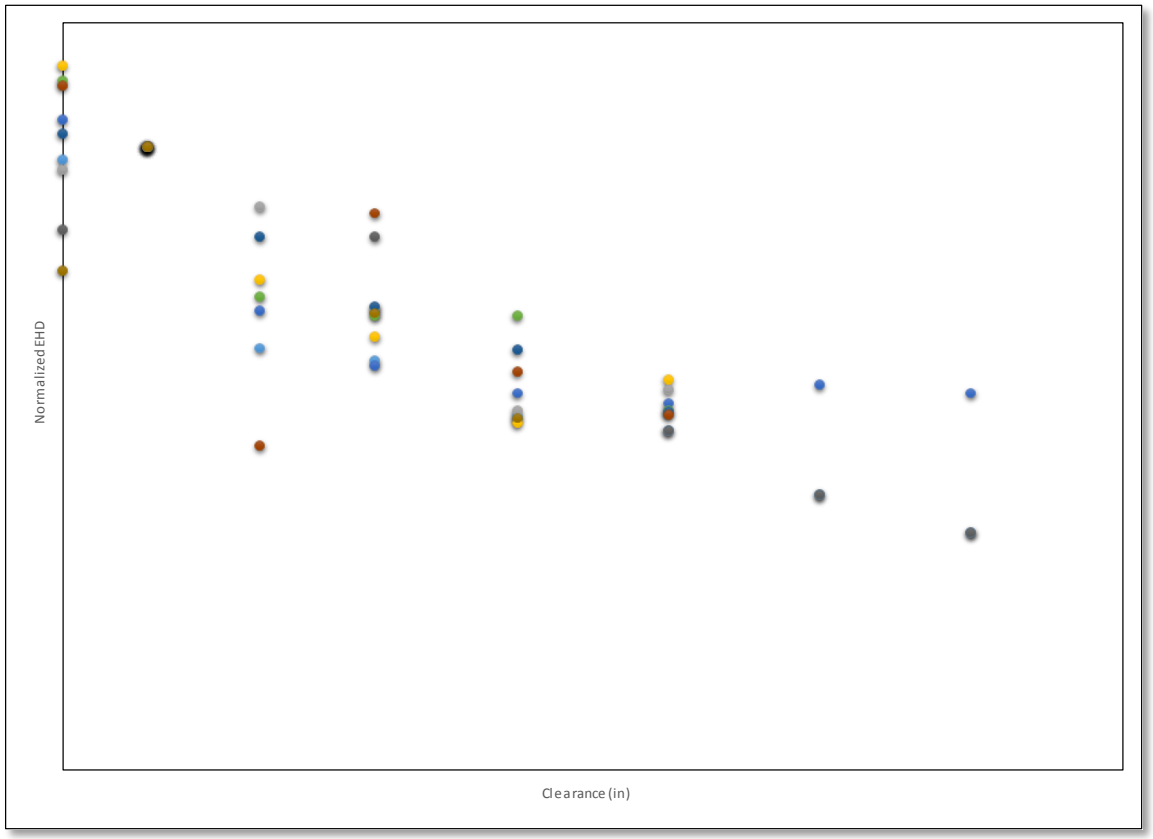
TEST CONFIGURATION

- Selection of charges shot in a test jig - all under the same configuration and casing dimension
- Jig simulated charge stand-off, scallop, clearance, and casing
- Used a segment of casing rather than flat plate
- Each charge shot at clearances ranging from 0 – 3 inches



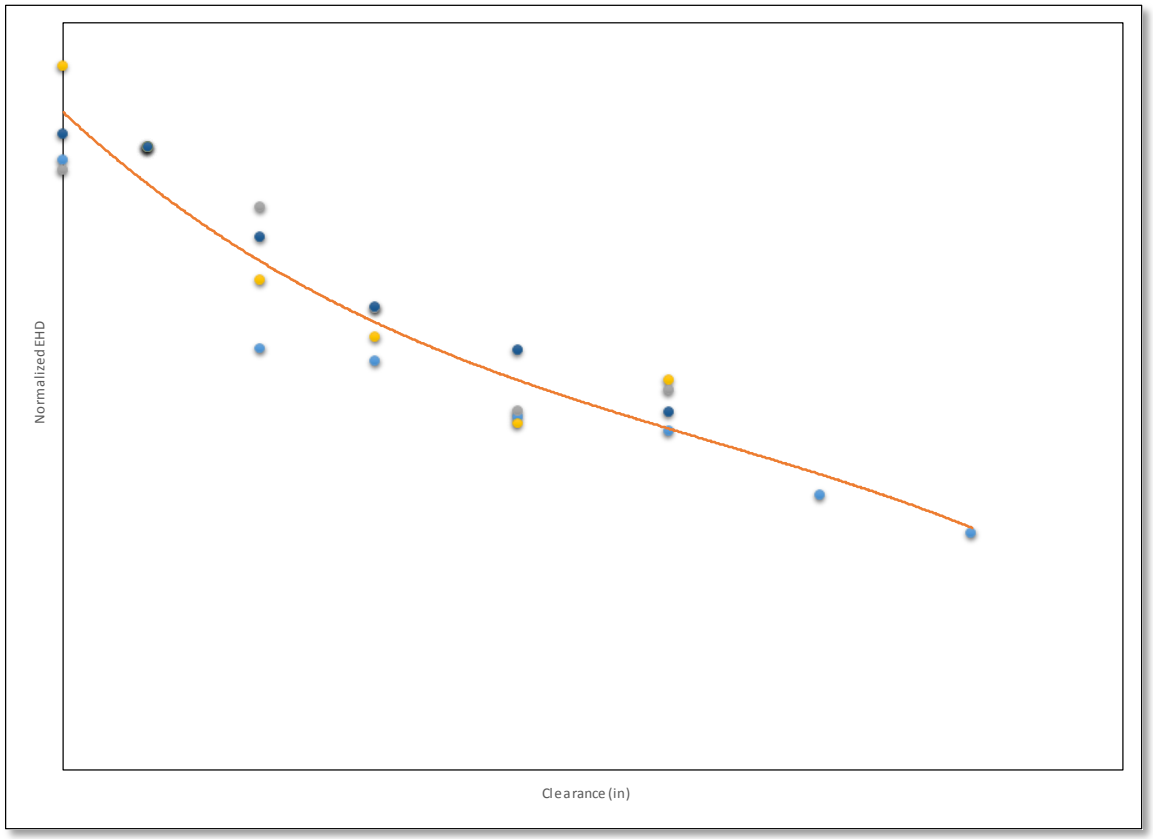
DATA GATHERING

- All entrance hole diameters where normalized to the EHD at a consistent clearance
- Plot the clearance versus the normalized EHD (Factor) and develop correlation from data
- Analysis done for both DP and SBH charges



ANALYSIS

- Analysis of the data resulted in the development of a number of “type” curves
- Certain charges exhibit similar variations in EHD with clearance



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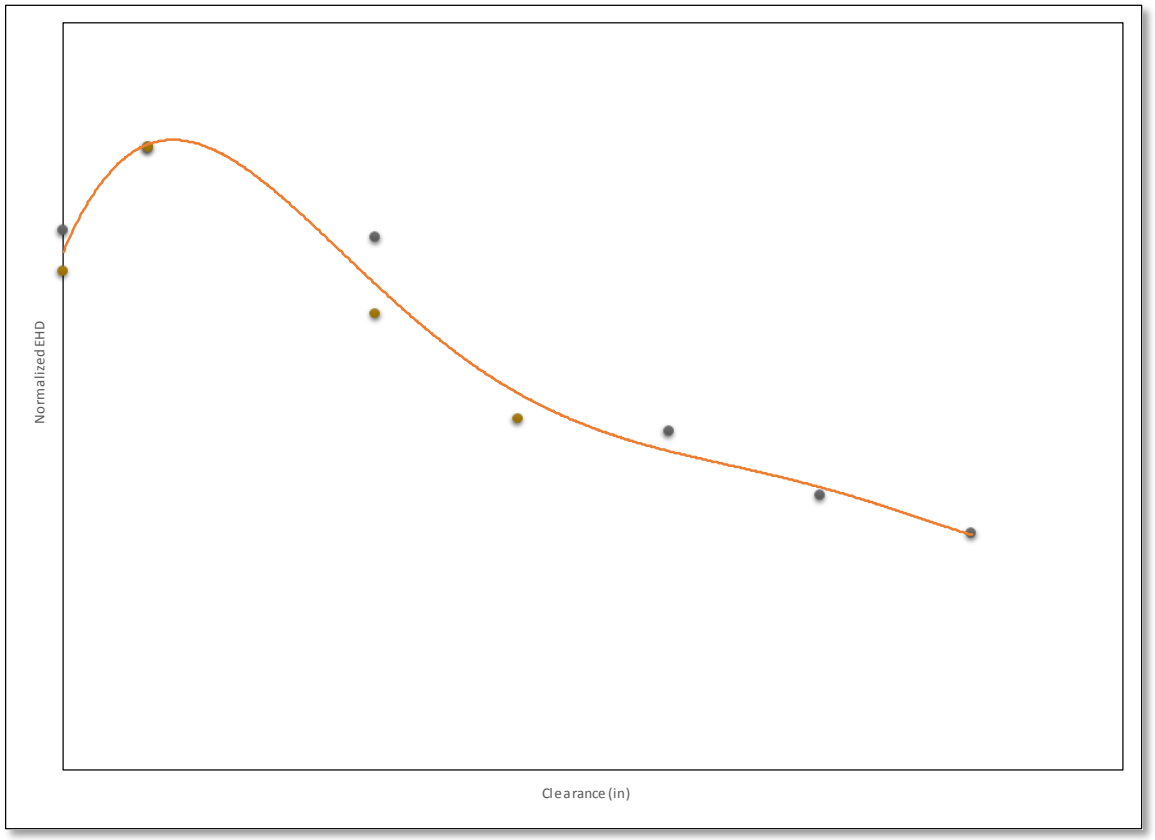

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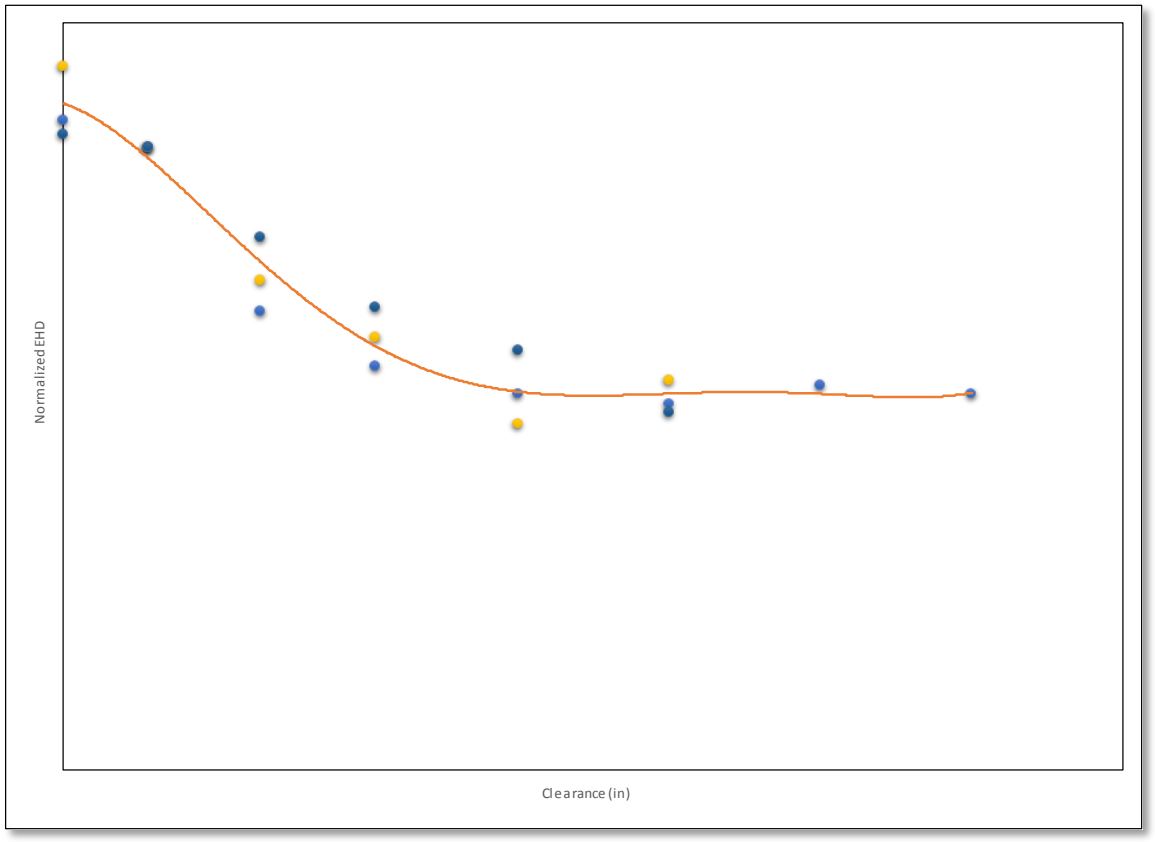
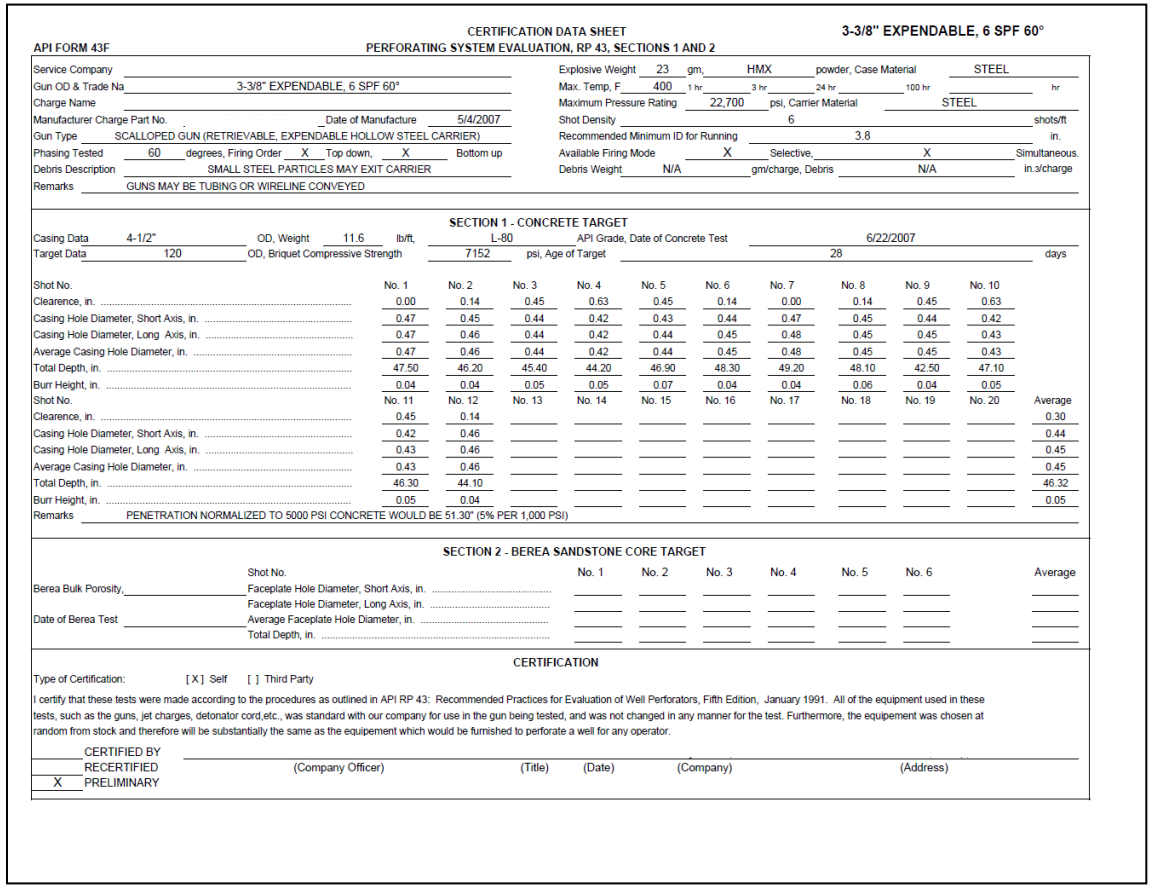


APPLYING THE CORRELATION

- Optimally need data for a specific charge at a few clearances as is available on an API RP19B, API RP43F, or from a QC datasheet
- Determine which correlation is applicable by testing the charge data against correlations
  - Use the correlation resulting in the least amount of error/deviation



CERTIFICATION DATA SHEET — 3-3/8" EXPENDABLE, 6 SPF 60°

API FORM 43F — PERFORATING SYSTEM EVALUATION, RP 43, SECTIONS 1 AND 2

Service Company

Gun OD & Trade Na: 3-3/8" EXPENDABLE, 6 SPF 60°

Charge Name

Manufacturer Charge Part No. — Date of Manufacture: 5/4/2007

Gun Type: SCALLOPED GUN (RETRIEVABLE, EXPENDABLE HOLLOW STEEL CARRIER)

Phasing Tested: 60 degrees, Firing Order: X Top down, X Bottom up

Debris Description: SMALL STEEL PARTICLES MAY EXIT CARRIER

Remarks: GUNS MAY BE TUBING OR WIRELINE CONVEYED

Explosive Weight: 23 gm, HMX powder, Case Material: STEEL

Max. Temp, F: 400 (1 hr / 3 hr / 24 hr / 100 hr / hr)

Maximum Pressure Rating: 22,700 psi, Carrier Material: STEEL

Shot Density: 6 shots/ft

Recommended Minimum ID for Running: 3.8 in.

Available Firing Mode: X Selective, X Simultaneous.

Debris Weight: N/A gm/charge, Debris: N/A in.3/charge

SECTION 1 - CONCRETE TARGET

Casing Data: 4-1/2" OD, Weight: 11.6 lb/ft, L-80 API Grade, Date of Concrete Test: 6/22/2007

Target Data: 120 OD, Briquet Compressive Strength: 7152 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	
Clearence, in.	0.00	0.14	0.45	0.63	0.45	0.14	0.00	0.14	0.45	0.63	
Casing Hole Diameter, Short Axis, in.	0.47	0.45	0.44	0.42	0.43	0.44	0.47	0.45	0.44	0.42	
Casing Hole Diameter, Long Axis, in.	0.47	0.46	0.44	0.42	0.44	0.45	0.48	0.45	0.45	0.43	
Average Casing Hole Diameter, in.	0.47	0.46	0.44	0.42	0.44	0.45	0.48	0.45	0.45	0.43	
Total Depth, in.	47.50	46.20	45.40	44.20	46.90	48.30	49.20	48.10	42.50	47.10	
Burr Height, in.	0.04	0.04	0.05	0.05	0.07	0.04	0.04	0.06	0.04	0.05	
Shot No.	**No. 11**	**No. 12**	**No. 13**	**No. 14**	**No. 15**	**No. 16**	**No. 17**	**No. 18**	**No. 19**	**No. 20**	**Average**
Clearence, in.	0.45	0.14									0.30
Casing Hole Diameter, Short Axis, in.	0.42	0.46									0.44
Casing Hole Diameter, Long Axis, in.	0.43	0.46									0.45
Average Casing Hole Diameter, in.	0.43	0.46									0.45
Total Depth, in.	46.30	44.10									46.32
Burr Height, in.	0.05	0.04									0.05

Remarks: PENETRATION NORMALIZED TO 5000 PSI CONCRETE WOULD BE 51.30" (5% PER 1,000 PSI)

SECTION 2 - BEREA SANDSTONE CORE TARGET

Shot No.	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	Average
Faceplate Hole Diameter, Short Axis, in.							
Faceplate Hole Diameter, Long Axis, in.							
Average Faceplate Hole Diameter, in.							
Total Depth, in.							

Berea Bulk Porosity,

Date of Berea Test

CERTIFICATION

Type of Certification: [X] Self [ ] Third Party

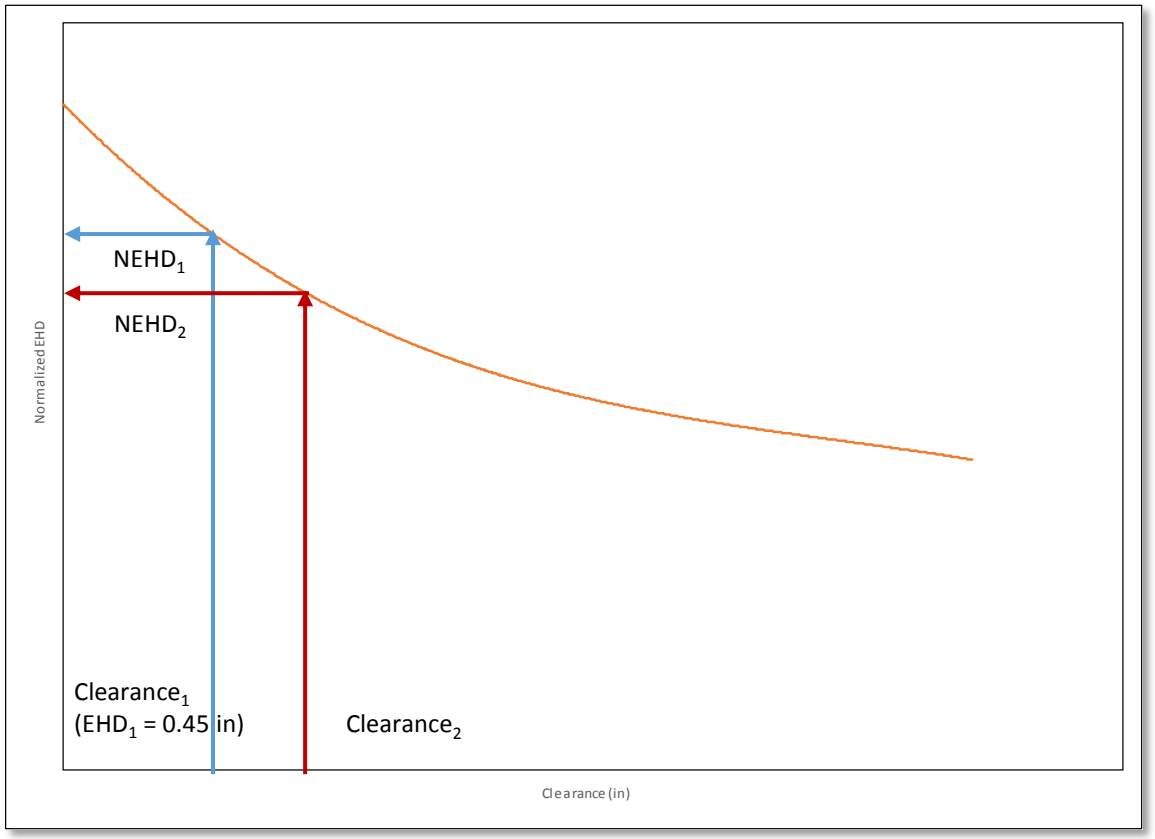
I certify that these tests were made according to the procedures as outlined in API RP 43: Recommended Practices for Evaluation of Well Perforators, Fifth Edition, January 1991. All of the equipment used in these tests, such as the guns, jet charges, detonator cord,etc., was standard with our company for use in the gun being tested, and was not changed in any manner for the test. Furthermore, the equipement was chosen at random from stock and therefore will be substantially the same as the equipement which would be furnished to perforate a well for any operator.

_ CERTIFIED BY
_ RECERTIFIED
X PRELIMINARY

(Company Officer) (Title) (Date) (Company) (Address)

APPLYING THE CORRELATION

- For a given clearance ($Clearance_1$) on the datasheet determine the corresponding value for the Normalized EHD ($NEHD_1$)
- From the data sheet also record the corresponding EHD (EHD_1) for $Clearance_1$
- Determine the Normalized EHD (NEHD2) for the clearance (Clearance2) to be determined
- Use … $EHD_2 = EHD_1 * NEHD_2/NEHD_1$
- A similar correlation has been developed for SBH charges



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QUESTIONS? THANK YOU!