HALLIBURTON

Boots & Coots

McMoran South Marsh Island Block 230 Well # 1 ST01

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3. Power Pack Hydraulic Schematic 10053783 PG. 11
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BOOTS & COOTS
CT WELL CONTROL EQUIPMENT AUDIT

PERFORMANCE TESTING AND CERTIFICATION OF BOOTS & COOTS CT WELL CONTROL ACCUMULATOR SYSTEM

Control Console	**B&C 10053796**
Power Pack	**B&C 10053783**

System Evaluation Based on Following B&C CT Stack:

TOT ES46 4-1/16" 15M Dual-Combi Assembly
TOT ES46 4-1/16" 15M Dual-Combi Assembly

180-Day PM Program (November 13, 2013 through May 12, 2014)

December 05, 2013

Prepared By:

SAS INDUSTRIES, INC.

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SAS Industries, Inc. Audit of Coiled Tubing Equipment
Boots & Coots Coiled Tubing - New Iberia, Louisiana

Boots & Coots (B&C) requested SAS Industries, Inc. (SAS) to conduct a performance Audit of the B&C coiled tubing (CT) well control equipment and systems identified in this Report. The SAS Audit was conducted to evaluate condition and performance capability of the B&C coiled tubing well control equipment listed below to certify compliance with the Recommended Practices and performance expectations outlined in **API RP 16ST** ***Coiled Tubing Well Control Equipment Systems*** and to meet or exceed ***30 CFR 250.616(f)6*** performance requirements.

The location and time period for the CT equipment performance testing audit is shown below:

Location	Start Date	End Date
Boots & Coots CT Facility - New Iberia, Louisiana	November 13, 2013	November 13, 2013

I. SUMMARY OF CT WELL CONTROL ACCUMULATOR EVALUATION

The B&C CT well control accumulator system and ram assemblies subjected to SAS testing and performance evaluation are shown below:

Table 1. Well Control Accumulator System Equipment Components Performance Tests

B&C Coiled Tubing Well Control Accumulator Equipment and System					
Met Requirements as Found	MET	Required Repairs/Adjustments	RR/A	Did Not Meet Requirements	DNM
Item	**Well Control Equipment Components**	**Size / Rating**	**B&C ID No.**	**Status**	
1.	Well Control Accumulator System	60-Gallon Circuit Volume	10053796	MET	

Coiled Tubing Unit Accumulator Bottle Volume: **60 Gallons**
Accumulator System Precharge Pressure (average): **1,200 psig (at 76° F)**
Accumulator "30-Minute Stabilized Operating Pressure": **2,930 psig (at 93° F)**

Table 2. Associated Well Control Stack Components Tested

B&C Coiled Tubing Well Control Stack Components		
Item	**Well Control Equipment Components**	**Size / Rating**
1.	Dual-Combi Ram Assembly	4-1/16", 15M TOT ES46
2.	Dual-Combi Ram Assembly	4-1/16", 15M TOT ES46

Accumulator System Pressure at Shear Ram Actuation: **2,525 psig ($P_{critical}$)**

Performance testing of the CT accumulator system integral to B&C Console ***10053796*** (**Table 1**) and the CT well control components described above in **Table 2** found that the ram "close-open-close" actuation tests were successfully completed with ***1,780 psig*** remaining within the accumulator system (tests conducted without assistance from the power pack hydraulic pumps). Based on an average accumulator precharge pressure of ***1,200 psig***, the aforementioned CT well control operating system meets the performance requirements of ***30 CFR 250.616(f)6*** and ***API RP 16ST Para. 13.6.2.***

Note that the aforementioned accumulator performance test was conducted with two Dual-Combi Ram stacks, each equipped with a Shear-Blind Ram and a Pipe-Slip Ram assembly.

II. RESULTS OF CT ACCUMULATOR SYSTEM CERTIFICATION TESTS

At the request of B&C, SAS prepared this Report which focuses on the Test Documentation and Performance Evaluation of the B&C CT accumulator system to be used with the CT well control stack rams identified in Table 2. The CT well control equipment performance expectation review conducted by SAS is based on the design capabilities recommended in API RP 16ST Coiled Tubing Well Control Equipment Systems (1st Edition, March 2009).

The major requirements for the well control stack accumulator circuit are shown in **Table 3**.

TABLE 3. Well Control Stack Accumulator Circuit Tests and Documentation

Description of SAS Audit Standards and Requirements	
Met Requirements as Found — MET; Required Repairs/Adjustments — RR/A; Did Not Meet Requirements — DNM	
Confirmed accumulator bottle ASME service limits and traceability numbers.	MET
Confirmed accumulator circuit is dedicated exclusively for well control operations.	MET
Confirmed accumulator circuit has console isolation valve to hold pressure until needed.	MET
Accumulator volume meets API requirements for well control stack rams in use.	MET
Accumulator circuit pressure integrity confirmed through tests.	MET
30-minute stabilized operating pressure meets API minimum Shear Ram $P_{critical}$ pressure	MET
30-minute stabilized operating pressure meets API minimum Shear-Blind Ram $P_{critical}$ pressure	TBD
Accumulator circuit pressure is ≥200 psig above precharge after C-O-C tests.	MET
Hydraulic hoses from power source to accumulator bank are pressure tight.	MET
Hydraulic hoses from accumulator bank to well control stack are pressure tight.	MET
Hydraulic hoses from accumulator bank to well control stack are purged with clean fluid.	MET

The well control stack accumulator circuit incorporates four (4) bladder-type bottles mounted horizontally within the Control Console skid (**B&C 10053796**). All accumulators were found to be 15-gallon nominal bottles with a MAWP of 3,000 psig in the temperature range from -65° F through 200° F and certified by BUCC. The well control accumulator circuit bottles installed in the Control Console skid were inspected and precharge pressures checked as shown in **Table 4**.

TABLE 4. Well Control Stack Accumulator Circuit Bottles

Bottle Number	Size	Serial Number	National Board Number	Installation In Skid	U-1A Stamp	Precharge Pressure	Precharge Temperature
1	15 Gallon	20576	332285	Horizontal	Yes	1,200 psig	74.0° F
2	15 Gallon	655	4832	Horizontal	Yes	1,200 psig	73.0° F
3	15 Gallon	20568	332277	Horizontal	Yes	1,200 psig	77.0° F
4	15 Gallon	20573	332282	Horizontal	Yes	1,200 psig	81.0° F

As per ***API RP 16ST*** and ***30 CFR 250.616(f)6*** CT well control accumulator requirements, the accumulator circuit must have sufficient ***USABLE*** power fluid to complete a "close-open-close" sequence of all well control stack rams operated from the accumulator circuit, with 200 psig above precharge remaining in the accumulator circuit without assistance from the power pack pumps. The aforementioned performance tests confirmed that the ***USABLE*** volume requirements for the well control stack equipment components seen in **Table 9** were met.

The **API RP 16ST** operating system design capabilities reviewed by SAS are listed in **Table 5**:

Table 5. API RP 16ST - Operating System Design Review

Referenced Paragraph	Comments	Status
13.1.1	Operating System Provides Source of Power Fluid to Operate the Ram Components	MET
13.1.2	Operating System is an Independent Hydraulic Circuit Exclusive to Well Control	MET
13.2.3	Operating System has a Direct Pump (primary) and an Accumulator Bank (secondary)	MET
13.3	Operating System Includes all Required Accumulator Circuit Components	MET
13.4.1	Operating System Reservoir is Sourced From CT Unit Power Pack Hydraulic System	MET
13.4.2	Hydraulic Fluid Available to Operating System is at Least 2-Times the Usable Volume	MET
13.4.3	Hydraulic Fluid Reservoir is Equipped with Pressure Relief Valve and Level Indicators	MET
13.5.1	Hydraulic Pump is Properly Sized for Well Control Operating System	MET
13.5.2	Operating System Hydraulic Pump Line Equipped With Pressure Regulator Valve	MET
13.6.1	Accumulator System Designed With at Least Two Bottles & Pump Isolation Valve	MET
13.6.2	Accumulator System Sized to Provide Usable Volume for Well Control Stack Rams	MET
13.7.1	Operating System Control Panel Located in CT Console & Rated for System Pressure	MET
13.7.2	Operating System Control Panel Includes Accumulator System Isolation Valve	MET
13.8	Hydraulic Fluid Used in Operating System is Compatible With Ram Components	MET

The **API RP 16ST** well control operating system equipment *performance tests* conducted by SAS are listed in **Table 6** below:

Table 6. API RP 16ST - Operating System Performance Tests

Referenced Paragraph	Comments	Status
12.2.7.1	All Well Control Components Function Tested to Confirm Integrity of Hydraulic System	MET
12.2.7.2	Hydraulic System Capable of Operating Well Control Components at MASP of Well	TBD
12.2.7.3	Hydraulic System Capable of Supplying Fluid to Components at MASP of Well	MET
13.6.2	Operating System Usable Volume Demonstrated Through Ram Actuation Testing	MET
13.6.3	Operating System Response Time Determined Through Test of Each Ram Component	MET
13.6.4	Stabilized Operating Pressure Observed During Testing Found Below Ram Limits	MET
13.6.5	Accumulator Precharge Pressures and Temperatures Obtained Through Measurement	MET

The **API RP 16ST** ***Annex A*** *(informative)* accumulator performance evaluation calculations prepared by SAS are listed in **Table 7** and were based on the inspection of the accumulator system, the observed "30-minute stabilized operating pressure" and the precharge pressure (and temperature).

Table 7. API RP 16ST - Accumulator Evaluation Calculations

CT Well Control Accumulators	API RP 16ST	Comments
Accumulator Volume	Annex A.1.2	Calculations for Demonstrating Usable Volume
Accumulator Pressure	Annex A.1.3	Calculations for Demonstrating Critical Pressure

The Status "***TBD***" in **Tables 3** and **6** reference "critical pressures" for the Shear Rams, Slip Rams, and Pipe-Slip Rams and require performance testing for each specific ram component using the CT OD size, wall thickness and Grade designated for the intervention program, along with MASP of the candidate well. ***SAS recommends that the User obtain a separate evaluation Report to confirm the "critical pressures" of the Shear Rams, Slip Rams and Pipe-Slip Rams at the MASP of the well prior to initiating well intervention activities.***

SAS conducted the aforementioned well control equipment performance tests and evaluated the performance as it relates to the captioned accumulator system (CT Unit Control Console) to be used with the well control equipment as seen in **Tables 8, 9** and **10** and **Figure 1**.

Table 8 shows the design and configuration of the accumulator system used with the captioned well control equipment, along with the "As-Found" precharge pressure (and temperature) and "30-Minute Stabilized Operating Pressure". The accumulator operating parameters seen in **Table 8** are required for determining the performance capability of the accumulator circuit (Usable Volume and Critical Pressure) with respect to the well control equipment to be used.

Table 9 shows the volumes for closing and opening each of the ram components installed within the proposed well control stack. This information was obtained from the manufacturer's Technical Manual provided to B&C with the well control equipment. Based on the "Usable" power fluid volume (**24.2914** gallons) available at the accumulator conditions stated above, the B&C accumulator circuit has more than sufficient "Usable" volume to complete the required ES46 ram "close-open-close" functions with a remaining system pressure at least 200 psig above precharge.

Table 10 is taken from the SAS ***Accumulator Performance Evaluation Spreadsheet***, which illustrates the comparison of the predicted accumulator pressure to the response observed during the physical "close-open-close" tests conducted by SAS. The pressure values seen in **Table 10** reflect the pressure in the accumulator circuit immediately after actuation of each of the ram components. Note that the predicted responses are based on empirical relationships that reflect changes in accumulator pressure due to changes in nitrogen temperature as the bladders expand. The sequence of ram closure is taken from **API RP 16ST**, where in a well control emergency, the first rams to be closed are the *Primary* Pipe-Slip Rams, followed by closure of the *Primary* Shear-Blind Rams (***second rams to close***). If the well is not secured, then the *Secondary* Pipe-Slip Ram is closed (***third ram function***), followed by closure of the *Secondary* Shear-Blind Ram (***fourth ram function***). This sequence was used to evaluate the "depressurization" of the accumulator circuit as the rams are actuated. This ram actuation sequence was used to evaluate the "depressurization" of the accumulator circuit as the rams were functioned. For the accumulator operating parameters identified above, the accumulator circuit pressure to be expected upon closure of the *Primary* Shear-Blind rams Rams is approximately **2,525 psig.**

Figure 1 represents the graphical representation of the "depressurization" of the accumulator circuit as each of the rams are closed, opened and closed again without assistance from the power pack pumps. The "red" line represents the predicted performance pressures for the accumulator circuit, with the "green" line representing the observed performance pressures. The horizontal "blue" dashed line across the graph represents the accumulator precharge pressure, with the horizontal "pink" dashed line across the graph representing an accumulator pressure 200 psig above precharge.

TABLE 8 BOOTS & COOTS CT UNIT 10053796 ACCUMULATOR SYSTEM DESIGN

Accumulator System Design			Precharge Conditions		Stabilized Conditions	
Number	Gallons	Orientation	Pressure	Temperature	Pressure	Temperature
1	15	Horizontal	1,200 Psig	74.0 F	2,930 Psig	93.0 F
2	15	Horizontal	1,225 Psig	73.0 F	2,930 Psig	93.0 F
3	15	Horizontal	1,220 Psig	77.0 F	2,930 psig	93.0 F
4	15	Horizontal	1,220 Psig	81.0 F	2,930 psig	93.0 F
5						
6						
TOTAL	60	Gallons	(Accumulator Test Performed November 13, 2013)			

TABLE 9 BOOTS & COOTS ES46 CT STACK CLOSING AND OPENING OPERATING VOLUMES

	Pipe-Slip 1	Shear Blind 1			Pipe-Slip 2	Shear Blind 2	Total
	Gallon	Gallon	Gallon	Gallon	Gallon	Gallons	Gallons
Close	0.41126	1.29870			0.41126	1.29870	3.41992
Open	0.41126	1.29870			0.41126	1.29870	3.41992

Volume for "Close - Open - Close" of CT Rams in Stack : 10.25976 Gallons

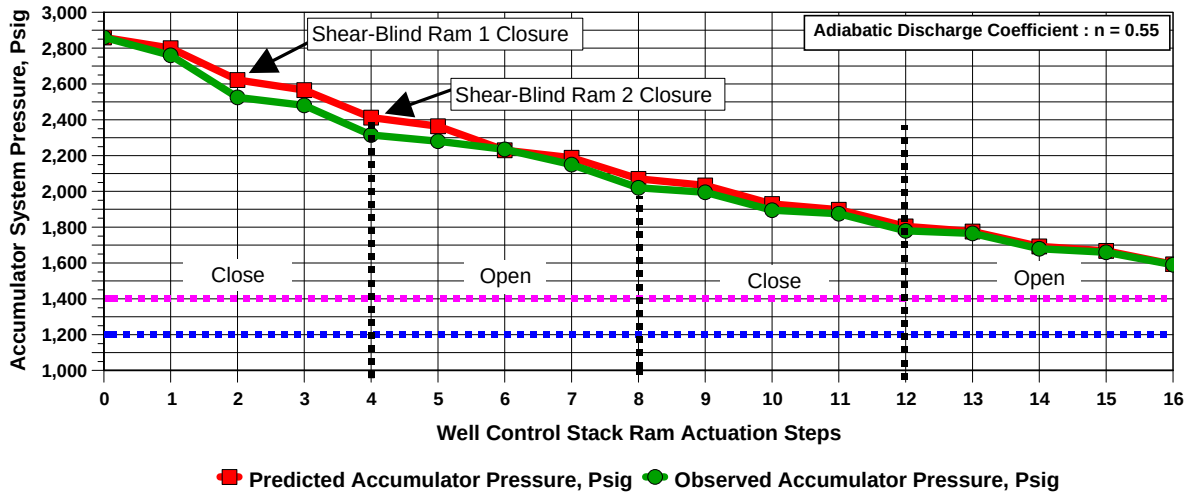
API RP16ST Accumulator Usable Volume Calculation : 24.2914 Gallons MET

(Note: Vacc Calculations Based on the Accumulator Pressures and Temperatures Noted Above)

TABLE 10 ACCUMULATOR CIRCUIT PERFORMANCE - Predicted Versus Actual

Adiabatic Cd:	0.55	Accumulator Pressure		Usable	Closing	Pressure /
Ram	Function	Calculated	Observed	Volume	Time	Rate Ratio
		(psig)	(psig)	(gallons)	(sec.)	(gpm/psig)
Initial Status	Open Valve	2,860	2,860	24.291	0.00	0.000000
Pipe-Slip 1	Close	2,800	2,760	23.880	6.00	0.001490
Shear-Blind 1	Close	2,622	2,525	22.581	17.00	0.001815
Pipe-Slip 2	Close	2,566	2,480	22.170	6.00	0.001658
Shear-Blind 2	Close	2,412	2,315	20.872	18.00	0.001870
Pipe-Slip 1	Open	2,364	2,280	20.460	6.00	0.001804
Shear-Blind 1	Open	2,230	2,235	19.162	19.00	0.001835
Pipe-Slip 2	Open	2,188	2,150	18.750	7.00	0.001640
Shear-Blind 2	Open	2,070	2,020	17.452	20.00	0.001929
Pipe-Slip 1	Close	2,034	1,995	17.040	7.00	0.001767
Shear-Blind 1	Close	1,930	1,895	15.742	20.00	0.002056
Pipe-Slip 2	Close	1,898	1,875	15.330	7.00	0.001880
Shear-Blind 2	Close	1,805	1,780	14.032	21.00	0.002085
Pipe-Slip 1	Open	1,776	1,765	13.620	8.00	0.001748
Shear-Blind 1	Open	1,693	1,680	12.322	22.00	0.002108
Pipe-Slip 2	Open	1,668	1,660	11.910	8.00	0.001858
Shear-Blind 2	Open	1,593	1,590	10.612	23.00	0.002131

FIGURE 1 Well Control Accumulator System Performance Evaluation



Based on the results of all performance testing concluded on November 13, 2013, SAS certifies that the aforementioned B&C coiled tubing well control accumulator and associated operating system equipment meets or exceeds the performance expectations stipulated in **API RP 16ST** for the operating conditions shown in **Table 4** and with CT well control equipment seen in **Table 9**.

SAS certifies that the statements made in this report regarding performance test results are true and complete to the best of our knowledge and belief, based on the data collected prior to and during the inspection and testing activities which concluded on or about November 13, 2013.

Alexander Sas-Jaworsky, P.E.

Alexander Sas-Jaworsky, PE (TX 79783)
Vice President - Engineering Services

STATE OF TEXAS
ALEXANDER SAS-JAWORSKY II
79783
REGISTERED
PROFESSIONAL ENGINEER

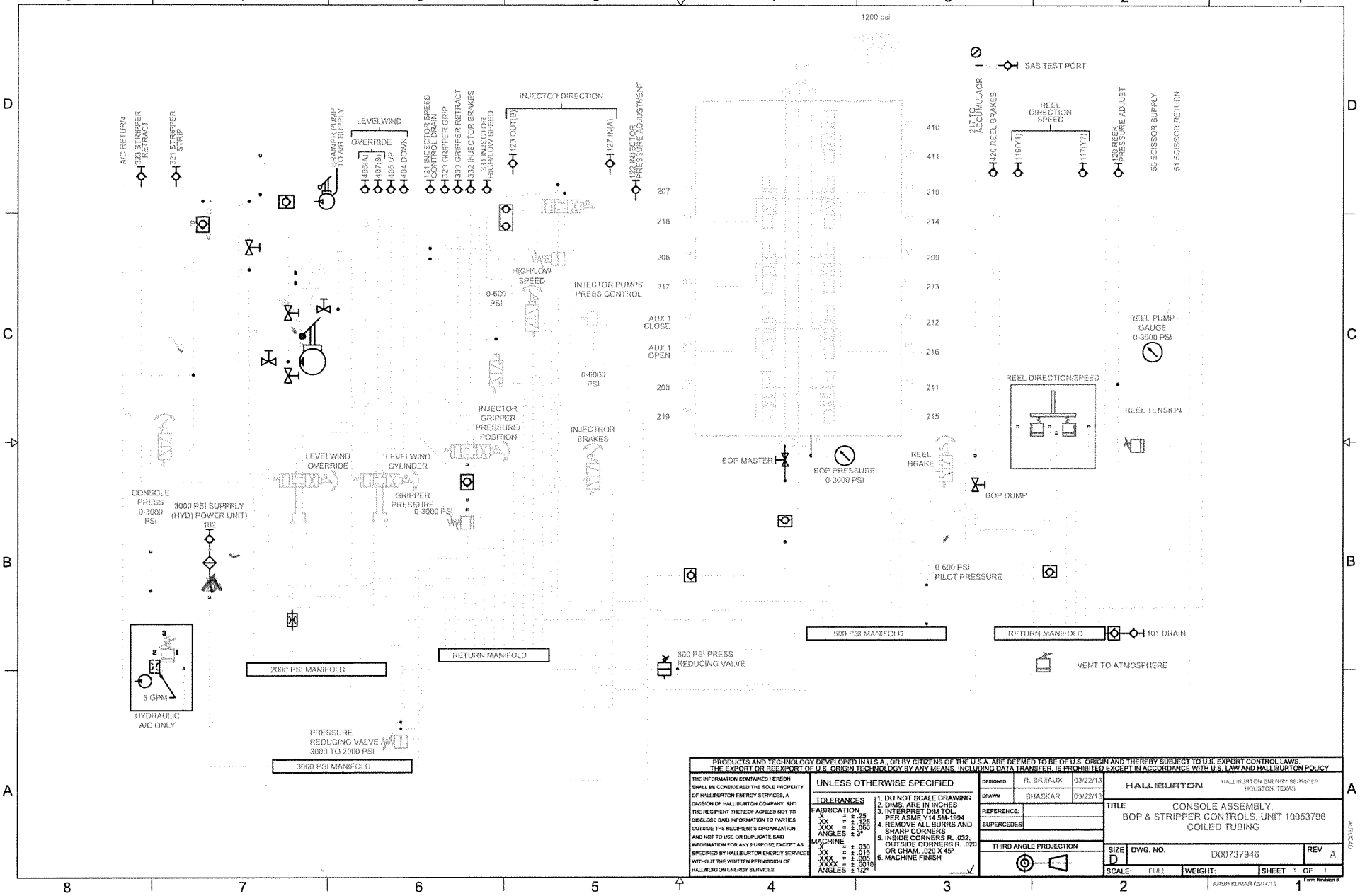
DISCLAIMER

This report was prepared by SAS Industries, Inc. ("SAS") based upon verified and documented performance audit testing activities concluded on November 13, 2013. The SAS performance audit testing process employs sound engineering practices, applied mathematical methods, assumptions of service application and data provided by the client (or service vendor). SAS makes no representation or warranty, expressed or implied, as to the accuracy of the information furnished by the client used to prepare test conditions described in this report. Due to variable well conditions, inaccurate well data, changing well conditions, tolerance variations of mechanical components tested, mechanical malfunctions and other factors and information which must be relied upon that are not within SAS's control, SAS makes no warranty, express or implied, that the mechanical components observed during the audit testing environment as described in this report will perform in future field applications in the same manner as that observed in the performance audit test program or that the calculations and/or opinions expressed herein are accurate as applied to any conditions in the field.

The user of this report is advised to consult with SAS if there are any questions concerning this report or its application to any specific field condition. The details regarding performance testing and qualification test methodology are seen in the SAS Formal Report to be issued to B&C at a later date.

Reviewed Schematic to Unit Hydraulics for ~~Atty~~ 2/24/14

Keiam Shum 2/24/14



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.XX	± .125
.XXX	± .060
ANGLES	± 3°
MACHINE	
X	± .030
.XX	± .015
.XXX	± .005
.XXXX	± .0010
ANGLES	± 1/2°

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4. REMOVE ALL BURRS AND SHARP CORNERS
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6. MACHINE FINISH

DESIGNED:	R. BREAUX	03/22/13
DRAWN:	BHASKAR	03/22/13
REFERENCE:		
SUPERCEDES:		

THIRD ANGLE PROJECTION

HALLIBURTON — HALLIBURTON ENERGY SERVICES, HOUSTON, TEXAS

TITLE: CONSOLE ASSEMBLY, BOP & STRIPPER CONTROLS, UNIT 10053796 COILED TUBING

SIZE	DWG. NO.	REV
D	D00737946	A

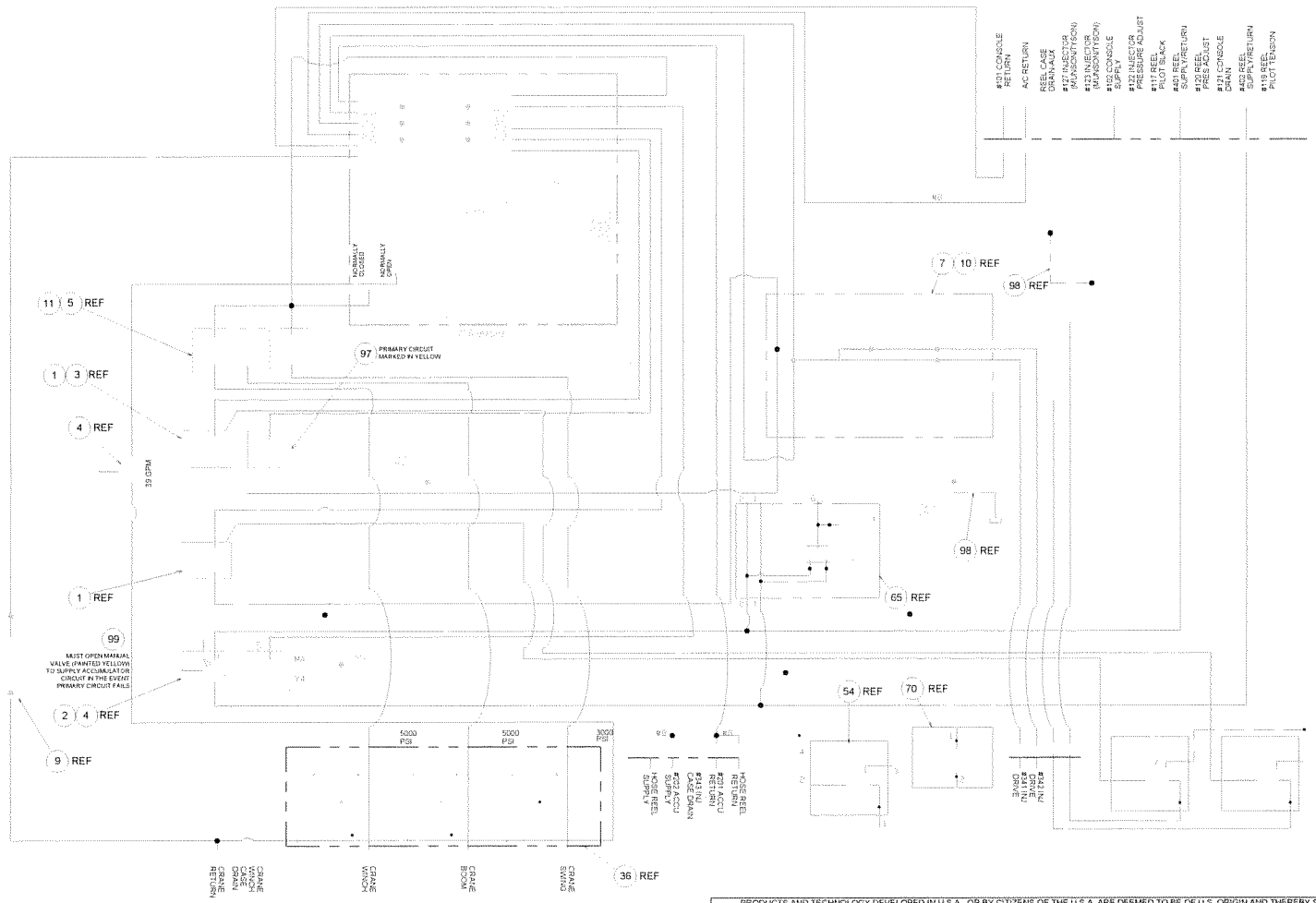
SCALE: FULL | WEIGHT: | SHEET 1 OF 1

ARUN KUMAR 05/14/13

Form Revision B

AUTOCAD

Reviewed Unit to schematic 2/24/14
Keiana Shipp 2/24/14



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DESIGNED	R. BREAUX	04/04/13
DRAWN	ARUN KUMAR	04/04/13
REFERENCE		
SUPERCEDES		

THIRD ANGLE PROJECTION

HALLIBURTON
HALLIBURTON ENERGY SERVICES
HOUSTON, TEXAS

TITLE INSTALLATION, HYDRAULIC PUMPS, RESERVOIR, COOLER, PIPING, FILTERS, 60K POWER PACK, UNIT 10053783

SIZE D | DWG. NO. D00742764 | REV A

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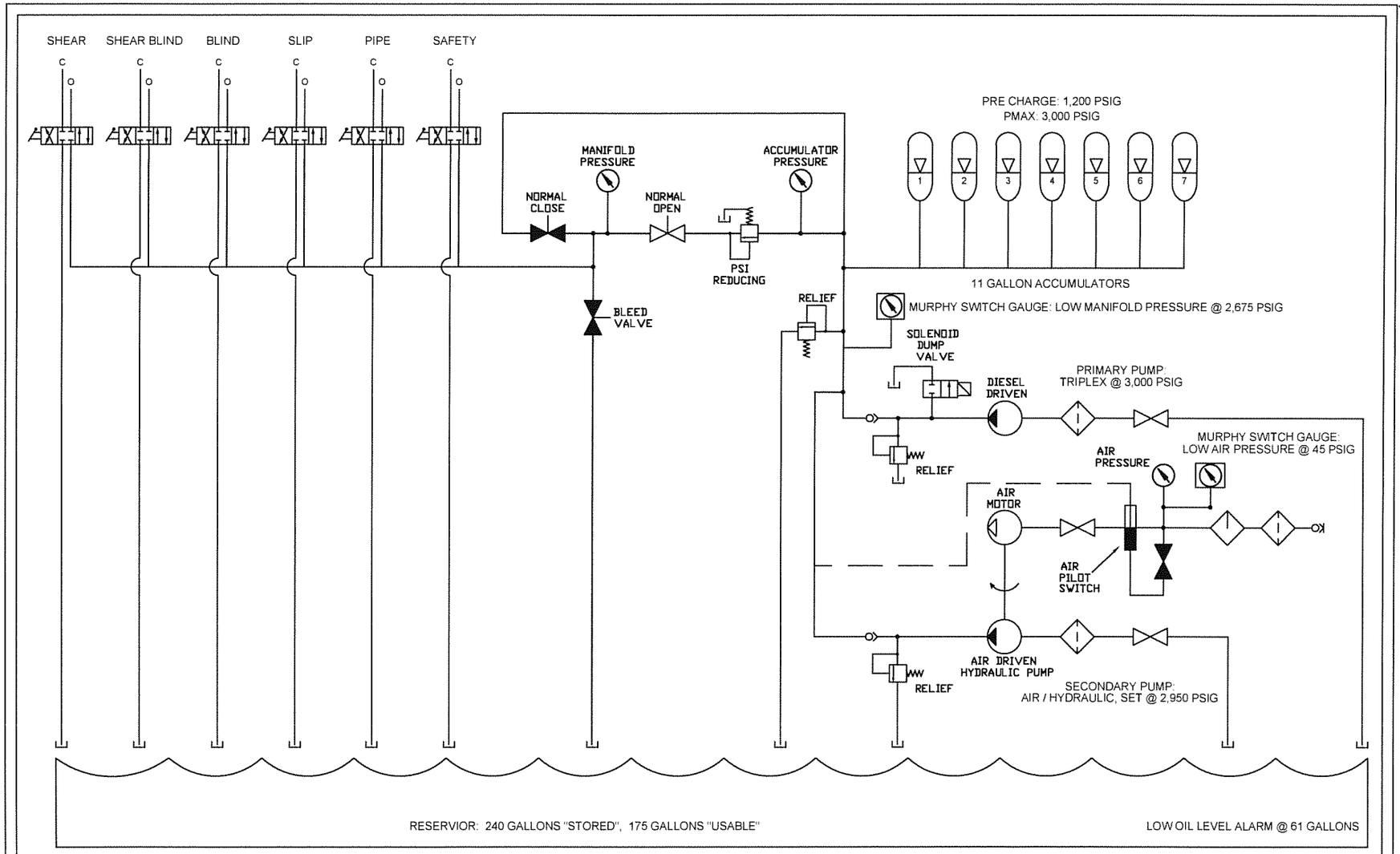
Form Revision B

AUTOCAD

Reviewed by
Joe Steckman
6.12.13



B & C 11939830

Note: Master gauge in box not adjustable.

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6. MACHINE FINISH

DESIGNED		
DRAWN	KS	6-12-2013
REFERENCE		
SUPERCEDES		

THIRD ANGLE PROJECTION

HALLIBURTON — HALLIBURTON ENERGY SERVICES, HOUSTON, TEXAS

TITLE: **Accumulator Skid Model No. ACC-51 Hydraulic Schematic 11939830**

SIZE: D | DWG. NO. | REV

SCALE: N/A | WEIGHT: - | SHEET 1 OF 1

BOOTS & COOTS
CT WELL CONTROL EQUIPMENT AUDIT

PERFORMANCE TESTING AND CERTIFICATION OF BOOTS & COOTS COILED TUBING ES56 SHEAR RAM

QUAD RAM STACK TOT 123-37667

API RP 16ST 180 Day PM Program
(January 02, 2014 through July 01, 2014)

System Evaluation Based on "Standardized" B&C CT Control Console With 60-Gallon Accumulator Circuit

January 08, 2014

Prepared By:

SAS INDUSTRIES, INC.

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Houston, TX 77084
Telephone (281) 398-9207 • Fax (281) 398-0564
sasindinc@cs.com

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STATEMENT FOR CERTIFICATION AND SIGNATURE 6

DISCLAIMER 6

ATTACHMENT A 7

Texas Oil Tool Theoretical Shear Ram Performance Calculations 7

ATTACHMENT B 8

Shear Ram Performance Chart 8

SAS Industries, Inc. Audit of Coiled Tubing Well Control Equipment
Boots & Coots - Coiled Tubing Division - New Iberia, Louisiana

Boots & Coots (B&C) requested SAS Industries, Inc. (SAS) to conduct a performance audit of the B&C coiled tubing (CT) well control equipment and systems identified in this Report. The SAS Audit was conducted to evaluate condition and performance capability of the B&C coiled tubing well control equipment listed below to certify compliance with the Recommended Practices and performance expectations outlined in **API RP 16ST** ***Coiled Tubing Well Control Equipment Systems*** and to meet or exceed the intent of **30 CFR 250.615** for Shear Ram "Performance Test" qualification.

The SAS well control and support equipment certification program is conducted to ensure conformance with **API RP 16ST** standards, **30 CFR 250.615** and **30 CFR 250.616** regulations, SAS Asset Integrity and Lifting Equipment Standards, OSHA Guidelines, DOT regulations (where applicable) and established "Industry Best Practice" performance requirements.

The location and time period for the CT equipment performance testing audit are shown below:

Location	Start Date	End Date
Boots & Coots Coiled Tubing - New Iberia, Louisiana	January 02, 2014	January 03, 2014

I. SUMMARY OF CT SHEAR RAM PERFORMANCE EVALUATION

The B&C well control equipment components subjected to performance testing are shown below.

Table 1 - List of Well Control Equipment Performance Tested

B&C Coiled Tubing Well Control Equipment and System					
Met Requirements as Found	MET	Required Repairs/Adjustments	RR/A	Did Not Meet Requirements	DNM
Item	**Well Control Equipment Components**	**Size / Rating**	**ID No.**	**Status**	
1.	Quad-Ram Well Control Stack	5-1/8", 15M TOT ES56	TOT 123-37667	MET	
2.	Well Control Accumulator System	60-Gallon Circuit Volume	B&C "Standardized"	MET	

*Note: Only the TOT ES56 Quad Ram Stack was used in the accumulator system volume qualification tests.

Coiled Tubing Test Specimen:	1.750" OD, 0.203" wall, CT – 130 grade
Shear Ram Performance Test Pressure:	1,169 psig (at atmospheric pressure)
Calculated Shear Ram Pressure:	1,078 psig (at atmospheric pressure) (with a **Blade Factor of 0.70**)
Minimum CT Unit Accumulator Volume:	60 Gallons
Accumulator Precharge Pressure:	1,200 psig at 45° F (average temperature)
30-Minute Stabilized Accumulator Pressure:	2,950 psig at 48° F (average temperature)
Expected Accumulator Pressure at Shear:	2,250 psig

Based on the performance testing of the Texas Oil Tools ES56 Quad-Ram 123–37667, the Shear Ram demonstrated the capability of shearing the referenced CT size wall thickness and grade to a ***MASP of 15,000 psig*** and is qualified for service when used with the "Standardized" B&C CT Control Console equipped with a 60-Gallon accumulator system.

II. RESULTS OF CT SHEAR RAM TEST CERTIFICATION

At the request of B&C, SAS prepared this abbreviated Report which is intended to focus exclusively on the Test Documentation and Performance Evaluation of the Shear Rams included in the captioned Quad-Ram well control stack assembly. The coiled tubing well control equipment performance expectation review conducted by SAS is based on the design capabilities recommended in API RP 16ST Coiled Tubing Well Control Equipment Systems (1st Edition, March 2009) as seen in the SAS Formal Audit Report.

SAS advises the User to review the Formal Audit Report to confirm that the well control stack components in the stack assembly meet the performance expectations stipulated in API RP 16ST.

B&C selected 1.750" OD, CT-130 grade coiled tubing as the workstring design to be qualified for the designated well control equipment. For this CT workstring design, the heaviest wall thickness selected was 0.203" wall thickness. Based on the aforementioned CT workstring design, the size, wall thickness and grade of the ***Quality Tubing, Inc.*** CT test specimen specified for the certification testing observed in this report are shown in **Table 2** below.

Table 2 - Coiled Tubing Test Specimen – Material Properties

Coiled Tube OD	Wall Thickness	CT Grade	QTI Strip No.	Minimum Yield	Ultimate Tensile
1.750 Inches	0.203 Inch	CT – 130	1500053903	142,000 psi	146,000 psi

Table 3 - Coiled Tubing Test Specimen – Dimensional Measurements

Tube OD Measurements		Wall Thickness Measurements			
Vertical Axis	Horizontal Axis	0 Degrees	90 Degrees	180 Degrees	270 Degrees
1.7580 Inches	1.7635 Inches	0.21230 Inch	0.21240 Inch	0.20895 Inch	0.21065 Inch

The results of the **API RP 16ST** Shear Ram performance tests conducted on the ES56 Quad Ram Assembly (SN: 123-37667) by SAS on January 02, 2014, are listed in **Table 4** below.

Table 4. Mechanical Component Tests - Shear Rams (API RP 16ST 12.2.1)

Component	Serial Number	Shear Pressure 1	Shear Pressure 2	Shear Pressure 3
Shear Ram	TOT 123-37667	1,169 Psig*	1,146 psig	1,228 psig

*Shear Test No.1 was performed with the CT specimen secured within the Slip Rams and serves as the ***test of record***.

B&C requested that SAS perform theoretical Shear Ram calculations to meet the BSEE approval requirements. SAS obtained the Shear Ram performance calculation method recommended by Texas Oil Tools (manufacturers of the ES56 Quad Ram).

The TOT calculation method is based on the Distortion Energy Theory (see Worksheet in **Attachment A** of this Report) and yielded a theoretical Shear Ram pressure (P_{shear}) of **1,540 psig** (at atmospheric conditions). In comparison to the theoretical calculations offered by TOT, the "Actual" Shear Ram pressure of **1,169 psig** is found to be **75.9%** of the "theoretical" shear value. For purposes of providing sensitivity to the theoretical shear value, a **Blade Factor** of **0.70** is shown in **Figure 1** and **Attachment A** of this Report, yielding an adjusted theoretical shear value of **1,078 psig**.

To the extent that there are differences between the Shear Ram performance tests observed by SAS and the TOT Calculations, SAS bases the findings in this Report on observed physical performance testing and does not rely on the TOT Calculations as a means for determining "fitness-for-purpose". SAS makes no representation or warranties regarding the accuracy of the TOT Calculations and provides them for comparative analysis only.

SAS conducted the aforementioned well control equipment performance tests and evaluated the performance as it relates to the "Standardized" accumulator system for the CT Unit power pack and Control Console to be used with this equipment as seen in **Tables 5, 6** and **7** and **Figure 1**.

Table 5 shows the design and configuration of the accumulator system used with the captioned well control equipment, along with the "As-Found" precharge pressure (and temperature) and "30-Minute Stabilized Operating Pressure". The accumulator operating parameters seen in **Table 5** are required for determining the performance capability of the accumulator circuit (Usable Volume and Critical Pressure) with respect to the well control equipment to be used.

Table 6 shows the volumes for closing and opening each of the Texas Oil Tools rams installed within the well control stack. This information was obtained from the TOT ES56 1430-Man Technical Manual provided to B&C with the well control equipment. Based on the "Usable" power fluid volume (**25.1251** gallons) available at the accumulator conditions stated above, the B&C accumulator circuit has more than sufficient "Usable" volume to complete the required ES56 ram "close-open-close" functions with a remaining system pressure at least 200 psig above precharge.

Table 7 is taken from the SAS ***Accumulator Performance Evaluation Spreadsheet***, which illustrates the comparison of the predicted accumulator pressure response to the response observed during the physical "close-open-close" ram tests conducted by SAS. The pressure values seen in **Table 7** reflect the pressure in the accumulator circuit immediately after closure of the respective ram. Note that the predicted pressure responses are based on empirical relationships that reflect changes in accumulator pressure due to changes in nitrogen temperature as the bladders expand.

The sequence of ram closure is taken from **API RP 16ST**, where in a well control emergency, the first rams to be closed are the Slip Rams, followed by closure of the Pipe Rams and the Shear Rams (third ram set to close). This sequence provides the means for evaluating the "depressurization" of the accumulator circuit as the rams are closed. For the accumulator operating parameters identified above, the maximum accumulator circuit pressure to be expected upon closure of the Shear Rams is approximately **2,250 psig**. ***As a result, SAS uses the projected accumulator circuit pressure of 2,250 psig as the limit for determining the capability of shearing the respective size of coiled tubing across the range of wellbore pressures***.

Figure 1 represents the graphical representation of the Shear Ram pressure to be expected when shearing the respective size of coiled tubing with wellbore pressure present. The "red" line represents the expected shear pressure using the observed shear test data. The "green" line represents the Shear Ram pressure projected using the theoretical calculations (see **Attachment A**). The "blue" dashed line across the graph represents the accumulator pressure recommended to be used in determining the wellbore pressure working limits for the Shear Ram with the captioned coiled tubing string.

TABLE 5 B&C "STANDARDIZED" CT CONTROL CONSOLE ACCUMULATOR SYSTEM DESIGN

Accumulator System Design			Precharge Conditions		Stabilized Conditions	
Number	Gallons	Orientation	Pressure	Temperature	Pressure	Temperature
1	15	Horizontal	1,200 Psig	46.0 F	2,950 Psig	48.0 F
2	15	Horizontal	1,200 Psig	46.0 F	2,950 Psig	48.0 F
3	15	Horizontal	1,200 Psig	44.0 F	2,950 Psig	48.0 F
4	15	Horizontal	1,200 Psig	44.0 F	2,950 Psig	48.0 F
TOTAL	60	Gallons	(Accumulator Tests Conducted at B&C Facility on 12.31.13)			

TABLE 6 B&C QUAD 123-37667 CLOSING AND OPENING OPERATING VOLUMES

	Blind Rams	Shear Rams	Slip Rams	Pipe Rams			Total
	Gallon	Gallon	Gallon	Gallon			Gallons
Close	0.87100	1.92210	1.92210	0.87100			5.5862
Open	0.87100	1.92210	1.92210	0.87100			5.5862

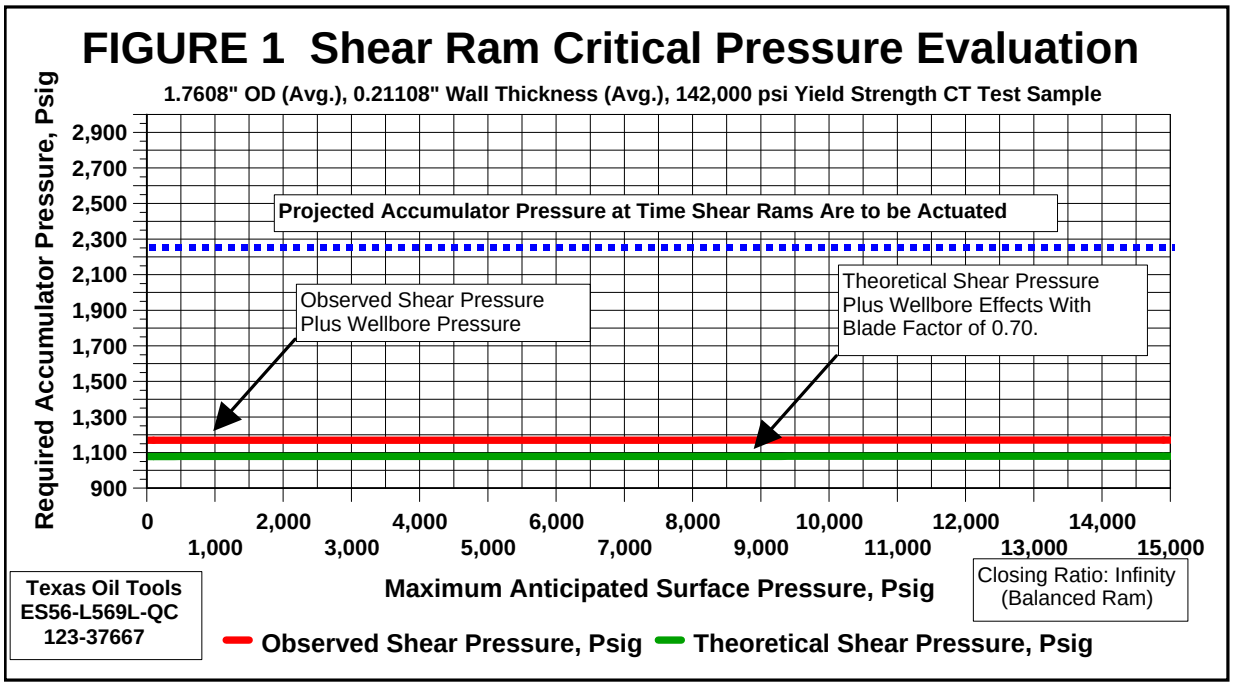
Volume for "Close - Open - Close" of CT Rams in Stack : 16.7586 Gallons

API RP16ST Accumulator Usable Volume Calculation : 25.1251 Gallons MET

(Note: Vacc Calculations Based on the Accumulator Pressures and Temperatures Noted Above)

TABLE 7 ACCUMULATOR CIRCUIT PERFORMANCE - Predicted Versus Actual

Adiabatic Cd:	0.35	Accumulator Pressure		Usable	Closing	Pressure /
Ram	Function	Calculated	Observed	Volume	Time	Rate Ratio
		(psig)	(psig)	(gallons)	(sec.)	(gpm/psig)
Initial Status	Open Valve	2,865	2,865	25.125	0.00	0.000000
Slip Ram	Close	2,626	2,620	23.203	30.00	0.001467
Pipe Ram	Close	2,527	2,500	22.332	25.00	0.000836
Shear Ram	Close	2,334	2,250	20.410	48.00	0.001068
Blind Ram	Close	2,254	2,180	19.539	26.00	0.000922
Pipe-Slip	Close	2,180	2,105	18.668	26.00	0.000955



Observed Shear Ram Test Pressure :	1,169	Psig (at atmospheric conditions)
Theoretical Shear Ram Pressure :	1,540	Psig (at atmospheric conditions With BF = 1.00)
Theoretical Shear Ram Pressure :	1,078	Psig (at atmospheric conditions With BF = 0.70)

The results of the test data obtained by SAS through the aforementioned testing program demonstrate that the B&C Shear Ram (ES56 Quad-Ram 123-37667) meets the performance expectations referenced in **API RP 16ST** to a **MASP** of **15,000 psig** for the coiled tubing workstring and accumulator system design parameters stated in **Table 8**.

Table 8. Well Control Stack Performance Qualification for CT String and MASP Service

Coiled Tubing Workstring OD	Wall	Grade	Wellbore MASP	Accumulator Volume	30-Minute Stabilized Accumulator Pressure	Pre-Charge Accumulator Pressure
1.750"	0.203"	CT – 130	15,000 Psig	60 Gallons	2,950 Psig	1,200 Psig

Based on the results of performance testing concluded on January 03, 2014, SAS certifies that the aforementioned B&C coiled tubing well control equipment meets or exceeds the performance expectations stipulated in **API RP 16ST** for the operating conditions shown in **Table 9** below when used with the accumulator system parameters seen in **Table 5**.

Table 9. Well Control Stack Performance Qualification for Additional CT Workstrings

Coiled Tubing Workstring Conditions		
CT Outside Diameter	CT Wall Thickness	Grade
1.750" and Below	0.203" and Below	CT-130 and Below

SAS certifies that the statements made in this report regarding performance test results are true and complete to the best of our knowledge and belief, based on the data collected prior to and during the inspection and testing activities which concluded on or about January 03, 2014.

Alexander Sas-Jaworsky P.E.

Alexander Sas-Jaworsky, PE (TX 79783)
Vice President - Engineering Services

STATE OF TEXAS
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79783
REGISTERED PROFESSIONAL ENGINEER

DISCLAIMER

This report was prepared by SAS Industries, Inc. ("SAS") based upon verified and documented performance audit testing activities concluded on January 03, 2014. The SAS performance audit testing process employs sound engineering practices, applied mathematical methods, assumptions of service application and data provided by the client (or service vendor). SAS makes no representation or warranty, expressed or implied, as to the accuracy of the information furnished by the client used to prepare test conditions described in this report. Due to variable well conditions, inaccurate well data, changing well conditions, tolerance variations of mechanical components tested, mechanical malfunctions and other factors and information which must be relied upon that are not within SAS's control, SAS makes no warranty, express or implied, that the mechanical components observed during the audit testing environment as described in this report will perform in future field applications in the same manner as that observed in the performance audit test program or that the calculations and/or opinions expressed herein are accurate as applied to any conditions in the field.

The user of this report is advised to consult with SAS if there are any questions concerning this report or its application to any specific field condition. The details regarding performance testing and qualification test methodology are seen in the SAS Formal Report to be issued to B&C at a later date.

ATTACHMENT A – Texas Oil Tools Theoretical Shear Performance Calculations

CT OD	CT ID	Material Yield Strength	Piston Diameter, D_p	Piston Rod Diameter, D_r	Booster Piston Diameter, D_{pb}	Booster Rod Diameter, D_{br}	Tail Rod Diameter, D_{tr}
1.7608"	1.3386"	142,000 psi	8.500"	1.625"	N/A	N/A	1.625"

TOT Calculations - 5.125" ES56 Quad Assembly

OD_{CT} = Coiled Tube Outside Diameter, (inch)
Sy = Material Yield Strength, (psi)
SA = Shear Ram Area, (inch^2)

ID_{CT} = Coiled Tube Inside Diameter, (inch)
T_{Shear} = Theoretical Shear Force, (Lb_f)
CR = Closing Ratio, (dimensionless)
BF = Blade Factor (**0.70**) TOT Recommended

MASP = Maximum Anticipated Surface Pressure, (psig)
P_{Shear} = Theoretical Ram Pressure to Shear at Atmospheric Conditions, (psig)
$P_{Critical}$ = Theoretical Ram Pressure to Shear at Wellbore Pressure Conditions, (psig)

$$\text{Theoretical Shear} = 0.7854\left(OD^2 - ID^2\right)\left(S_y\right)\left(0.577\right) \qquad \textbf{Eq. A1}$$

$$\text{Shear Ram Area} = 0.7854\left(D_p^2\right) - 0.7854\left(D_{tr}^2\right) \qquad \textbf{Eq. A2}$$

$$\text{Closing Ratio} = \text{Shear Ram Area} \div (0.7854)(D_r^2) \qquad \textbf{Eq. A3}$$

$$P_{Shear} = (\text{Theoretical Shear x } \textbf{Blade Factor} \text{ /Shear Ram Area}) \qquad \textbf{Eq. A4}$$

$$P_{critical} = P_{shear} + (\text{MASP / Closing Ratio}) \qquad \textbf{Eq. A5}$$

The TOT theoretical calculations for estimating ES56 Shear Ram pressure for well conditions where the MASP is 15,000 psig, are shown below:

$$\text{Theoretical Shear} = 0.7854\left(1.7608^2 - 1.3386^2\right)\left(142{,}000\,psi\right)\left(0.577\right) = 84{,}208\ Lb_f$$

$$\text{Shear Ram Area} = 0.7854\left(8.500^2\right) - 0.7854\left(1.625^2\right) = 54.67\ Inches^2$$

Closing Ratio = Infinity (Shear Ram is Pressure Balanced)

P_{Shear} = (84,208 lb_f x **0.70** /54.67 in^2) = **1,078 psig**

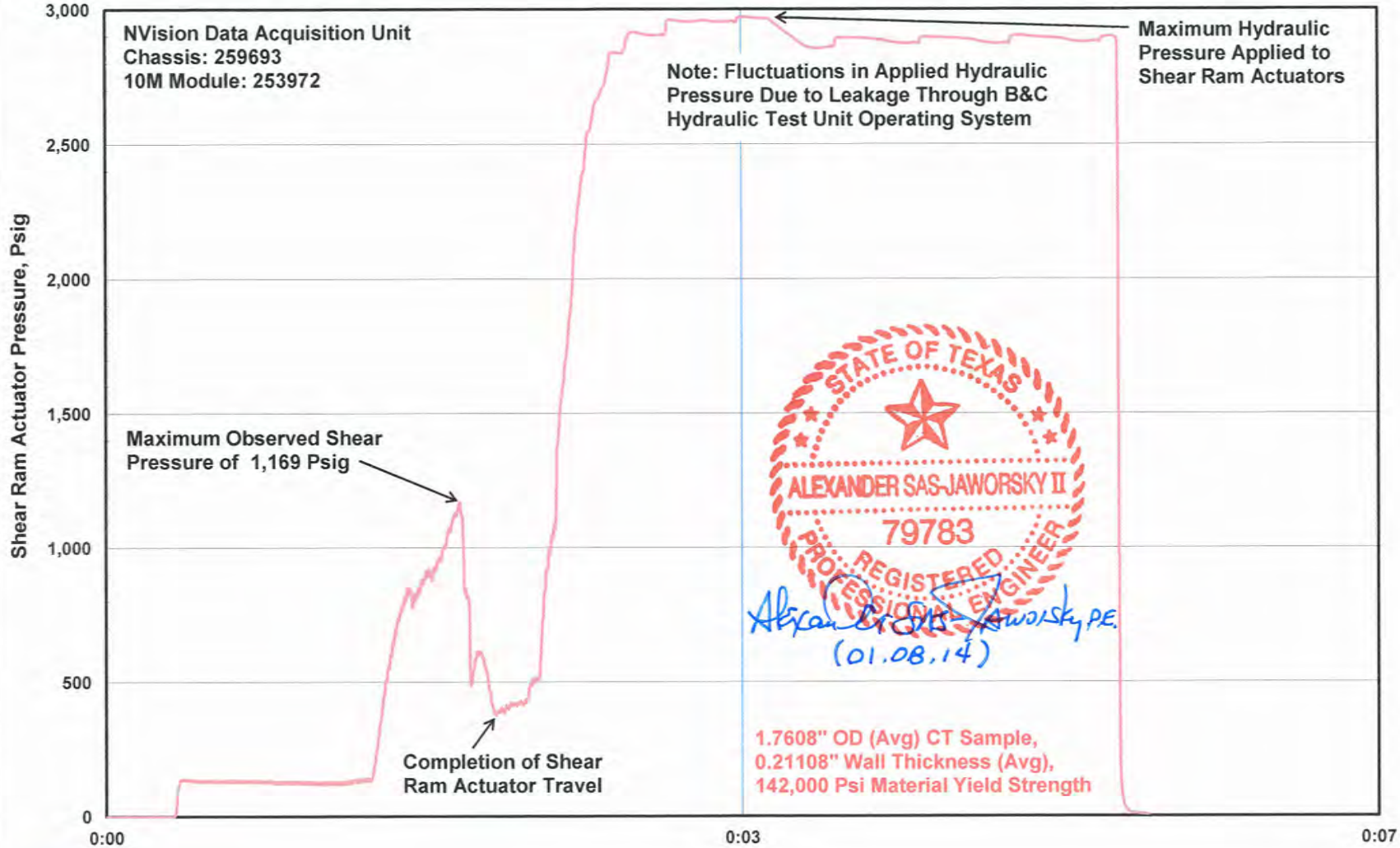
$P_{critical}$ = 1,078 psig + (0) = **1,078 psig**

Alex SAS-Zawarsky P.E.
(TX 79783 01.08.14)

To the extent that there are differences between the Shear Ram performance tests observed by SAS Industries, Inc. and the TOT Calculations, SAS Industries, Inc. bases the findings in this report on observed physical performance testing and does not rely on the TOT Calculations as a means for determining "fitness-for-purpose". SAS Industries, Inc. makes no representation or warranties regarding the accuracy of the TOT Calculations and provides them at the request of B&C for comparative analysis only.

TOT ES56 123-37667 SHEAR RAM PERFORMANCE TEST

SHEAR RAM TEST CONDUCTED ON JANUARY 02, 2014 AT B&C FACILITY (New Iberia, LA)



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(01.08.14)

SAS INDUSTRIES, INC.

January 08, 2014

BOOTS & COOTS
CT WELL CONTROL EQUIPMENT AUDIT

PERFORMANCE TESTING AND CERTIFICATION OF BOOTS & COOTS COILED TUBING ES56 SHEAR-BLIND RAM

DUAL COMBI RAM STACK TOT 123-37672

API RP 16ST 180 Day PM Program
(January 03, 2014 through July 02, 2014)

System Evaluation Based on the B&C 11939830 Stand-Alone Closing Unit With the 77-Gallon Accumulator Circuit

January 10, 2014

Prepared By:

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SAS Industries, Inc. Audit of Coiled Tubing Well Control Equipment
Boots & Coots - Coiled Tubing Division - New Iberia, Louisiana

Boots & Coots (B&C) requested SAS Industries, Inc. (SAS) to conduct a performance audit of the B&C coiled tubing (CT) well control equipment and systems identified in this Report. The SAS Audit was conducted to evaluate condition and performance capability of the B&C coiled tubing well control equipment listed below to certify compliance with the Recommended Practices and performance expectations outlined in **API RP 16ST** ***Coiled Tubing Well Control Equipment Systems*** and to meet or exceed the intent of **30 CFR 250.615** for Shear-Blind Ram (SBR) "Performance Test" qualification.

The SAS well control and support equipment certification program is conducted to ensure conformance with **API RP 16ST** standards, **30 CFR 250.615** and **30 CFR 250.616** regulations, SAS Asset Integrity and Lifting Equipment Standards, OSHA Guidelines, DOT regulations (where applicable) and established "Industry Best Practice" performance requirements.

The location and time period for the CT equipment performance testing audit are shown below:

Location	Start Date	End Date
Boots & Coots Coiled Tubing - New Iberia, Louisiana	January 03, 2014	January 04, 2014

I. SUMMARY OF CT SHEAR-BLIND RAM PERFORMANCE EVALUATION

The B&C well control equipment components subjected to performance testing are shown below.

Table 1 - List of Well Control Equipment Performance Tested

B&C Coiled Tubing Well Control Equipment and System					
Met Requirements as Found	MET	Required Repairs/Adjustments	RR/A	Did Not Meet Requirements	DNM
Item	**Well Control Equipment Components**	**Size / Rating**	**ID No.**	**Status**	
1.	Dual Combi Well Control Stack	5-1/8", 15M TOT ES56	TOT 123-37672	MET	
2.	Well Control Closing Unit	77-Gallon Circuit Volume	B&C 11939830	MET	

*Note: The ES56 Shear-Blind Ram and Pipe-Slip Ram were the only ram assemblies used in the accumulator system volume qualification tests.

Coiled Tubing Test Specimen:	1.750" OD, 0.203" wall, CT – 130 grade
Shear-Blind Ram Performance Test Pressure:	2,061 psig (at atmospheric pressure)
Post-Shear Sealing Pressure Test:	14,900 Psig (with 1,800 psig closing pressure)
Calculated Shear-Blind Ram Pressure:	2,094 psig (at atmospheric pressure) (with **Blade Factor** of **0.91**)
Minimum CT Unit Accumulator Volume:	77 Gallons
Accumulator Precharge Pressure:	1,200 psig at 42° F (average temperature)
30-Minute Stabilized Accumulator Pressure:	2,950 psig at 55° F (average temperature)
Expected Accumulator Pressure at Shear:	2,480 psig

Based on the performance testing of the Texas Oil Tools (TOT) ES56 Dual Combi Ram assembly 123–37672, the SBR demonstrated the capability of shearing the referenced CT size wall thickness and grade to a ***MASP of 15,000 psig*** and is qualified for service when used with the ***B&C 11939830 Closing Unit equipped with a 77-Gallon accumulator system***.

II. RESULTS OF CT SHEAR-BLIND RAM TEST CERTIFICATION

At the request of B&C, SAS prepared this abbreviated Report which is intended to focus exclusively on the Test Documentation and Performance Evaluation of the Shear-Blind Rams included in the captioned Dual-Combi Ram well control stack assembly. The coiled tubing well control equipment performance expectation review conducted by SAS is based on the design capabilities recommended in API RP 16ST Coiled Tubing Well Control Equipment Systems (1st Edition, March 2009) as seen in the SAS Formal Audit Report.

SAS advises the User to review the Formal Audit Report to confirm that all well control stack components in the stack assembly meet the performance expectations stipulated in API RP 16ST.

B&C selected 1.750" OD, CT-130 grade coiled tubing as the workstring design to be qualified for the designated well control equipment. For this CT workstring design, the heaviest wall thickness selected was 0.203" wall thickness. Based on the aforementioned CT workstring design, the size, wall thickness and grade of the ***Quality Tubing, Inc.*** CT test specimen specified for the certification testing observed in this report are shown in **Table 2** below.

Table 2 - Coiled Tubing Test Specimen – Material Properties

Coiled Tube OD	Wall Thickness	CT Grade	QTI Strip No.	Minimum Yield	Ultimate Tensile
1.750 Inches	0.203 Inch	CT – 130	1500053093	142,000 psi	146,000 psi

Table 3 - Coiled Tubing Test Specimen – Dimensional Measurements

Tube OD Measurements		Wall Thickness Measurements			
Vertical Axis	Horizontal Axis	0 Degrees	90 Degrees	180 Degrees	270 Degrees
1.7545 Inches	1.7565 Inches	0.21310 Inch	0.21270 Inch	0.20860 Inch	0.20810 Inch

The results of the **API RP 16ST** Shear-Blind Ram performance tests conducted on the ES56 Dual Combi Ram Assembly (SN: 123-37672) by SAS on January 03, 2014, are listed in **Table 4** below.

Table 4. Mechanical Component Tests - Shear-Blind Rams (API RP 16ST 12.2.3)

Component	Serial Number	Shear Pressure 1	Shear Pressure 2	Shear Pressure 3
Shear-Blind Ram	TOT 123-37672	2,061 Psig*	2,141 psig	2,102 psig

*Shear-Blind Test No.1 was performed with the CT specimen secured within the Pipe-Slip Rams and serves as the ***test of record***. Note that the "post-shear" SBR pressure sealing test was conducted immediately after SBR Test No. 1.

B&C requested that SAS perform theoretical Shear-Blind Ram calculations to meet the BSEE approval requirement. SAS obtained the Shear-Blind Ram performance calculation method recommended by Texas Oil Tools (manufacturers of the ES56 Dual Combi Ram).

The TOT calculation method is based on the Distortion Energy Theory (see Worksheet in **Attachment A** of this Report) and yielded a theoretical Shear-Blind Ram pressure (P_{shear}) of **2,301 psig** (at atmospheric conditions). In comparison to the theoretical calculations offered by TOT, the "Actual" SBR pressure of **2,061 psig** is found to be **89.6%** of the "theoretical" shear value. For purposes of providing sensitivity to the theoretical shear value, the TOT **Blade Factor** of **0.91** is shown in **Figure 1** and **Attachment A** of this Report, yielding an adjusted theoretical shear value of **2,094 psig**.

To the extent that there are differences between the Shear-Blind Ram performance tests observed by SAS and the TOT Calculations, SAS bases the Report findings on observed physical performance testing and does not rely on the TOT Calculations as a means for determining "fitness-for-purpose". ***SAS makes no representation or warranties regarding the accuracy of the TOT Calculations and provides them for comparative analysis only.***

SAS conducted the aforementioned well control equipment performance tests and evaluated the performance as it relates to the ***B&C 11939830 Closing Unit*** equipped with a ***77-gallon Accumulator system*** to be used with this equipment as seen in **Tables 5, 6** and **7** and **Figure 1**.

Table 5 shows the design and configuration of the accumulator system used with the captioned well control equipment, along with the "As-Found" precharge pressure (and temperature) and "30-Minute Stabilized Operating Pressure". The accumulator operating parameters seen in **Table 5** are required for determining the performance capability of the accumulator circuit (Usable Volume and Critical Pressure) with respect to the well control equipment to be used.

Table 6 shows the volumes for closing and opening the Texas Oil Tools ES56 rams installed within the Dual Combi-Ram well control stack. This information was obtained from the TOT 1449 Technical Manual provided to B&C with the well control equipment. Based on the "Usable" power fluid volume (**31.5019** gallons) available at the accumulator conditions stated above, the B&C accumulator circuit has more than sufficient "Usable" volume to complete the required ES56 SBR "close-open-close" functions with a remaining system pressure at least 200 psig above precharge.

Table 7 is taken from the SAS ***Accumulator Performance Evaluation Spreadsheet***, which illustrates the comparison of the predicted accumulator pressure response to the response observed during the physical "close-open-close" ram tests conducted by SAS. The pressure values seen in **Table 7** reflect the pressure in the accumulator circuit immediately after closure of the PSR (first ram to close) and then closure of the SBR (second ram to close). Note that the predicted responses are based on empirical relationships that reflect changes in accumulator pressure due to changes in nitrogen temperature as the bladders expand.

For this application, the B&C ES56 PSR and SBR are the only ram assemblies to be operated from the **B&C 11939830 Closing Unit**. For the accumulator operating parameters identified above, the maximum accumulator circuit pressure to be expected upon initial closure of the ES56 SBR is approximately **2,480 psig**. ***As a result, SAS uses the projected accumulator circuit pressure of 2,480 psig as the limit for determining the capability of shearing the respective size of coiled tubing across the range of wellbore pressures using the 77-gallon accumulator system.***

Figure 1 represents the graphical representation of the Shear-Blind Ram pressure to be expected when shearing the respective size of coiled tubing with wellbore pressure present. The "red" line represents the expected shear pressure using the observed shear test data. The "green" line represents the Shear-Blind Ram pressure projected using the theoretical calculations (see **Attachment A**). The "blue" dashed line across the graph represents the accumulator pressure recommended to be used in determining the wellbore pressure working limits for the Shear-Blind Ram with the captioned coiled tubing string.

TABLE 5 B&C 11939830 CLOSING UNIT WITH 77-GALLON ACCUMULATOR BOTTLE PACKAGE

Accumulator System Design			Precharge Conditions		Stabilized Conditions	
Number	Gallons	Orientation	Pressure	Temperature	Pressure	Temperature
1	11	Vertical	1,200 Psig	42.0 F	2,950 Psig	55.0 F
2	11	Vertical	1,200 Psig	42.0 F	2,950 Psig	55.0 F
3	11	Vertical	1,200 Psig	42.0 F	2,950 Psig	55.0 F
4	11	Vertical	1,200 Psig	42.0 F	2,950 Psig	55.0 F
5	11	Vertical	1,200 Psig	42.0 F	2,950 Psig	55.0 F
6	11	Vertical	1,200 Psig	42.0 F	2,950 Psig	55.0 F
7	11	Vertical	1,200 Psig	43.0 F	2,950 Psig	55.0 F
TOTAL	77	Gallons	(Accumulator Test Performed on December 31, 2013)			

TABLE 6 BOOTS & COOTS ES56 CT STACK CLOSING AND OPENING OPERATING VOLUMES

	Blind Rams	Shear Rams	Slip Rams	Pipe Rams	Pipe Slips	Shear Blinds	Total
	Gallon	Gallon	Gallon	Gallon	Gallon	Gallons	Gallons
Close					1.06494	1.83550	2.90044
Open					1.06494	1.93939	3.00433

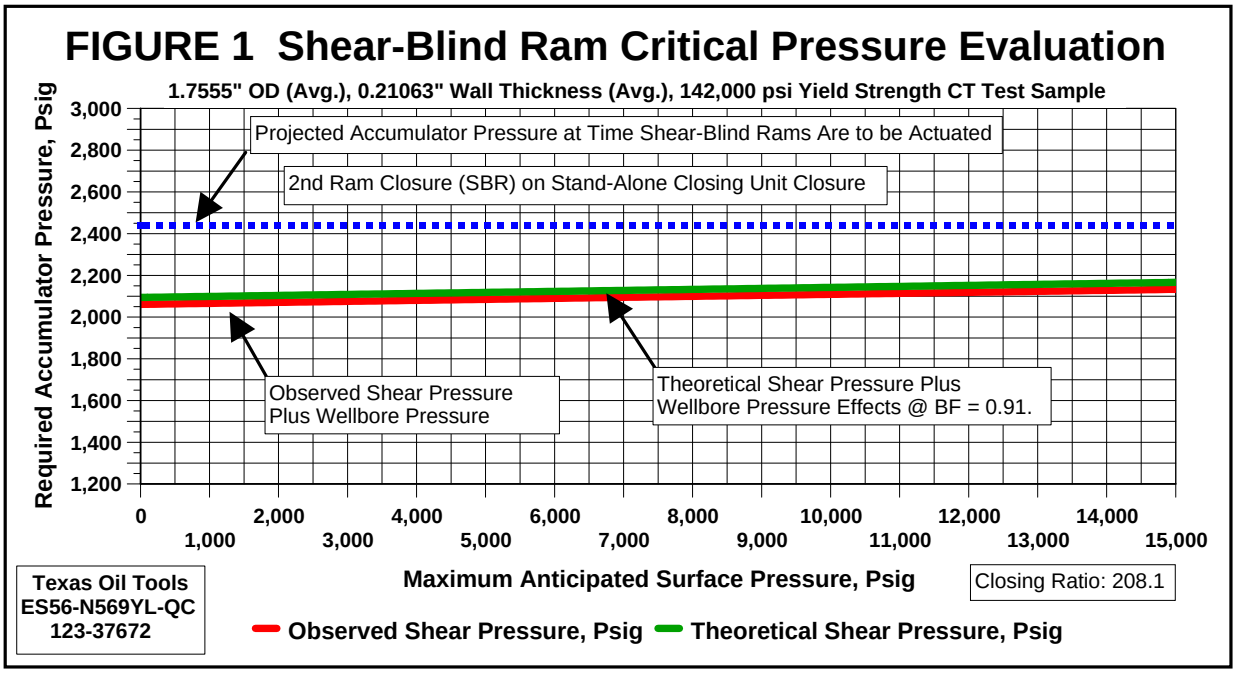
Volume for "Close - Open - Close" of CT Rams in Stack : 8.80521 Gallons

API RP16ST Accumulator Usable Volume Calculation : 31.5019 Gallons MET

(Note: Vacc Calculations Based on the Accumulator Pressures and Temperatures Noted Above)

TABLE 7 ACCUMULATOR CIRCUIT PERFORMANCE - Predicted Versus Actual

Adiabatic Cd:	0.8	Accumulator Pressure		Usable	Closing	Pressure /
Ram	Function	Calculated	Observed	Volume	Time	Rate Ratio
		(psig)	(psig)	(gallons)	(sec.)	(gpm/psig)
Initial Status	Open Valve	2,950	2,950	31.502	0.00	0.000000
Pipe-Slips	Close	2,806	2,725	30.437	10.00	0.002345
Shear-Blinds	Close	2,576	2,480	28.601	17.00	0.002612
Pipe-Slips	Open	2,451	2,360	27.537	10.00	0.002707
Shear-Blinds	Open	2,255	2,180	25.597	17.00	0.003140
Pipe-Slips	Close	2,155	2,105	24.532	10.00	0.003035
Shear-Blinds	Close	2,004	1,980	22.697	19.00	0.002927



Observed Shear-Blind Ram Test Pressure :	2,061	Psig (at atmospheric conditions)
Theoretical Shear-Blind Ram Pressure :	2,301	Psig (at atmospheric conditions With BF = 1.00)
Theoretical Shear-Blind Ram Pressure :	2,094	Psig (at atmospheric conditions With BF = 0.91)

The results of the test data obtained by SAS through the aforementioned testing program demonstrate that the B&C Shear-Blind Ram (ES56 Dual Combi Ram 123-37672) meets the performance expectations referenced in **API RP 16ST** to a **MASP** of **15,000 psig** for the coiled tubing workstring and accumulator system design parameters stated in **Table 8**.

Table 8. Well Control Stack Performance Qualification for CT String and MASP Service

Coiled Tubing Workstring OD	Wall	Grade	Wellbore MASP	Accumulator Volume	30-Minute Stabilized Accumulator Pressure	Pre-Charge Accumulator Pressure
1.750"	0.203"	CT – 130	15,000 Psig	77 Gallons	2,950 Psig	1,200 Psig

Based on the results of all performance testing concluded on January 04, 2014, SAS certifies that the aforementioned B&C coiled tubing well control equipment meets or exceeds the performance expectations stipulated in **API RP 16ST** for the operating conditions shown in **Table 9** below when used with the accumulator system parameters seen in **Table 5**.

Table 9. Well Control Stack Performance Qualification for Additional CT Workstrings

Coiled Tubing Workstring Conditions		
CT Outside Diameter	CT Wall Thickness	Grade
1.750" and Below	0.203" and Below	CT-130 and Below

SAS certifies that the statements made in this report regarding performance test results are true and complete to the best of our knowledge and belief, based on the data collected prior to and during the inspection and testing activities which concluded on or about January 04, 2014.

Alexander Sas-Jaworsky P.E.

Alexander Sas-Jaworsky, PE (TX 79783)
Vice President - Engineering Services

STATE OF TEXAS
ALEXANDER SAS-JAWORSKY II
79783
REGISTERED PROFESSIONAL ENGINEER

DISCLAIMER

This report was prepared by SAS Industries, Inc. ("SAS") based upon verified and documented performance audit testing activities concluded on January 04, 2014. The SAS performance audit testing process employs sound engineering practices, applied mathematical methods, assumptions of service application and data provided by the client (or service vendor). SAS makes no representation or warranty, expressed or implied, as to the accuracy of the information furnished by the client used to prepare test conditions described in this report. Due to variable well conditions, inaccurate well data, changing well conditions, tolerance variations of mechanical components tested, mechanical malfunctions and other factors and information which must be relied upon that are not within SAS's control, SAS makes no warranty, express or implied, that the mechanical components observed during the audit testing environment as described in this report will perform in future field applications in the same manner as that observed in the performance audit test program or that the calculations and/or opinions expressed herein are accurate as applied to any conditions in the field.

The user of this report is advised to consult with SAS if there are any questions concerning this report or its application to any specific field condition. The details regarding performance testing and qualification test methodology are seen in the SAS Formal Report to be issued to B&C at a later date.

ATTACHMENT A – Texas Oil Tools Theoretical Shear Performance Calculations

CT OD	CT ID	Material Yield Strength	Piston Diameter, D_p	Piston Rod Diameter, D_r	Booster Piston Diameter, D_{pb}	Booster Rod Diameter, D_{br}	Tail Rod Diameter, D_{tr}
1.7555"	1.3342"	142,000 psi	7.000"	1.625"	N/A	N/A	1.625"

TOT Calculations - 5.125" ES56 Shear-Blind Ram Assembly

OD_{CT} = Coiled Tube Outside Diameter, (inch)
Sy = Material Yield Strength, (psi)
SA = Shear Ram Area, (inch^2)

ID_{CT} = Coiled Tube Inside Diameter, (inch)
T_{Shear} = Theoretical Shear Force, (Lb_f)
CR = Closing Ratio, (dimensionless)
BF = Blade Factor (0.91)

MASP = Maximum Anticipated Surface Pressure, (psig)
P_{Shear} = Theoretical Ram Pressure to Shear at Atmospheric Conditions, (psig)
$P_{Critical}$ = Theoretical Ram Pressure to Shear at Wellbore Pressure Conditions, (psig)

$$\text{Theoretical Shear} = 0.7854\left(OD^2 - ID^2\right)\left(S_y\right)\left(0.577\right) \quad \textbf{Eq. A1}$$

$$\text{SBR Area} = 0.7854\left(D_p^2\right) - 0.7854\left(D_{tr}^2\right) \quad \textbf{Eq. A2}$$

$$\text{Closing Ratio} = \text{Shear Ram Area} \div (0.7854)(D_r^2) \quad \textbf{Eq. A3}$$

$$P_{Shear} = (\text{Theoretical Shear x Blade Factor/Shear-Blind Ram Area}) \quad \textbf{Eq. A4}$$

$$P_{critical} = P_{shear} + (\text{MASP / Closing Ratio}) \quad \textbf{Eq. A5}$$

The TOT theoretical calculations for estimating ES56 Shear-Blind Ram pressure for well conditions where the MASP is 15,000 psig, are shown below:

$$\text{Theoretical Shear} = 0.7854\left(1.7555^2 - 1.3342^2\right)\left(142{,}000\,psi\right)\left(0.577\right) = 83{,}765\ Lb_f$$

$$\text{SBR Area} = 0.7854\left(7.000^2\right) - 0.7854\left(1.625^2\right) = 36.41\,Inches^2$$

Closing Ratio = **208.1** (SBR is Nearly Pressure Balanced)

P_{Shear} = (83,765 lb_f x **0.91** /36.41 in^2) = **2,094 psig**

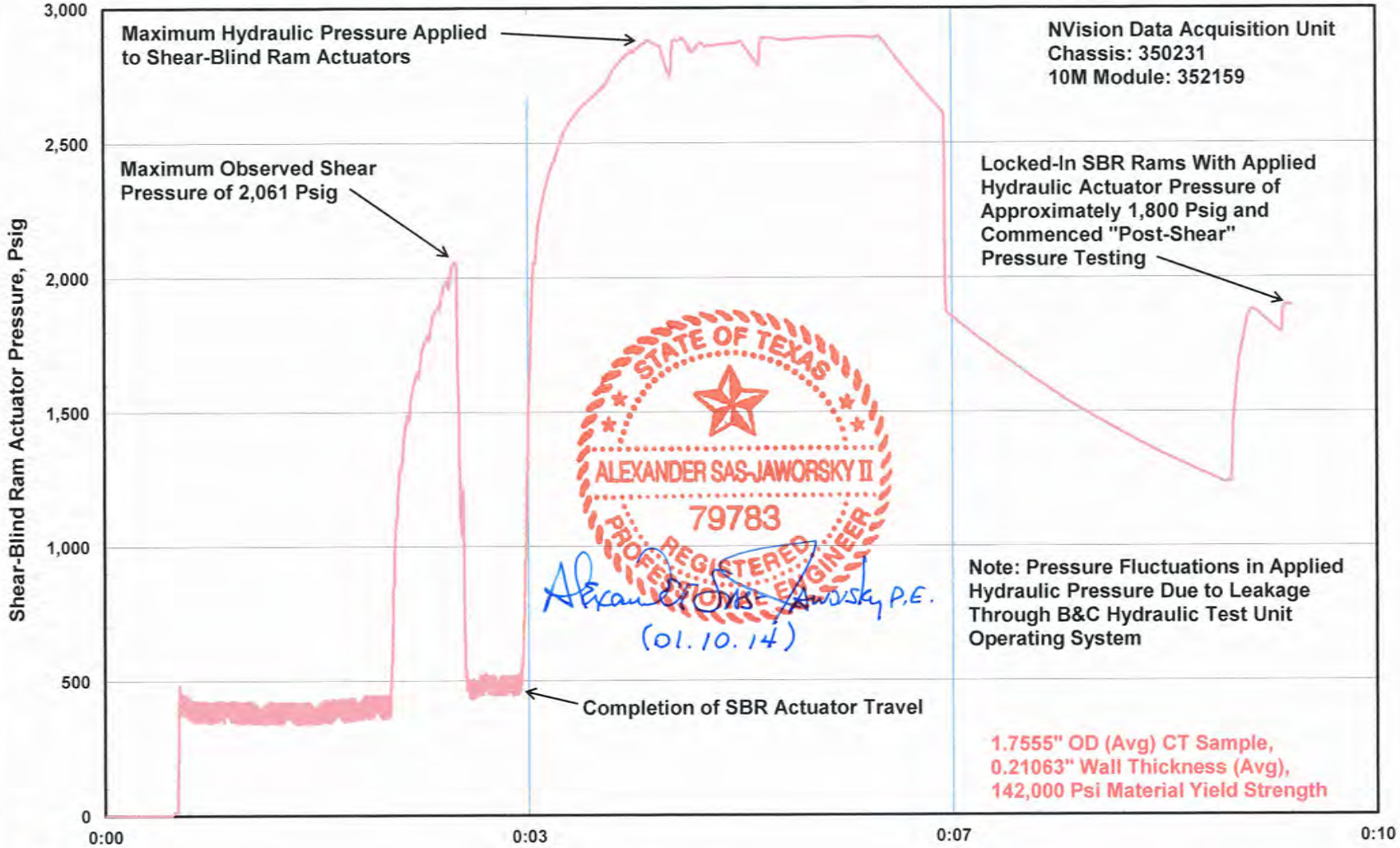
$P_{critical}$ = 2,094 psig + (15,000 / 208.1) = **2,166 psig**

Alex Sas-Jaworsky P.E.
(TX 79783 01.10.14)

To the extent that there are differences between the Shear-Blind Ram performance tests observed by SAS Industries, Inc. and the TOT Calculations, SAS Industries, Inc. bases the findings in this Report on observed physical performance testing and does not rely on the TOT Calculations as a means for determining "fitness-for-purpose". SAS Industries, Inc. makes no representation or warranties regarding the accuracy of the TOT Calculations and provides them at the request of B&C for comparative analysis only.

TOT ES56 123-37672 SHEAR-BLIND RAM PERFORMANCE TEST

SHEAR-BLIND RAM TEST CONDUCTED ON JANUARY 03, 2014 AT B&C FACILITY (New Iberia, LA)



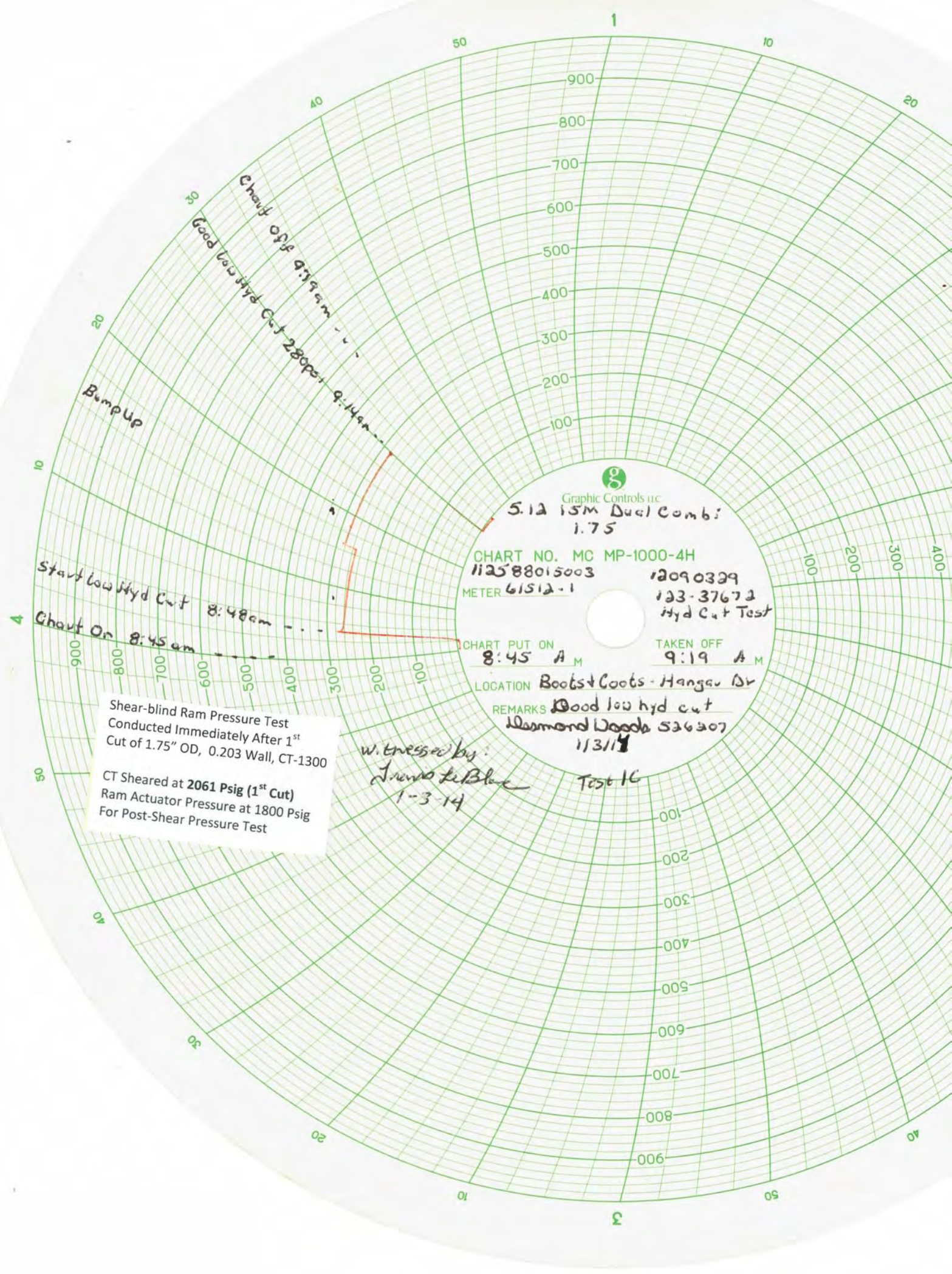
STATE OF TEXAS
ALEXANDER SAS-JAWORSKY II
79783
PROFESSIONAL ENGINEER
REGISTERED

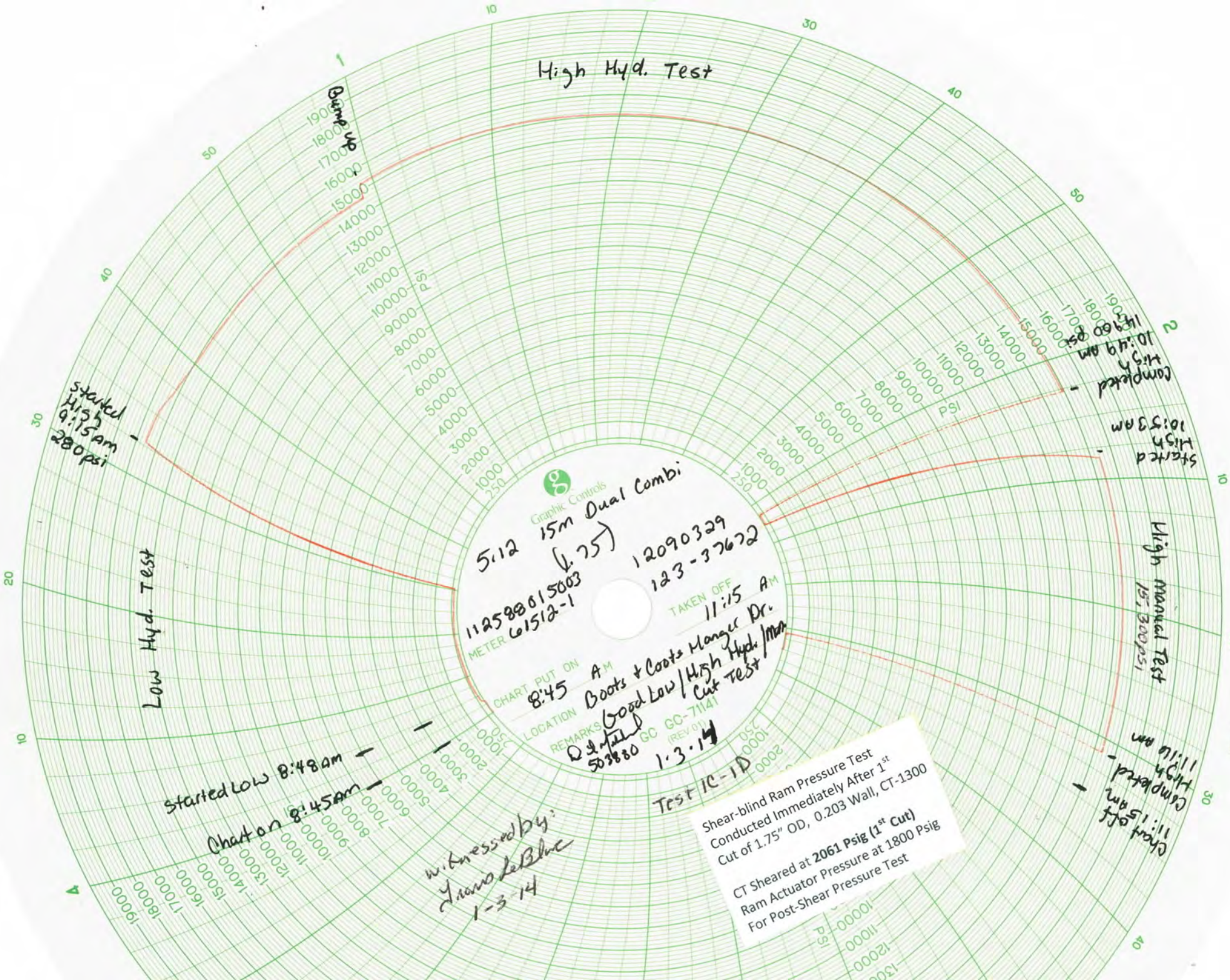
Alexander Sas-Jaworsky, P.E.
(01.10.14)

SAS INDUSTRIES, INC.

TIME DURATION OF TEST, Hours:Minutes

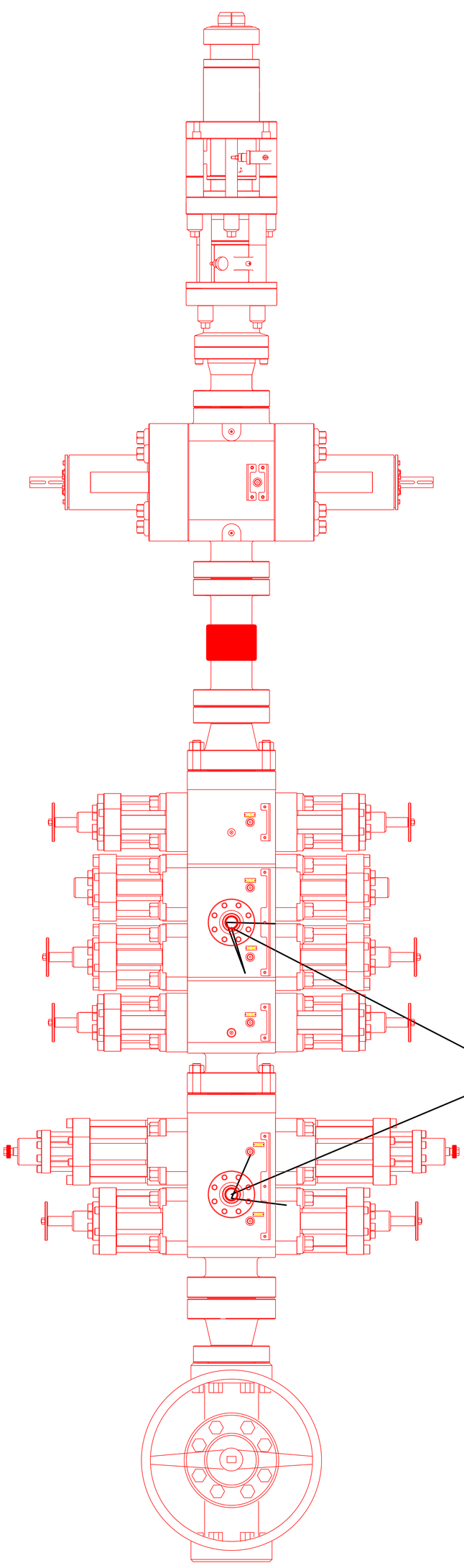
January 10, 2014


Graphic Controls LLC
5.12 15M Dual Comb:
1.75
CHART NO. MC MP-1000-4H
11258801 5003
12090329
METER 61512-1
123-37672
Hyd Cut Test
CHART PUT ON 8:45 AM
TAKEN OFF 9:19 AM
LOCATION Boots & Coots - Hangar Dr
REMARKS Good low hyd cut
Desmond Doods 526207
1/3/14
Test 16
Witnessed by:
Travis LeBlanc
1-3-14
Chart Off 9:19am
Good low Hyd Cut 28psi 9:14am
Bump up
Start low Hyd Cut 8:48am
Chart On 8:45am
Shear-blind Ram Pressure Test
Conducted Immediately After 1st
Cut of 1.75" OD, 0.203 Wall, CT-1300
CT Sheared at 2061 Psig (1st Cut)
Ram Actuator Pressure at 1800 Psig
For Post-Shear Pressure Test


High Hyd. Test
Pump up
Started High 9:15am 280psi
Low Hyd. Test
Started Low 8:48am
Chart on 8:45am
Witnessed by: Jason LeBlanc 1-3-14
Test 1C-1D
Shear-blind Ram Pressure Test
Conducted Immediately After 1st
Cut of 1.75" OD, 0.203 Wall, CT-1300
CT Sheared at 2061 Psig (1st Cut)
Ram Actuator Pressure at 1800 Psig
For Post-Shear Pressure Test
Chart off 11:15am
Completed High 11:10 am
High Manual Test 15 300psi
Started High 10:53 am
Completed High 10:49 am 14960 psi
Graphic Controls
5.12 15m Dual Combi
(1.75)
11258801 5003
METER 61512-1
12090329
123-37622
CHART PUT ON 8:45 AM
TAKEN OFF 11:15 AM
LOCATION Boots & Coots Hanger Dr.
REMARKS Good Low/High Hyd. Test/Man Cut Test
503880 GC GC-71141 (REV 01)
1-3-14
PRINTED IN U.S.A.

BOOTS & COOTS

A HALLIBURTON SERVICE



4.06 15M Sidedoor Stripper

4.06 15M Sidewinder Stripper

4.06 15M Quick Test Sub

Blind Rams 5.125-in 15M

Shear Rams 5.125-in 15M

Slip Rams 5.125-in 15M

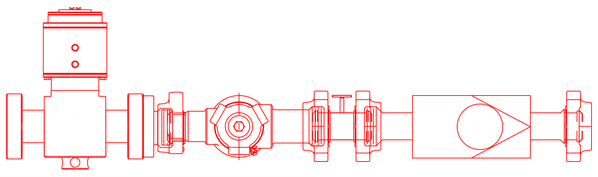
Pipe Rams 5.125-in 15M

Blind / Shear Rams 5.125-in 15M

Pipe / Slip Rams 5.125-in 15M

4.06 15M Gate valve

Primary kill on top Quad Rams, Secondary Kill on bottom Dual Combi
All rated to 15,000 psi
Hydraulic Flanged Valve
Manual 1502 valve
Bleeder sub
Flow Check Valve



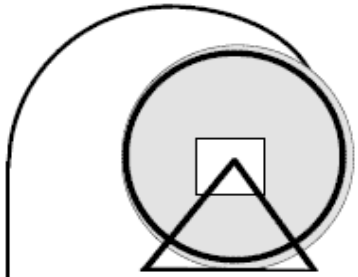
Note: All rams dressed appropriately for 1.75" Coiled Tubing

QTI Form No. 57
3/9/2010:1247

WELD LOCATION RECORD and MATERIAL CERTIFICATE

Quality Tubing

CUSTOMER HALLIBURTON ENERGY SERVICES
PO# 4200839828
QTI# 53985
STRING# 388780000
DIAMETER 1.750 INCH
WALL .134 - .203
GRADE QT1300
HYDROTESTED TO 15000 PSI
SHIPPED ON 337
Spool/Reel #RLSKD



	Strip#	Wall	Length	Weld Loc	Weld Type	COIL Number	HEAT Number	Yield Strength psi (0.2%)	Tensile Strength psi	Tensile to Yield ratio %	Elong %	Rockwell Hardness Mat'l		Rockwell Hardness Weld		C	Mn	P	S	Si	Cr	Cu	Ni	Mo	V	Nb	N
22	1500036821	.203 - .203	240	240	BIAS	108566	1721717	137000	141500	1.03	26.5	30	HRC	31	HRC	0.120	1.500	0.013	0.0001	0.390	0.580	0.230	0.080	0.240	0.064	0.053	
21	1500041466	.203 - .203	515	755	BIAS	130989	1721717	137000	141500	1.03	26.5	30	HRC	31	HRC	0.120	1.500	0.013	0.0001	0.390	0.580	0.230	0.080	0.240	0.064	0.053	
20	1500047039	.203 - .203	1035	1790	BIAS	136739	1721717	137000	141500	1.03	26.5	30	HRC	31	HRC	0.120	1.500	0.013	0.0001	0.390	0.580	0.230	0.080	0.240	0.064	0.053	
19	1500036822	.203 - .203	1503	3293	BIAS	108566	1721717	136500	141000	1.03	26.5	30	HRC	31	HRC	0.120	1.500	0.013	0.0001	0.390	0.580	0.230	0.080	0.240	0.064	0.053	
18	1500047041	.188 - .203	672	3965	BIAS	246434	2230409	140000	145500	1.03	27.0	93	HRB	94	HRB	0.120	1.490	0.018	0.0010	0.370	0.600	0.230	0.080	0.240	0.062	0.052	
17	1500000134	.188 - .188	1649	5614	BIAS	539905	9721832	141500	147500	1.04	22.5	31	HRC	32	HRC	0.120	1.500	0.011	0.0010	0.410	0.590	0.240	0.080	0.250	0.066	0.055	
16	1500047041	.175 - .188	818	6432	BIAS	246434	2230409	140000	145500	1.03	27.0	93	HRB	94	HRB	0.120	1.490	0.018	0.0010	0.370	0.600	0.230	0.080	0.240	0.062	0.052	
15	1500041458	.175 - .175	1508	7940	BIAS	511208	1512512	140000	145500	1.03	20.0	32	HRC	34	HRC	0.120	1.470	0.014	0.0010	0.380	0.600	0.230	0.090	0.250	0.064	0.055	
14	1500041454	.175 - .175	1104	9044	BIAS	511208	1512512	140000	145500	1.03	20.0	32	HRC	34	HRC	0.120	1.470	0.014	0.0010	0.380	0.600	0.230	0.090	0.250	0.064	0.055	
13	1500035622	.156 - .175	1786	10830	BIAS	512564	1512512	141000	145500	1.03	22.5	34	HRC	35	HRC	0.120	1.470	0.014	0.0010	0.380	0.600	0.230	0.090	0.250	0.064	0.055	
12	1500028249	.156 - .156	1288	12118	BIAS	291877	0320223	143500	148000	1.03	21.0	31	HRC	30	HRC	0.110	1.480	0.012	0.0010	0.390	0.590	0.240	0.090	0.240	0.071	0.060	
11	1500035613	.145 - .156	1103	13221	BIAS	511198	1512512	141000	146000	1.03	24.0	35	HRC	36	HRC	0.120	1.470	0.014	0.0010	0.380	0.600	0.230	0.090	0.250	0.064	0.055	
10	1500034834	.145 - .145	1803	15024	BIAS	514020	1512512	137500	143500	1.04	25.0	33	HRC	34	HRC	0.120	1.470	0.014	0.0010	0.380	0.600	0.230	0.090	0.250	0.064	0.055	
9	1500035613	.134 - .145	1109	16133	BIAS	511198	1512512	141000	146000	1.03	24.0	35	HRC	36	HRC	0.120	1.470	0.014	0.0010	0.380	0.600	0.230	0.090	0.250	0.064	0.055	
8	1500050728	.134 - .134	960	17093	BIAS	650383	2710534	139500	145500	1.04	22.0	33	HRC	31	HRC	0.120	1.450	0.017	0.0010	0.410	0.580	0.220	0.080	0.250	0.064	0.055	
7	1500050727	.134 - .134	2270	19363	BIAS	650383	2710534	139500	145500	1.04	22.0	33	HRC	31	HRC	0.120	1.450	0.017	0.0010	0.410	0.580	0.220	0.080	0.250	0.064	0.055	
6	1500050750	.134 - .134	2442	21805	BIAS	650385	2710534	139500	145500	1.04	22.0	33	HRC	31	HRC	0.120	1.450	0.017	0.0010	0.410	0.580	0.220	0.080	0.250	0.064	0.055	
5	1500050749	.134 - .134	2435	24240	BIAS	650385	2710534	139500	145500	1.04	22.0	33	HRC	31	HRC	0.120	1.450	0.017	0.0010	0.410	0.580	0.220	0.080	0.250	0.064	0.055	
4	1500050748	.134 - .134	2425	26665	BIAS	650385	2710534	139500	145500	1.04	22.0	33	HRC	31	HRC	0.120	1.450	0.017	0.0010	0.410	0.580	0.220	0.080	0.250	0.064	0.055	
3	1500050747	.134 - .134	2420	29085	BIAS	650385	2710534	139500	145500	1.04	22.0	33	HRC	31	HRC	0.120	1.450	0.017	0.0010	0.410	0.580	0.220	0.080	0.250	0.064	0.055	
2	1500041428	.134 - .134	1591	30676	BIAS	632128	0A12720	145500	151000	1.03	23.0	35	HRC	33	HRC	0.120	1.480	0.014	0.0010	0.380	0.600	0.240	0.070	0.260	0.069	0.057	
1	1500047178	.134 - .134	2573	33249	BIAS	657792	1B11018	146000	150500	1.03	24.5	35	HRC	36	HRC	0.120	1.470	0.014	0.0010	0.390	0.560	0.230	0.100	0.250	0.067	0.062	
0	1500047177	.134 - .134	341	33590	END	657792	1B11018	146000	150500	1.03	24.5	35	HRC	36	HRC	0.120	1.470	0.014	0.0010	0.390	0.560	0.230	0.100	0.250	0.067	0.062	

Total String: **33590** **FT**

QUALITY TUBING

QTI Form No. 57
3/9/2010:1247

WELD LOCATION RECORD and MATERIAL CERTIFICATE

Quality Tubing

By

Henry Cabrera Quality Tech 2

String Manufactured: 11/10/2012 **Date** 12/13/2012

ORIENTATION Y BED

Material Specification:	**ASTM A1011, Modified**
N.D.E. Tested ASTM E-309/E570	**Mechanical Test Method per ASTM A370**
Customer Specification:	**HES D00646175revA & D00027483revI**
Weld Location Notes:	

We hereby certify that the material described herein has been manufactured, tested and inspected satisfactorily in accordance with the requirements of the above specifications or applicable exceptions.

Theoretical Shear Ram Performance – Texas Oil Tools Calculation Method

Operator: McMoran **Well:** South Marsh Island Block 230 Well No. 1 ST01 **Reported MASP:** 15,000 psig

Coiled Tubing Vendor: B&C Coiled Tubing Services **CT Yield Strength:** 140,000 psi @ 0.203" Wall

Workstring Construction: 1.750" OD, Tapered Wall (0.134" - 0.203"), CT-130 (**QTI String No. 38878**)

Stack Description: 5-1/8", 15M ES56 Quad Ram Assembly (SN: 123-37667)

TOT 5.125" ES56 Quad Shear Ram Assembly

CT OD	CT ID	Material Yield Strength	Piston Diameter, D_p	Piston Rod Diameter, D_r	Booster Piston Diameter, D_{pb}	Booster Rod Diameter, D_{br}	Tail Rod Diameter, D_{tr}
1.750"	1.344"	140,000 psi	8.500"	1.625"	N/A	N/A	1.625"

OD_{CT} = Coiled Tube Outside Diameter, (inch)
Sy = Material Yield Strength, (psi)
SA = Shear Ram Area, (inch^2)
MASP = Maximum Anticipated Surface Pressure, (psig)

ID_{CT} = Coiled Tube Inside Diameter, (inch)
T_{Shear} = Theoretical Shear Force, (Lb_f)
CR = Closing Ratio, (dimensionless)
BF = TOT Blade Factor (0.80)
(Based on SAS Industries,Inc. Testing)

P_{Shear} = Ram Pressure to Shear at Atmospheric Conditions, (psig)
$P_{Critical}$ = Ram Pressure to Shear at Wellbore Pressure Conditions, (psig)

$$\text{Theoretical Shear} = 0.7854\left(OD^2 - ID^2\right)\left(S_y\right)\left(0.577\right) \quad \textbf{Eq. 1a}$$

$$\text{Shear Ram Area} = 0.7854\left(D_p^2\right) - 0.7854\left(D_{tr}^2\right) \quad \textbf{Eq. 2a}$$

$$\text{Closing Ratio} = SA \div (0.7854)(D_r^2) \quad \textbf{Eq. 3a}$$

$$P_{Shear} = (\text{Theoretical Shear x Blade Factor} / \text{Shear Ram Area}) \quad \textbf{Eq. 4a}$$

$$P_{critical} = P_{shear} + (MASP / CR) \quad \textbf{Eq. 5a}$$

The TOT theoretical calculations for estimating ES56 Shear Ram pressure for **1.750" OD**, **0.203" wall thickness**, **CT-130** grade coiled tubing with a **MASP of 15,000 psig** are shown below:

$$\text{Theoretical Shear} = 0.7854\left(1.750^2 - 1.344^2\right)\left(140{,}000\,psi\right)\left(0.577\right) = 79{,}697\ Lb_f$$

$$\text{Shear Ram Area} = 0.7854\left(8.500^2\right) - 0.7854\left(1.625^2\right) = 54.67\ Inches^2$$

Closing Ratio = Infinity (Shear Ram is Pressure Balanced)

P_{Shear} = (79,697 lb_f x **0.80** /54.67 inch^2) = **1,166 psig**

$P_{critical}$ = 1,166 psig + (0) = **1,166 psig**

The evaluation of the "Standardized" B&C Coiled Tubing Unit well control accumulator system (60-gallon volume, precharge pressure of 1,200 psig and a "30-minute stabilized operating pressure" of 2,950 psig) predicts a minimum of ***2,225 psig*** remaining in the system after closure of the ES56 Shear Ram in a simulated well control emergency drill (***third ram to close***). Based on the calculated $P_{critical}$ value of ***1,166 psig***, and the predicted available accumulator operating pressure of ***2,225 psig***, *the ES56 Shear Rams are capable of performing the required shearing operation for the CT workstring shown above.*

SAS Industries, Inc. makes no representation or warranty, expressed or implied, as to the accuracy of the information furnished by the Operator or Service Vendor used to establish the conditions used in the theoretical calculations. Due to variable well conditions, inaccurate well data, changing well conditions, tolerance variations of mechanical components tested, mechanical malfunctions and other factors and information which must be relied upon that are not within SAS's control, SAS makes no warranty, express or implied, that the calculations and/or opinions expressed herein are accurate as applied to any conditions in the field.

Alex SAS-Jurcsik, P.E.
(TX 79783 06.10.13)

SAS INDUSTRIES, INC.

June 10, 2013

Theoretical Shear Ram Performance – Texas Oil Tools Calculation Method

Operator: McMoran **Well:** South Marsh Island Block 230 Well No. 1 ST01 **Reported MASP:** 15,000 psig

Coiled Tubing Vendor: B&C Coiled Tubing Services **CT Yield Strength:** 140,000 psi @ 0.203" Wall

Workstring Construction: 1.750" OD, Tapered Wall (0.134" - 0.203"), CT-130 (**QTI String No. 38878**)

Stack Description: 5-1/8", 15M ES56 Shear-Blind Ram Assembly (SN: 123-37672)

TOT 5.125" ES56 Combi Shear-Blind Ram Assembly

CT OD	CT ID	Material Yield Strength	Piston Diameter, D_p	Piston Rod Diameter, D_r	Booster Piston Diameter, D_{pb}	Booster Rod Diameter, D_{br}	Tail Rod Diameter, D_{tr}
1.750"	1.344"	140,000 psi	7.000"	1.625"	N/A	N/A	1.625"

OD_{CT} = Coiled Tube Outside Diameter, (inch)
Sy = Material Yield Strength, (psi)
SA = Shear Ram Area, (inch^2)
MASP = Maximum Anticipated Surface Pressure, (psig)

ID_{CT} = Coiled Tube Inside Diameter, (inch)
T_{Shear} = Theoretical Shear Force, (Lb_f)
CR = Closing Ratio, (dimensionless)
BF = TOT Blade Factor (0.91)

P_{Shear} = Ram Pressure to Shear at Atmospheric Conditions, (psig)
$P_{Critical}$ = Ram Pressure to Shear at Wellbore Pressure Conditions, (psig)

$$\text{Theoretical Shear} = 0.7854\left(OD^2 - ID^2\right)\left(S_y\right)\left(0.577\right) \quad \textbf{Eq. 1a}$$

$$\text{Shear Ram Area} = 0.7854\left(D_p^2\right) - 0.7854\left(D_{tr}^2\right) \quad \textbf{Eq. 2a}$$

$$\text{Closing Ratio} = SA \div (0.7854)(D_r^2) \quad \textbf{Eq. 3a}$$

$$P_{Shear} = (\text{Theoretical Shear x Blade Factor / Shear Ram Area}) \quad \textbf{Eq. 4a}$$

$$P_{critical} = P_{shear} + (MASP / CR) \quad \textbf{Eq. 5a}$$

The TOT theoretical calculations for estimating ES56 Shear Ram pressure for **1.750" OD**, **0.203" wall thickness**, **CT-130** grade coiled tubing with a **MASP of 15,000 psig** are shown below:

$$\text{Theoretical Shear} = 0.7854\left(1.750^2 - 1.344^2\right)\left(140{,}000\,psi\right)\left(0.577\right) = 79{,}697\ Lb_f$$

$$\text{Shear Ram Area} = 0.7854\left(7.000^2\right) - 0.7854\left(1.625^2\right) = 36.41\ Inches^2$$

Closing Ratio = 208.1 (SBR is Nearly Pressure Balanced)

P_{Shear} = (79,697 lb_f x **0.91** /36.41 inch^2) = **1,992 psig**

$P_{critical}$ = 1,992 psig + (15,000 / 208.1) = **2,064 psig**

The evaluation of the B&C 11939830 Closing Unit with the 77-gallon Accumulator Package (precharge pressure of 1,200 psig and a "30-minute stabilized operating pressure" of 2,880 psig) demonstrated a minimum of ***2,600 psig*** remaining in the system after closure of the ES56 SBR in a simulated well control emergency drill (***first ram to close from the Closing Unit***). Based on the calculated $P_{critical}$ value of ***2,064 psig***, and the predicted available accumulator operating pressure of ***2,600 psig***, *the ES56 Shear-Blind Rams are capable of performing the required shearing operation for the CT workstring shown above.*

SAS Industries, Inc. makes no representation or warranty, expressed or implied, as to the accuracy of the information furnished by the Operator or Service Vendor used to establish the conditions used in the theoretical calculations. Due to variable well conditions, inaccurate well data, changing well conditions, tolerance variations of mechanical components tested, mechanical malfunctions and other factors and information which must be relied upon that are not within SAS's control, SAS makes no warranty, express or implied, that the calculations and/or opinions expressed herein are accurate as applied to any conditions in the field.

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