HALLIBURTON

Boots & Coots

McMoRan South Marsh Island Block 234 Well #14

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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 ES56 5-1/8" 15M Quad Ram Assembly

180-Day PM Program (March 19, 2014 through September 16, 2014)

March 25, 2014

Prepared By:

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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	March 19, 2014	March 19, 2014

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 60° F)**
Accumulator "30-Minute Stabilized Operating Pressure": **2,955 psig (at 73° 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.	Quad Ram Assembly	5-1/8", 15M TOT ES56

Accumulator System Pressure at Shear Ram Actuation: **2,250 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 ***1,565 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 a ES56 Quad-Ram stack equipped with a Blind Ram, Shear Ram, Slip Ram and Pipe 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	58.0° F
2	15 Gallon	655	4832	Horizontal	Yes	1,200 psig	58.0° F
3	15 Gallon	20568	332277	Horizontal	Yes	1,200 psig	62.0° F
4	15 Gallon	20573	332282	Horizontal	Yes	1,200 psig	63.0° 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 and 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 and 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 (**24.6562** 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 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 Slip Rams, followed by closure of the Pipe Rams and the Shear Rams (***third ram to close***). Upon removal of the CT from across the Blind Ram cavity, the Blind Ram is then closed to secure the well. 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 Shear Rams is approximately **2,250 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	58.0 F	2,955 Psig	73.0 F
2	15	Horizontal	1,200 Psig	58.0 F	2,955 Psig	73.0 F
3	15	Horizontal	1,200 Psig	62.0 F	2,955 psig	73.0 F
4	15	Horizontal	1,200 Psig	63.0 F	2,955 psig	73.0 F
5						
6						
TOTAL	60	Gallons	(Accumulator Performance Test Conducted on 03.19.14)			

TABLE 9 BOOTS & COOTS ES56 CT STACK CLOSING AND OPENING OPERATING VOLUMES

	Blind Rams	Shear Blinds	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

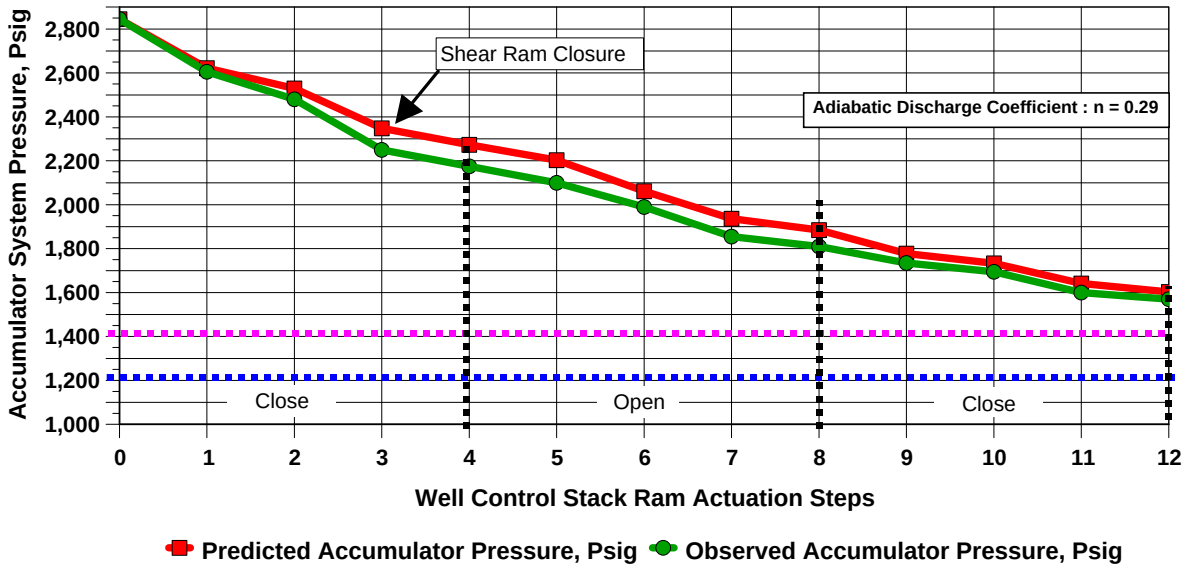
API RP16ST Accumulator Usable Volume Calculation : 24.6562 Gallons MET

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

TABLE 10 ACCUMULATOR CIRCUIT PERFORMANCE - Predicted Versus Actual

Adiabatic Cd:	0.29	Accumulator Pressure		Usable	Closing	Pressure /
Ram	Function	Calculated	Observed	Volume	Time	Rate Ratio
		(psig)	(psig)	(gallons)	(sec.)	(gpm/psig)
Initial Status	Open Valve	2,845	2,845	24.656	(Through 3/8" Hoses)	
Slip Rams	Close	2,622	2,605	22.734	25.00	0.001771
Pipe Rams	Close	2,530	2,480	21.863	19.00	0.001109
Shear Rams	Close	2,348	2,250	19.941	41.00	0.001250
Blind Rams	Close	2,273	2,175	19.070	20.00	0.001201
Pipe Rams	Open	2,203	2,100	18.199	20.00	0.001244
Slip Rams	Open	2,062	1,990	16.277	25.00	0.002318
Shear Rams	Open	1,937	1,855	14.355	42.00	0.001480
Blind Rams	Open	1,884	1,810	13.484	21.00	0.001375
Slip Rams	Close	1,778	1,735	11.562	31.00	0.002144
Pipe Rams	Close	1,733	1,695	10.691	24.00	0.001285
Shear Rams	Close	1,642	1,600	8.769	48.00	0.001502
Blind Rams	Close	1,603	1,570	7.898	25.00	0.001331

FIGURE 1 Well Control Accumulator System Performance Evaluation



Based on the results of all performance testing concluded on March 19, 2014, 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 March 19, 2014.

Alexander Sas-Jaworsky P.E.

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

DISCLAIMER

This report was prepared by SAS Industries, Inc. ("SAS") based upon verified and documented performance audit testing activities concluded on March 19, 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.

BOOTS & COOTS
CT WELL CONTROL EQUIPMENT AUDIT

REPORT ON AUDIT PERFORMANCE TESTING OF B&C 11939830 CLOSING UNIT WITH 77-GALLON ACCUMULATOR VOLUME PACKAGE FOR USE WITH 5-1/8" 15M DUAL COMBI-RAMS

March 24, 2014

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Report on SAS Industries, Inc. Audit of B&C 11939830 Closing Unit
Equipped With 77- Gallon Accumulator Volume to Operate B&C 5-1/8" 15M Combi Rams

Boots & Coots (B&C) requested SAS Industries, Inc. (SAS) to conduct a performance Audit of the B&C 11939830 "Stand-Alone" Closing Unit to evaluate condition and performance capability for operation of 5-1/8", 15M ES56 Pipe-Slip Rams (PSR) and Shear-Blind Rams (SBR). The location and time period for the closing unit performance testing audit is shown below:

Location	Start Date	End Date
Boots & Coots Facility - New Iberia, Louisiana	March 19, 2014	March 19, 2014

I. STATUS OF CLOSING UNIT EQUIPMENT

The SAS Audit program is conducted to ensure conformance with **API RP 16ST** and **API Spec 16D** Standards, **30 CFR 250.616 (*f*) 6**, SAS Asset Integrity Standards, SAS Lifting Equipment Standards, OSHA Guidelines, DOT regulations (where applicable) and established "Industry Best Practice" performance requirements.

Upon completion of the performance testing and documentation Audit, the status of the Closing Unit equipment components and Accumulator Bottle Package inspected and tested is shown below.

Table 1. Well Control Equipment Closing Unit System Components Tested

Well Control Equipment Closing Unit and Systems				
Met Requirements as Found	MET	Required Repairs/Adjustments	RR/A	Did Not Meet Requirements	DNM
Item	**Closing Unit Equipment Components**	**Size / Rating**	**ID No.**	**Status**
1.	Main Closing Unit Assembly	6 Station, 77 Gallons	B&C 11939830	MET

Accumulator System Precharge Pressure (average): **1,200 psig (at 69° F)**
Accumulator "30-Minute Stabilized Operating Pressure": **2,920 psig (at 83° F)**

Table 2. Associated Well Control Stack Components Tested

B&C Coiled Tubing Well Control Stack Components			
Item	**Well Control Equipment Components**	**Size / Rating**	**B&C ID No.**
1.	Dual-Combi Ram Assembly	5-1/8", 15M TOT ES56	12090329

Accumulator System Pressure at Shear-Blind Ram Actuation: **2,465 psig**

Performance testing of the B&C 11939830 Closing Unit and Accumulator system (**Table 1**) was conducted to operate the 5-1/8" 15M TOT ES56 Dual Combi-Ram assembly comprising the Pipe-Slip Rams (PSR) and Shear-Blind Rams (SBR) **(Table 2)**. The test results found that the PSR and SBR "close-open-close" actuation tests were successfully completed with ***1,965 psig*** remaining within the accumulator system (tests conducted without assistance from the Closing Unit 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.***

II. OVERVIEW OF AUDIT NONCONFORMANCE ISSUES

1. The B&C 11939830 Closing Unit accumulator circuit is configured with one, seven (7) bottle manifold installed. As per **API Spec 16D**, ***Para. 5.1.3.2***, the loss of one manifold will result in greater than 25% reduction in accumulator system capacity.

   However, the intended service of the B&C 11939830 Closing Unit is for coiled tubing services, which do not require multiple accumulator banks for well control service (**API RP 16ST *Para. 13.6.2*** and **30 CFR 250.616 (*f*) 6**).

2. The B&C 11939830 Closing Unit accumulator circuit is configured with only one (1) pressure manifold. This design does not comply with the **API Spec 16D 4.3.2** requirement for two power fluid manifolds. However, coiled tubing operations do not incorporate use of Annular Preventers which require a separate manifold regulated to a lower pressure.

   As found in the SAS Industries, Inc. Performance Audit review, the B&C 11939830 Closing Unit is constructed to supply power fluid at full accumulator pressure to all rams, as intended for coiled tubing operations and the lack of a second manifold does not compromise the designated service in any way.

I. WELL CONTROL STACK EQUIPMENT

The well control stack components included in the performance audit of the Closing Unit and Accumulator Bottle Package is shown in **Table 3** below:

TABLE 3. Well Control Stack Components

Well Control Stack Components	Series	Size	Rating	Designation	TOT ID Number
TOT Dual Combi-Ram Assembly	ES56	5-1/8"	15M	N569YL-QC	123-37672

The evaluation of the Closing Unit and Accumulator Bottle Package systems contained in this Report require that the results of the SAS ES56 SBR Audit Tests be presented. The following is a brief overview of the ES56 SBR CT shear test results found in the formal SAS 5-1/8", 15M, ES56 SBR Test Report, with the conclusions reproduced here to establish qualification parameters for the Closing Unit and Accumulator Bottle Package.

Shear-Blind Ram Performance Test

The TOT 5-1/8" ES56-N569YL-QC, 15M SBR provided by B&C was subjected to shear testing on March 20, 2014, to determine the minimum actuator pressure needed to sever the 1.750" OD, 0.203" wall thickness, CT-130 grade coiled tube at atmospheric pressure and confirm the capability to seal and contain pressure below the rams to 15,000 psig. The results of the 5-1/8" ES56-N569YL-QC, 15M SBR performance test with the 1.75" OD, 0.203" wall thickness, CT-130 grade coiled tube test specimen rigidly held within the Pipe-Slip Rams are seen in **Table 4** below:

Table 4 - Shear-Blind Ram Test (API RP 16ST 12.2.3)

Well Control Component	Shear Test Pressure (Psig)	Closing Ratio (Dimensionless)	Reported Well MASP (Psig)	Ram Piston Balance Pressure (Psig)	$P_{critical}$ Accumulator Circuit Pressure (Psig)
Shear-Blind	1,947	208.10	15,000	72	2,019

The **Ram Piston Balance Pressure** for the SBR establishes the hydraulic actuator pressure required to balance the forces developed by the projected **MASP** (MASP divided by Closing Ratio). The SBR was found to have a reported closing ratio of 208.1, requiring an additional **72 psig** of hydraulic actuator pressure to balance a **MASP** of **15,000 psig**. Based on the recorded SBR test pressure of **1,947 psig** and the calculated "ram piston balance pressure" of **72 psig** for the 5-1/8" ES56-N569YL-QC, 15M SBR, the $\mathbf{P_{critical}}$ pressure was found to be **2,019 psig**. For the SAS evaluation of closing unit performance using the aforementioned SBR assembly, the minimum $\mathbf{P_{critical}}$ pressure required for the accumulator system was set at ***2,120 psig***.

The ram actuator performance details for the TOT 5-1/8" Shear-Blind Rams to be used in the accumulator volume calculations are seen in **Table 5** below.

Table 5 - TOT ES56 Shear-Blind Ram Actuator Design

Bore Size (Inches)	Working Pressure (Psig)	Volume to Open (Gallons)	Volume to Close (Gallons)	Closing Ratio
5.125"	15,000	1.9394	1.8355	208.10

II. WELL CONTROL STACK CLOSING UNIT

The Closing Unit and Accumulator Bottle Package was found to be manufactured by MEYER Service Company. B&C acquired the Closing Unit and assigned the SAP Number of 11939830. All accumulators were found to be 11-gallon, bladder-type accumulators mounted vertically in the transport skid. The description of the Closing Unit design and performance tests are discussed below.

Hydraulic Fluid Reservoir

The B&C Closing Unit 11939830 is constructed with a hydraulic fluid reservoir having the dimensions and calculated capacities shown in **Table 6** below. The dimensions seen in **Table 6** represent the outside dimensions of the tank, with the capacity calculations based on subtracting one-half (1/2) inch from each dimension to account for containment wall thickness (projected to be 1/4" steel walls).

TABLE 6. Hydraulic Fluid Reservoir

Overall Volume Capacity Calculations				Effective Stored Volume Capacity Calculations			
Length (Inches)	Width (Inches)	Height (Inches)	Total Capacity (Gallons)	Length (Inches)	Width (Inches)	Height (Inches)	Stored Capacity (Gallons)
96.250	16.250	39.250	241	96.250	16.250	27.250	178

The total capacity of the reservoir tank was calculated to be approximately 178 gallons. However, the effective volume of fluid contained within the reservoir is the fluid height between the 4" ID upper access cap and the suction lines near the base of the tank. Based on the Air/Hydraulic pump suction line located 5" above the tank base and the lower edge of the 4" ID access cap located 32.250 inches above the tank base, the effective height of fluid available for use within the well control accumulator system is approximately **27.250 inches**. Therefore, the volume of reservoir tank fluid available for ***storage*** within the accumulators is calculated to be approximately **178 gallons**. As per **API Spec 16D**, the "stored" hydraulic fluid volume is defined as the power fluid stored within the accumulators between precharge pressure and the maximum charge pressure applied to the accumulator circuit by the closing unit pumps.

The review of **API Spec 16D** design requirements for the "Return-to-Reservoir" Hydraulic Reservoirs is seen in **Table 7** below.

TABLE 7. API Spec 16D "Return-To-Reservoir" Hydraulic Reservoirs

Referenced Paragraph	Comments	Status
4.2.4.2	Usable Capacity is > Two Times the Accumulator Stored Hydraulic Fluid Capacity	MET
4.2.4.2	Low Reservoir Level Alarm Installed on Reservoir Tank	MET
4.2.4.2	Closing Unit has Low Reservoir Level Alarms (Audible and Visual) Installed	MET
4.2.4.2	Remote Panels have Low Reservoir Level Alarms (Audible and Visual) Installed	N/A
4.2.4.2	Low Reservoir Level Alarm Tested to Alert when Fluid is Below 35% of Tank	MET

Pumping Systems

The Primary Pump was found to be a Comet TWS 8035 pump with a reported displacement of **1.096** cubic inches per revolution. Based on the reported diesel engine speed of 1,750 RPM, the Comet TWS 8035 pump is capable of displacing approximately **8.30 gallons per minute** (GPM).

One Secondary Pump was found to be installed on the Closing Unit. This pump was identified as a NOV "Bear Pump" Model 31232 pneumatically powered reciprocating hydraulic pump with a discharge-to-air pressure ratio of 55:1. The power source (air pressure and rate) for this pump during the Audit test is identified as the B&C shop compressor (120 - 140 psig tank pressure).

The primary power source for the B&C 11939830 pump was identified as a HATZ Model 9HZXL 997V40 diesel engine. The Serial Number for this engine is 0912109 052634. The review of power source tests and documentation for the Primary Pump is shown in **Table 8**.

TABLE 8. Review of Primary Power Source 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
Electric motor power connections properly insulated and run to control panel.					MET
Electric motor control panel enclosed and protected from atmosphere (weather).					MET
Prime mover engine normal kill switch tested within specifications.					MET
Electric motor automatic start switch tested within specifications.					MET
Electric motor ground wire installed and complies with industry standards.					MET

The projected pump delivery for a single NOV Bear Pump hydraulic pump with sustained air pressure of approximately 100 psig available is seen in **Table 9** below:

TABLE 9. NOV 31232 Bear Pump Discharge Rating

Discharge Pressure of 2,000 Psig	Discharge Pressure of 2,500 Psig	Discharge Pressure of 3,000 Psig
2.65 GPM	2.15 GPM	1.65 GPM

The NOV Bear Pump was tested with air pressure available at the B&C facility. Upon initiation of operations, the air supply pressure held at approximately 100 psig during the Audit tests.

With the accumulators precharged to approximately 1,200 psig, the initial charge-up test for the B&C Closing Unit found the Primary and Secondary Pumps achieving maximum charge pressure (**Pmax**) within six (6) minutes within the 7-bottle accumulator system.

The review of **API Spec 16D** design requirements for the Pumping Systems is seen in **Table 10** below. Note the designation of **Pmax** seen in **Table 10** represents the maximum operating system pressure for the Closing Unit and Accumulator Bottle package.

TABLE 10. API Spec 16D Pumping Systems Requirements

Referenced Paragraph	Comments	Status
5.1.2.1	Manifold Pumping Unit has a Minimum of Two (2) independent Pumping Systems	MET
5.1.2.1.a	Cumulative Output Capacity Charges Accumulator Circuit to Pmax Within 15 Minutes	MET
5.1.2.2	Each Pump Provides Discharge Pressure at Least Equal to Pmax	MET
5.1.2.2	Air Drive Pumps Capable of Charging Accumulators to Pmax with 75 Psig Air Pressure	MET
5.1.2.3	Each Pump System Protected From Overpressurization by a Minimum of Two Devices	MET
5.1.2.4	Primary Pump Starts When System Pressure Decreases to 90% of Pmax	MET
5.1.2.4	Primary Pump Stops When System Pressure Reaches 100% of Pmax	MET
5.1.2.4	Secondary Pumps Start When System Pressure Decreases to 85% of Pmax	MET
5.1.2.4	Secondary Pumps Stop When System Pressure Reaches 95% of Pmax	MET

With the accumulator circuit stabilized at **Pmax**, the Secondary Pump (NOV Bear Pump) was turned off and the accumulator circuit pressure allowed to bleed down slowly. At an accumulator circuit pressure of **2,590 psig**, the Primary Pump kicked-on and restored the accumulator circuit pressure to **Pmax** (**2,920 psig**) in approximately 55 seconds.

With the accumulator circuit stabilized at **Pmax**, the Primary Pump (Comet TWS 8035) was turned off and the accumulator circuit pressure allowed to bleed down slowly. At an accumulator circuit pressure of approximately **2,590 psig**, the Secondary Pump kicked-on and restored the accumulator circuit pressure to **2,890 psig** in approximately 150 seconds. Note that during this test, the air pressure from the B&C air pressure line delivered the required air flow rate at approximately 100 psig with ambient temperature of approximately 70°F.

Hydraulic Control Manifold

The review of **API Spec 16D** design requirements for the Hydraulic Control Manifold is seen in **Table 11** below.

TABLE 11. API Spec 16D Hydraulic Control Manifold

Referenced Paragraph	Comments	Status
4.3.1	At Least Two (2) Control Stations are Provided to Operate the Closing Unit Manifold	N/A
4.3.2	Manifold has Two (2) independent Hydraulic Pressure Control Circuits	DNM
4.3.2.1	Manifold has a Common Fluid Supply, Control Valves and Pressure Regulator	MET
4.3.2.1	Manifold has Regulator By-Pass Valve to Increase Manifold Pressure to Pmax	MET
4.3.2.3	Manifold Control Valves Configured and Oriented Properly	MET
4.3.2.3	Manifold Valve and Gauge Functions Clearly Marked	MET
4.3.2.3	Protective Cover Installed over SBR Control Valve	MET
4.3.4	Working Pressure of Control Valves, Fittings, Lines and Manifolds > System Pressure	MET
4.3.4.2	Piping Components and Threaded Connections Conform to Industry Standards	MET

The hydraulic control manifold is the assembly of hydraulic control valves, regulators and gauges needed to operate the closing unit system functions. The hydraulic manifold provides direct pressure reading of the accumulator circuit supply and regulated pressures and allows manual regulation of the power fluid pressure, if needed.

Note that the application for operating the TOT 5-1/8", 15M ES56 SBR does not require that the Closing Unit provide for remote stations to access the manifold. As such, ***Para. 4.3.3*** in **API Spec 16D** does not apply and was not included in the review of the Hydraulic Control Manifold.

Accumulator System

The B&C Closing Unit (11939830) is equipped with seven (7) bladder-type bottles mounted vertically within the skid. All accumulators bottles were found to be 11-gallon nominal bottles with a MAWP of 3,000 psig in the temperature range from -65° F through 200° F and certified by *Tobul*. The accumulators were mounted directly onto header piping, with all seven (7) accumulator bottles installed on a single header manifold.

The well control accumulator circuit bottles installed in the B&C 11939830 Closing Unit skid were inspected on March 19, 2014 to confirm design and traceability. On the morning of March 19, 2014, the precharge pressure settings were found to be approximately 1,200 psig at an average ambient temperature of 69°F. The precharge pressures and temperatures are seen in **Table 12** below.

TABLE 12. Primary Well Control Stack Accumulator Bank Vessels

Bottle Number	Size	Serial Number	National Board Number	Installation In Skid	U-1A Stamp	Precharge Pressure	Precharge Temperature
1	11 Gallon	09341	15040	Vertical	Yes	1,200 psig	70.0° F
2	11 Gallon	09409	15035	Vertical	Yes	1,200 psig	69.0° F
3	11 Gallon	09387	15031	Vertical	Yes	1,200 psig	69.0° F
4	11 Gallon	09318	14985	Vertical	Yes	1,200 psig	68.0° F
5	11 Gallon	09343	15038	Vertical	Yes	1,200 psig	68.0° F
6	11 Gallon	09244	15000	Vertical	Yes	1,200 psig	68.0° F
7	11 Gallon	09406	15033	Vertical	Yes	1,200 psig	72.0° F

The manufacturing and certification documentation for the Accumulator Bottle Package was requested by SAS to confirm compliance with **API Spec 16D Para. 9.2** ***Pressure Containing Components***. B&C is receiving documents from Meyer Service Company at the time of this Report.

Note that the design of the accumulator manifold for the B&C 11939830 Closing Unit has all bottles on a single manifold. As such, this design does not comply with **API Spec 16D Para. 5.1.3.2** (***Loss of accumulator manifold does not reduce accumulator system volume greater than 25%***).

The review of **API Spec 16D** design requirements for the Accumulator Bottles and Manifolds is seen in **Table 13** below.

TABLE 13. API Spec 16D Accumulator Bottles and Manifold Requirements

Referenced Paragraph	Comments	Status
5.1.3.1	Accumulator Bottles Comply with Design and Documentation Requirements	MET
5.1.3.2	Loss of Accumulator or Manifold does not Reduce Accumulator System Volume > 25%	DNM
5.1.3.3	Accumulators may be Bladder, Piston or Float Type Assemblies	MET
5.1.3.4	Supply-Pressure Isolation Valves and Bleed-Down Valves Installed on Each Acc. Bank	MET
5.1.3.5	Accumulators are Precharged with Nitrogen Gas Only	MET
5.1.3.6	Precharge Pressures of Accumulator Bottles Remain Below Rated Working Pressure	MET

In reference to API **Spec 16D Para. 5.1.4** ***Accumulator Volumetric Capacity Requirements***, the Closing Unit and Accumulator Bottle Package are configured to operate only the 5-1/8", 15M ES56 Dual Combi-Ram assembly. As such, the tests conducted and volumetric evaluation of the Closing Unit system is based on **API RP 16ST Para. 13.6.2** and **30 CFR 250.616 (*f*) 6**, as seen below.

API RP 16ST Para. 13.6.2 states ***"The accumulator bank shall have sufficient usable hydraulic fluid capacity (with the pump system inoperative) to operate all well control equipment components through a complete close-open-close sequence. After completing the close-open-close sequence, the pressure remaining in the accumulator bank shall be at least 200 psig above the precharge pressure (see 13.6.5). The volumetric capacity of the well control equipment accumulator bank and pre-charge pressure may be calculated using the method in Annex A".***

30 CFR 250.616 (*f*) 6 states that ***"You must have a hydraulic-actuating system that provides sufficient accumulator capacity to close-open-close each component in the BOP stack. This cycle must be completed with at least 200 psi above the pre-charge pressure, without assistance from a charging system".***

The overview of the SAS accumulator circuit inspection and performance test results are seen in **Table 14** below.

TABLE 14. 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
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-Blind Ram $P_{critical}$ pressure.					MET
Accumulator circuit pressure is ≥200 psig above precharge after Close-Open-Close 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

On March 19, 2014, the B&C 11939830 Closing Unit was prepared for test operation at the B&C facility (New Iberia, LA) and connected to the TOT 5-1/8", 15M, ES56 Dual Combi Ram assembly **123-37672** to perform tests to confirm compliance with **API RP 16ST** ***Para. 13.6.2*** and **30 CFR 250.616 (*f*) 6** requirements. SAS conducted the aforementioned well control equipment performance tests and evaluated the performance as it relates to the Closing Unit and accumulator system to be used with the well control equipment as seen in **Tables 15, 16** and **17** and **Figure 1**.

Table 15 shows the design and configuration of the B&C 11939830 Closing Unit accumulator package used with the captioned well control equipment, along with the final precharge pressures (and temperatures) and stabilized operating pressure.

Table 16 shows the volumes for closing and opening the TOT 5-1/18", 15M ES56 Pipe-Slip Ram and Shear-Blind Ram. This information was obtained from the manufacturer's Technical Manual provided to SAS. Based on the "Usable" power fluid volume (**31.1056** gallons) available at the accumulator conditions stated above, the B&C Closing Unit and accumulator circuit has more than sufficient "Usable" volume to complete the required TOT 5-1/18", 15M ES56 SBR "Close-Open-Close" sequence with a remaining system pressure at least 200 psig above precharge.

Table 17 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" and "open" tests conducted by SAS. The pressure values seen in **Table 17** reflect the pressure in the accumulator circuit immediately after actuation of the respective Dual Combi-Rams. 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 and approximate the adiabatic conditions to be expected during "real-time" well control ram actuations.

Figure 1 is a graphic representation of the "depressurization" of the accumulator circuit as each of the rams are closed, opened and closed again without assistance from the accumulator charge pumps. As discussed previously, the B&C 11939830 Closing Unit and accumulator circuit was configured for operating the TOT 5-1/8", 15M ES56 Pipe-Slip Ram (PSR) and Shear-Blind Ram (SBR) through 3/4" ID hydraulic hoses. These ram actuation tests were performed to evaluate the adiabatic "depressurization" of the accumulator circuit as the Dual Combi-Rams were functioned and then compared to the theoretical predictions. For the accumulator operating parameters identified above, the accumulator circuit pressure to be expected upon closure of the ES56 Shear-Blind Ram is approximately **2,465 psig**. Based on an observed shear test pressure of ***1,947 psig*** and the addition of ***72 psig*** of "ram piston balance pressure", the minimum required accumulator system pressure at the time of Shear-Blind Ram closure must be **2,019 psig**. As such, ***the B&C 11939830 Closing Unit accumulator system meets or exceeds the performance expectation for operating the TOT 5-1/8", 15M ES56 Shear-Blind rams in wellbore pressures up to 15,000 psig.***

TABLE 15 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	70.0 F	2,920 Psig	83.0 F
2	11	Vertical	1,200 Psig	69.0 F	2,920 Psig	83.0 F
3	11	Vertical	1,200 Psig	69.0 F	2,920 Psig	83.0 F
4	11	Vertical	1,200 Psig	68.0 F	2,920 Psig	83.0 F
5	11	Vertical	1,200 Psig	68.0 F	2,920 Psig	83.0 F
6	11	Vertical	1,200 Psig	68.0 F	2,920 Psig	83.0 F
7	11	Vertical	1,200 Psig	72.0 F	2,920 Psig	83.0 F
TOTAL	77	Gallons	(Accumulator Performance Test Conducted on 03.19.14)			

TABLE 16 B&C ES56 COMBI 123-37672 CT STACK CLOSING AND OPENING OPERATING VOLUMES

	Blind Rams	Shear Rams	Slip Rams	Pipe Rams	Pipe Slips	Shear Blinds	Total
	Gallons	Gallons	Gallons	Gallons	Gallons	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 : 31.1056 Gallons MET

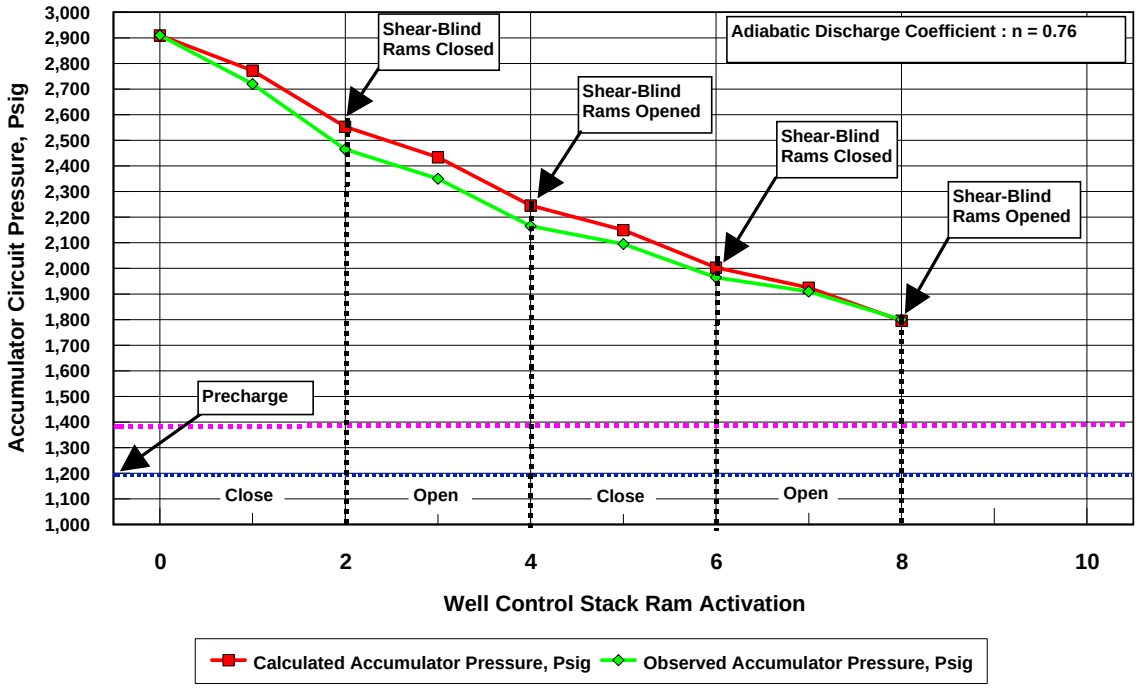
(Note: Vacc Calculations Based on the Accumulator Pressures and Temperatures Noted Above)

TABLE 17 ACCUMULATOR CIRCUIT PERFORMANCE - Predicted Versus Actual

Adiabatic Cd:	0.76	Accumulator Pressure		Usable	Closing	Pressure /
Ram	Function	Calculated	Observed	Volume	Time	Rate Ratio
		(psig)	(psig)	(gallons)	(sec.)	(gpm/psig)
Initial Status	Open Valve	2,910	2,910	31.106	(Through 3/4" ID Hoses)	
Pipe-Slips	Close	2,772	2,720	30.041	3.00	0.007830
Shear-Blinds	Close	2,553	2,465	28.205	5.00	0.008935
Pipe-Slips	Open	2,434	2,350	27.140	3.00	0.009063
Shear-Blinds	Open	2,246	2,165	25.201	5.00	0.010750
Pipe-Slips	Close	2,150	2,095	24.136	3.00	0.010166
Shear-Blinds	Close	2,004	1,965	22.300	5.00	0.011209

FIGURE 1 B&C 11939830 CLOSING UNIT ACCUMULATOR SYSTEM EVALUATION

5-1/8", 15M ES56 DUAL COMBI-RAM ASSEMBLY (123 - 37672) SBR & PSR



The Performance Audit testing and follow-up inspection activities for the B&C 11939830 Closing Unit and accumulator circuit concluded on March 19, 2014, with follow-up discussions with B&C and Meyer Services ongoing to obtain additional performance documentation. This report reflects the full extent of the SAS Industries, Inc. Performance Audit tests and inspections performed at the B&C facility located in New Iberia, Louisiana.

Alexander Sas-Jaworsky P.E.

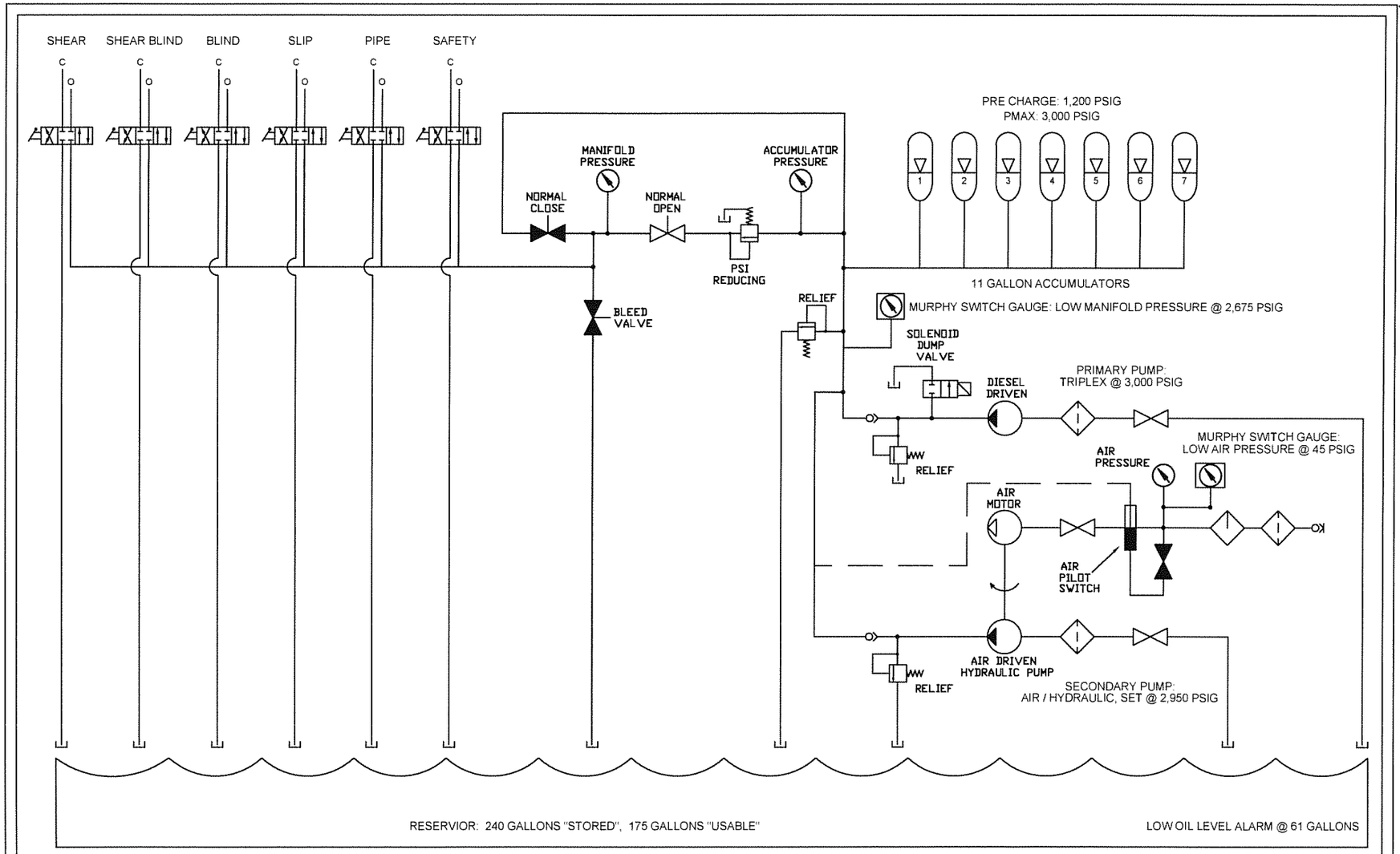
Alexander Sas-Jaworsky, PE (TX 79783)
Vice President - Engineering Services

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

DISCLAIMER

This report was prepared by SAS Industries, Inc. based upon verified and documented performance audit testing activities concluded on March 19, 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.

Reviewed by
Joe Steckman
6.12.13



B & C 11939830

Note: Master gauge in box not adjustable.

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THIRD ANGLE PROJECTION

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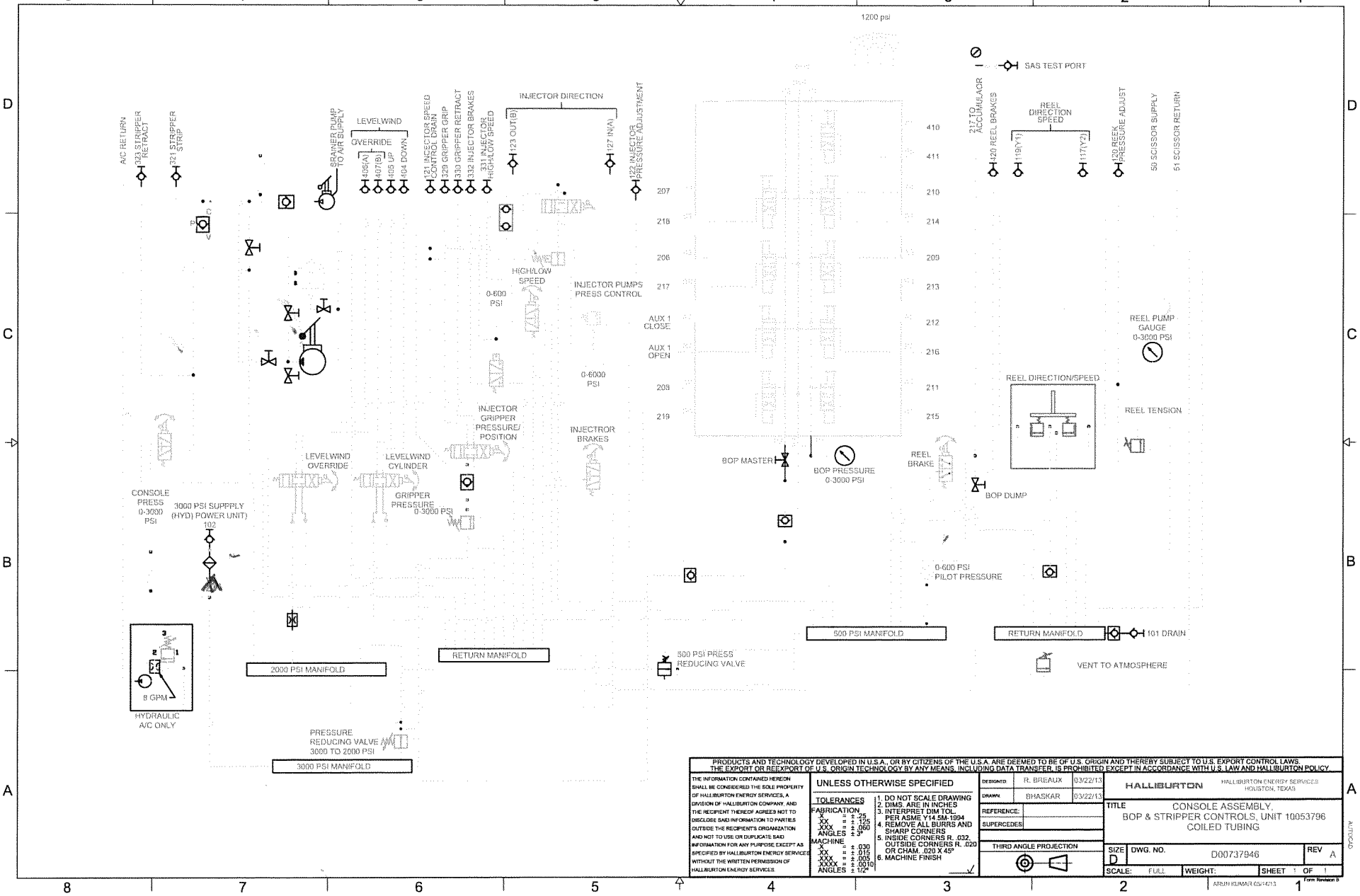
TITLE: **Accumulator Skid Model No. ACC-51 Hydraulic Schematic 11939830**

SIZE: D | DWG. NO. | REV

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

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

Keiam Shum 2/24/14



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

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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

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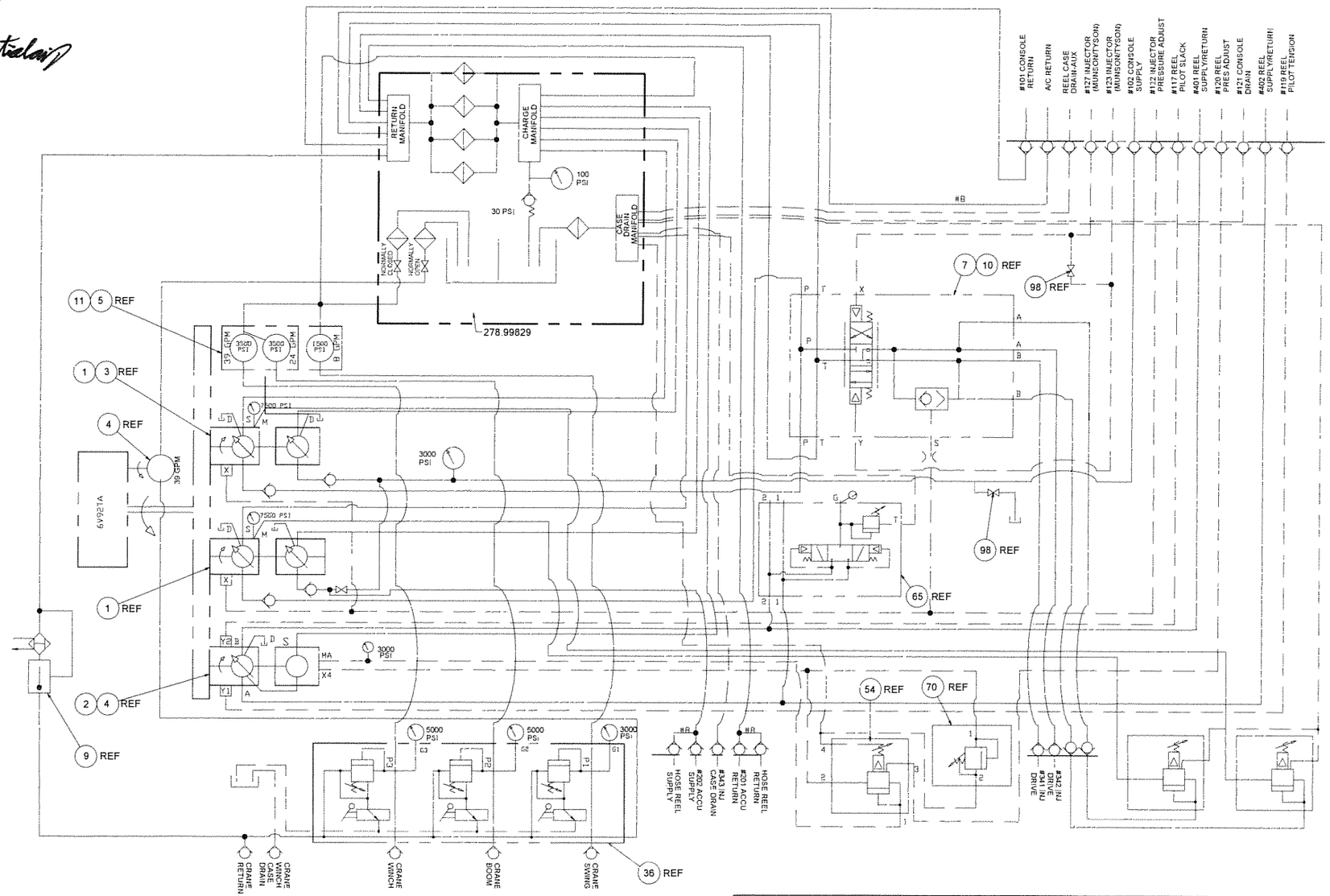
ARUN KUMAR 05/14/13

Form Revision B

AUTOCAD

Reviewed by
Joe Steggman
6.10.13
Miguel Satiedaip



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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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DRAWN	ARUN KUMAR	04/04/13
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TITLE: INSTALLATION, HYDRAULIC, PUMPS, RESERVOIRS, COOLER, PIPING, FILTERS, UNIT 10843532

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ARUN KUMAR 04/04/13

Form Revision B

AUTOCAD

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
(March 20, 2014 through September 17, 2014)

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

March 25, 2014

Prepared By:

SAS INDUSTRIES, INC.

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Houston, TX 77084
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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 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	March 20, 2014	March 21, 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:	946 psig (at atmospheric pressure)
Calculated Shear Ram Pressure:	1,107 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 60° F (average temperature)
30-Minute Stabilized Accumulator Pressure:	2,955 psig at 73° 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	1500057097	146,000 psi	150,000 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
1.7525 Inches	1.7520 Inches	0.21450 Inch	0.21260 Inch	0.21100 Inch	0.20985 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 March 20, 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	946 Psig*	1,124 psig	1,198 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 **1,581 psig** (at atmospheric conditions). In comparison to the theoretical calculations offered by TOT, the "Actual" Shear Ram pressure of **946 psig** is found to be **59.8%** 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 **1,107 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 (**24.6562** 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 CT CONTROL CONSOLE 10053796 ACCUMULATOR SYSTEM DESIGN

Accumulator System Design			Precharge Conditions		Stabilized Conditions	
Number	Gallons	Orientation	Pressure	Temperature	Pressure	Temperature
1	15	Horizontal	1,200 Psig	58.0 F	2,955 Psig	73.0 F
2	15	Horizontal	1,200 Psig	58.0 F	2,955 Psig	73.0 F
3	15	Horizontal	1,200 psig	62.0 F	2,955 Psig	73.0 F
4	15	Horizontal	1,200 Psig	63.0 F	2,955 Psig	73.0 F
TOTAL	60	Gallons	(Accumulator Performance Test Conducted on 03.19.14)			

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

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

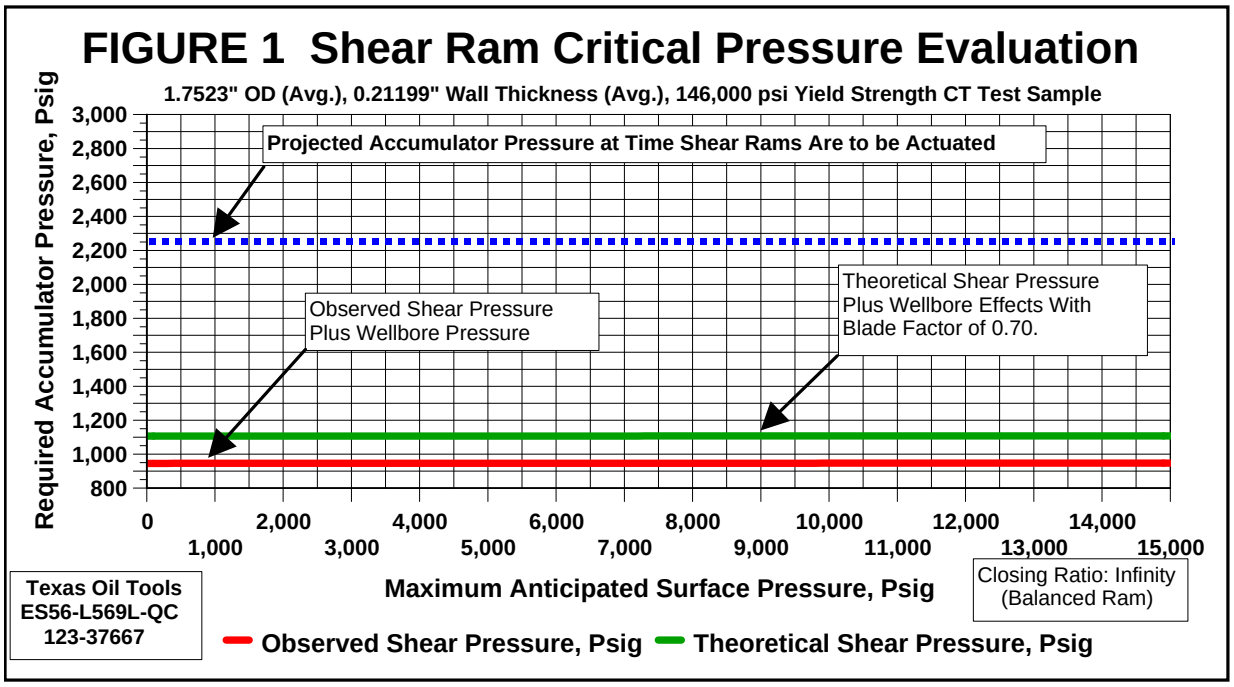
Volume for "Close - Open - Close" of CT Rams in Stack : 16.7586 Gallons

API RP16ST Accumulator Usable Volume Calculation : 24.6562 Gallons MET

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

TABLE 7 ACCUMULATOR CIRCUIT PERFORMANCE - Predicted Versus Actual

Adiabatic Cd:	0.29	Accumulator Pressure		Usable	Closing	Pressure /
Ram	Function	Calculated	Observed	Volume	Time	Rate Ratio
		(psig)	(psig)	(gallons)	(sec.)	(gpm/psig)
Initial Status	Open Valve	2,845	2,845	24.656	(Through 3/8" Hoses)	
Slip Ram	Close	2,622	2,605	22.734	25.00	0.001771
Pipe Ram	Close	2,530	2,480	21.863	19.00	0.001109
Shear Ram	Close	2,348	2,250	19.941	41.00	0.001250
Blind Ram	Close	2,273	2,175	19.070	20.00	0.001201



Observed Shear Ram Test Pressure :	946	Psig (at atmospheric conditions)
Theoretical Shear Ram Pressure :	1,581	Psig (at atmospheric conditions With BF = 1.00)
Theoretical Shear Ram Pressure :	1,107	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	2,955 Psig	1,200 Psig

Based on the results of performance testing concluded on March 21, 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 March 21, 2014.

Alexander Sas-Jaworsky P.E.

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

DISCLAIMER

This report was prepared by SAS Industries, Inc. ("SAS") based upon verified and documented performance audit testing activities concluded on March 21, 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}
1.7523"	1.3283"	146,000 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:

$$\text{Theoretical Shear} = 0.7854\left(1.7523^2 - 1.3283^2\right)\left(146{,}000\,psi\right)\left(0.577\right) = 86{,}421\ Lb_f$$

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

Closing Ratio = Infinity (Shear Ram is Pressure Balanced)

P_{Shear} = (86,421 lb_f x **0.70** /54.67 in^2) = **1,107 psig**

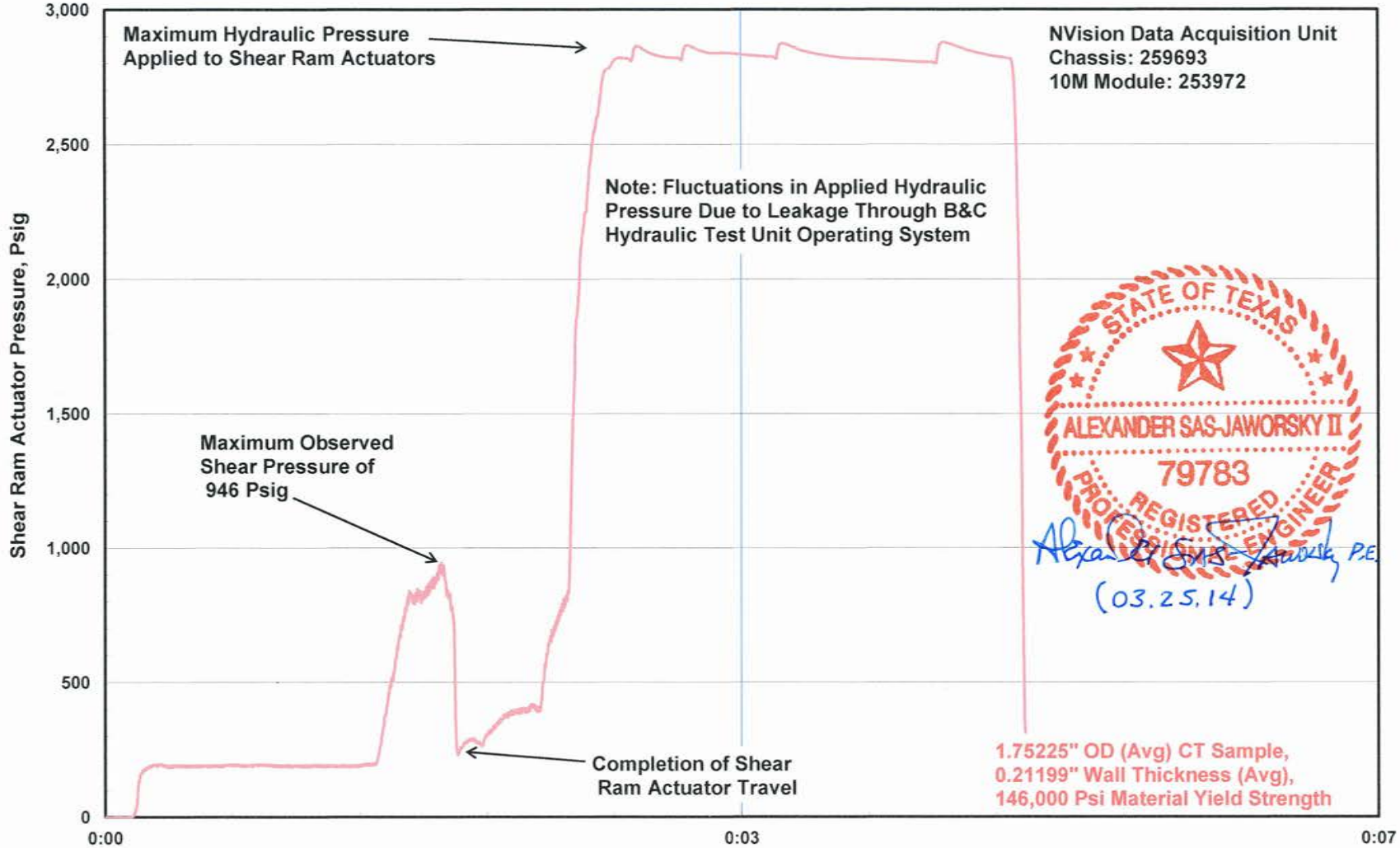
$P_{critical}$ = 1,107 psig + (0) = **1,107 psig**

Alex SAS-Jaworsky, P.E.
(TX 79783 03.25.14)

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 MARCH 20, 2014 AT B&C FACILITY (New Iberia, LA)



SAS INDUSTRIES, INC.

TIME DURATION OF TEST, Hours:Minutes

March 25, 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
(March 20, 2014 through September 16, 2014)

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

March 24, 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	March 20, 2014	March 21, 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:	1,947 psig (at atmospheric pressure)
Post-Shear Sealing Pressure Test:	15,400 Psig (with 1,800 psig closing pressure)
Calculated Shear-Blind Ram Pressure:	2,124 psig (at atmospheric pressure) (with **Blade Factor** of **0.91**)
Minimum CT Unit Accumulator Volume:	77 Gallons
Accumulator Precharge Pressure:	1,200 psig at 69° F (average temperature)
30-Minute Stabilized Accumulator Pressure:	2,920 psig at 83° F (average temperature)
Expected Accumulator Pressure at Shear:	2,465 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	1500057097	146,000 psi	150,000 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
1.7515 Inches	1.7515 Inches	0.21100 Inch	0.20985 Inch	0.20120 Inch	0.20995 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 March 20, 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	1,947 Psig*	2,014 psig	2,016 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 **2,334 psig** (at atmospheric conditions). In comparison to the theoretical calculations offered by TOT, the "Actual" SBR pressure of **1,947 psig** is found to be **83.4%** 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 **2,124 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 (**31.1056** 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 **2,465 psig**. ***As a result, SAS uses the projected accumulator circuit pressure of 2,465 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	70.0 F	2,920 Psig	83.0 F
2	11	Vertical	1,200 Psig	69.0 F	2,920 Psig	83.0 F
3	11	Vertical	1,200 Psig	69.0 F	2,920 Psig	83.0 F
4	11	Vertical	1,200 Psig	68.0 F	2,920 Psig	83.0 F
5	11	Vertical	1,200 Psig	68.0 F	2,920 Psig	83.0 F
6	11	Vertical	1,200 Psig	68.0 F	2,920 Psig	83.0 F
7	11	Vertical	1,200 Psig	72.0 F	2,920 Psig	83.0 F
TOTAL	77	Gallons	(Accumulator Performance Test Conducted on 03.19.14)			

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
	Gallons	Gallons	Gallons	Gallons	Gallons	Gallons	Gallons
Close					1.06494	1.83550	2.90044
Open					1.06494	1.93939	3.00433

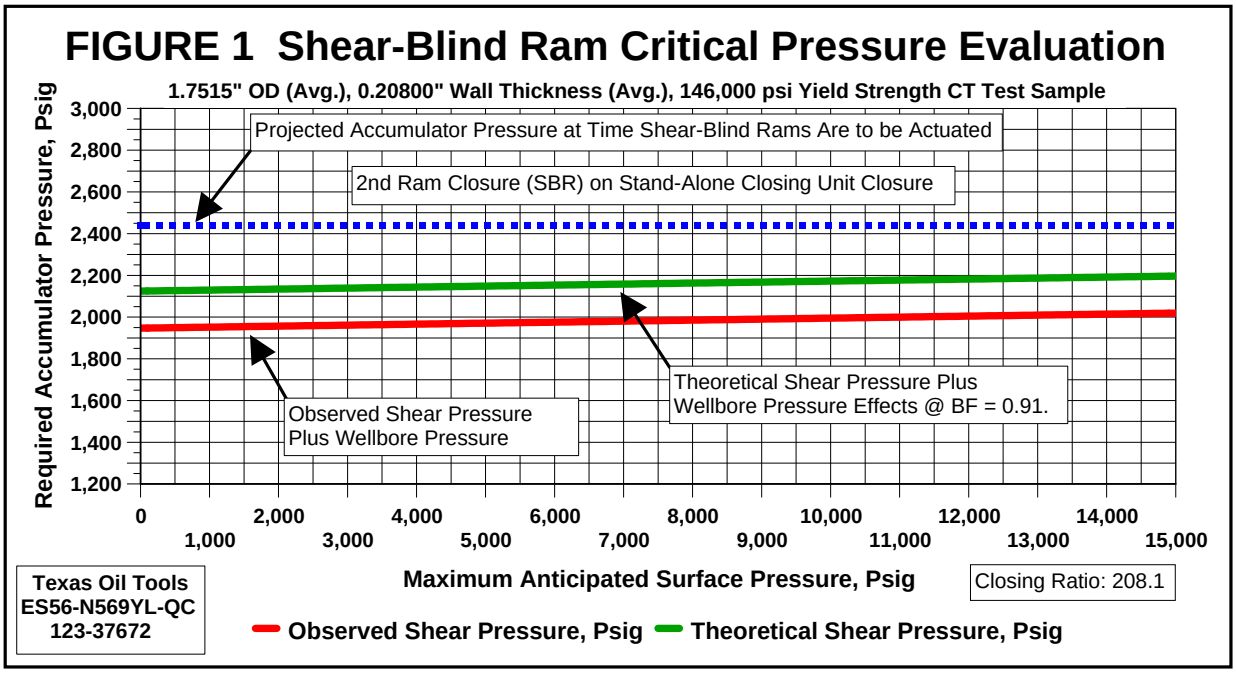
Volume for "Close - Open - Close" of CT Rams in Stack : 8.80521 Gallons

API RP16ST Accumulator Usable Volume Calculation : 31.1056 Gallons MET

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

TABLE 7 ACCUMULATOR CIRCUIT PERFORMANCE - Predicted Versus Actual

Adiabatic Cd:	0.76	Accumulator Pressure		Usable	Closing	Pressure /
Ram	Function	Calculated	Observed	Volume	Time	Rate Ratio
		(psig)	(psig)	(gallons)	(sec.)	(gpm/psig)
Initial Status	Open Valve	2,910	2,910	31.106	(Through 3/4" ID Hoses)	
Pipe-Slips	Close	2,772	2,720	30.041	3.00	0.007830
Shear-Blinds	Close	2,553	2,465	28.205	5.00	0.008935
Pipe-Slips	Open	2,434	2,350	27.140	3.00	0.009063
Shear-Blinds	Open	2,246	2,165	25.201	5.00	0.010750
Pipe-Slips	Close	2,150	2,095	24.136	3.00	0.010166
Shear-Blinds	Close	2,004	1,965	22.300	5.00	0.011209



Observed Shear-Blind Ram Test Pressure : 1,947 Psig (at atmospheric conditions)
Theoretical Shear-Blind Ram Pressure : 2,334 Psig (at atmospheric conditions With BF = 1.00)
Theoretical Shear-Blind Ram Pressure : 2,124 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	2,920 Psig	1,200 Psig

Based on the results of all performance testing concluded on March 21, 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 March 21, 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 March 21, 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}
1.7515"	1.3355"	146,000 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:

$$\text{Theoretical Shear} = 0.7854\left(1.7515^2 - 1.3355^2\right)\left(146{,}000\,psi\right)\left(0.577\right) = 84{,}967\ Lb_f$$

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

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

P_{Shear} = (84,967 lb_f x **0.91** /36.41 in^2) = **2,124 psig**

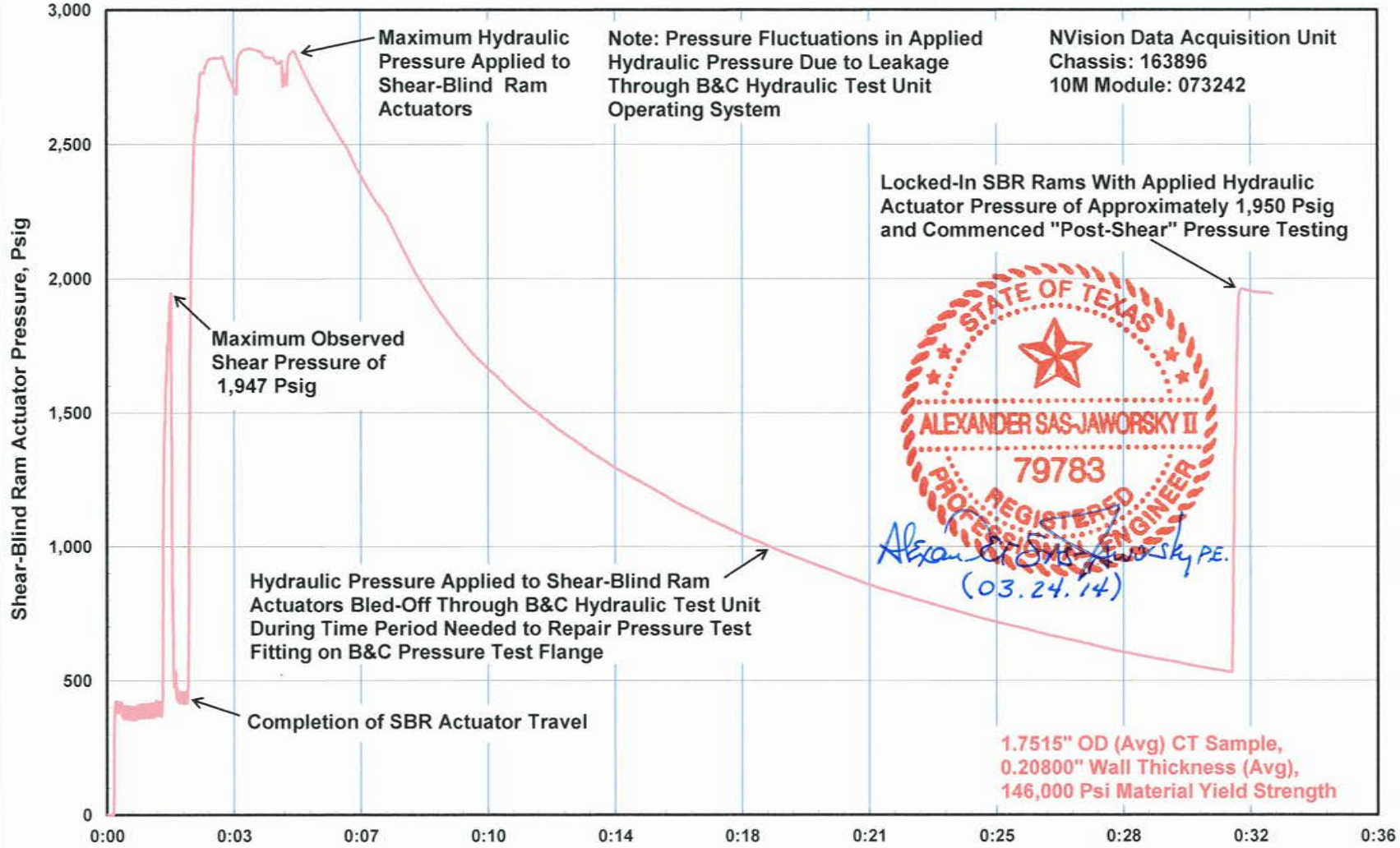
$P_{critical}$ = 2,124 psig + (15,000 / 208.1) = **2,196 psig**

Alex Sas-Jaworsky P.E.
(TX 79783 03.24.14)

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

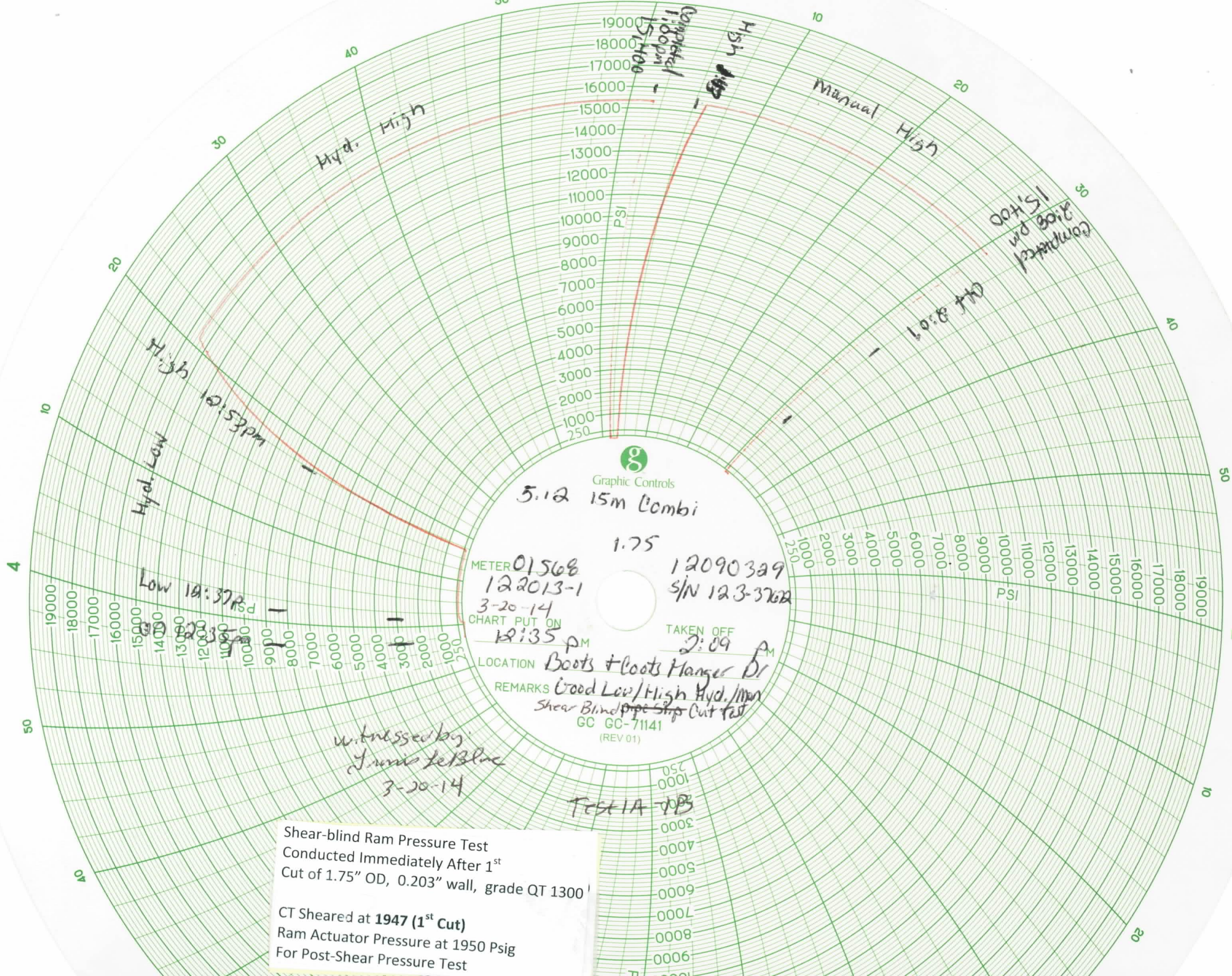
SHEAR-BLIND RAM TEST CONDUCTED ON MARCH 20, 2014 AT B&C FACILITY (New Iberia, LA)



SAS INDUSTRIES, INC.

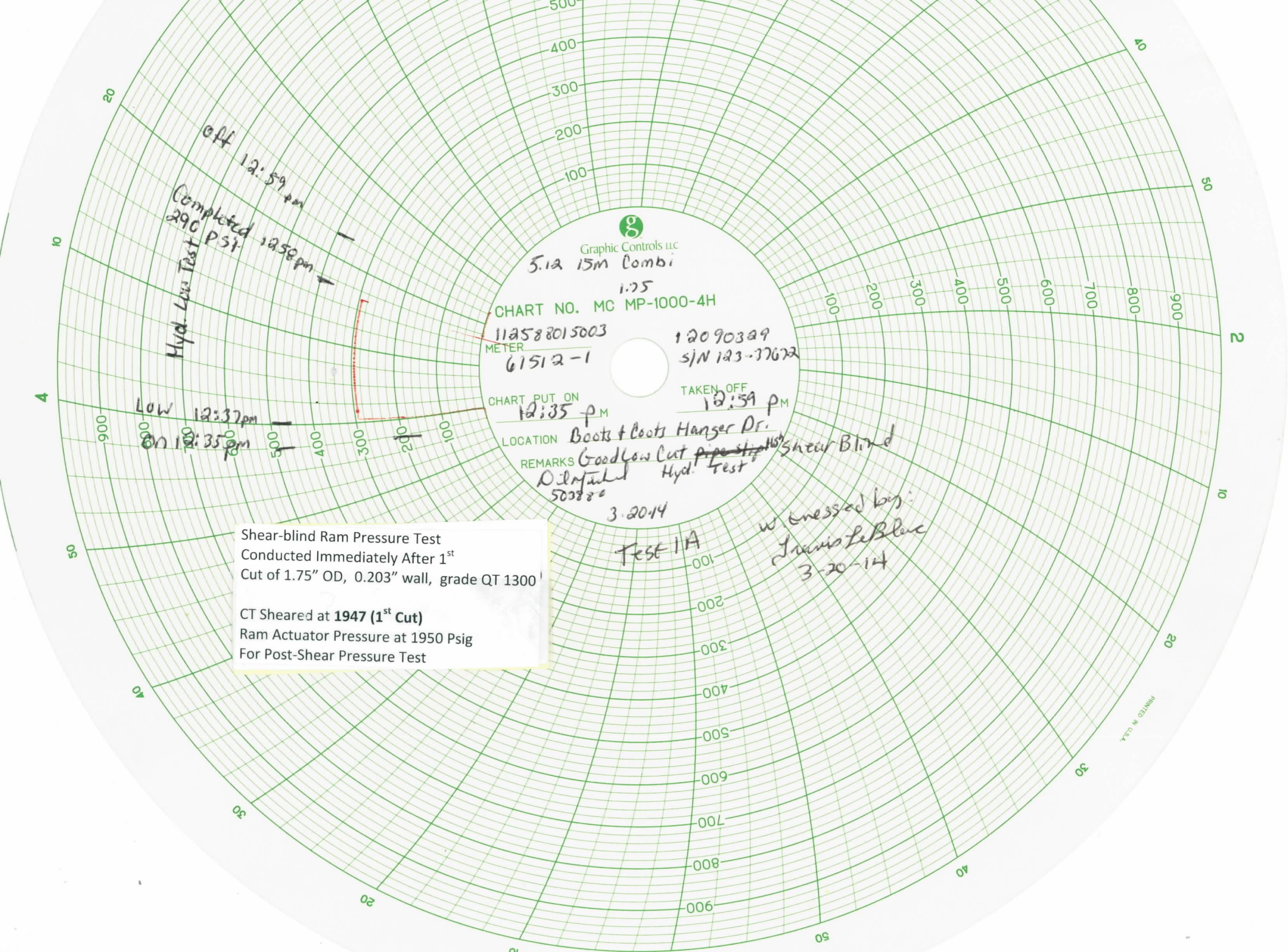
TIME DURATION OF TEST, Hours:Minutes

March 24, 2014



Shear-blind Ram Pressure Test
Conducted Immediately After 1st
Cut of 1.75" OD, 0.203" wall, grade QT 1300

CT Sheared at **1947 (1st Cut)**
Ram Actuator Pressure at 1950 Psig
For Post-Shear Pressure Test

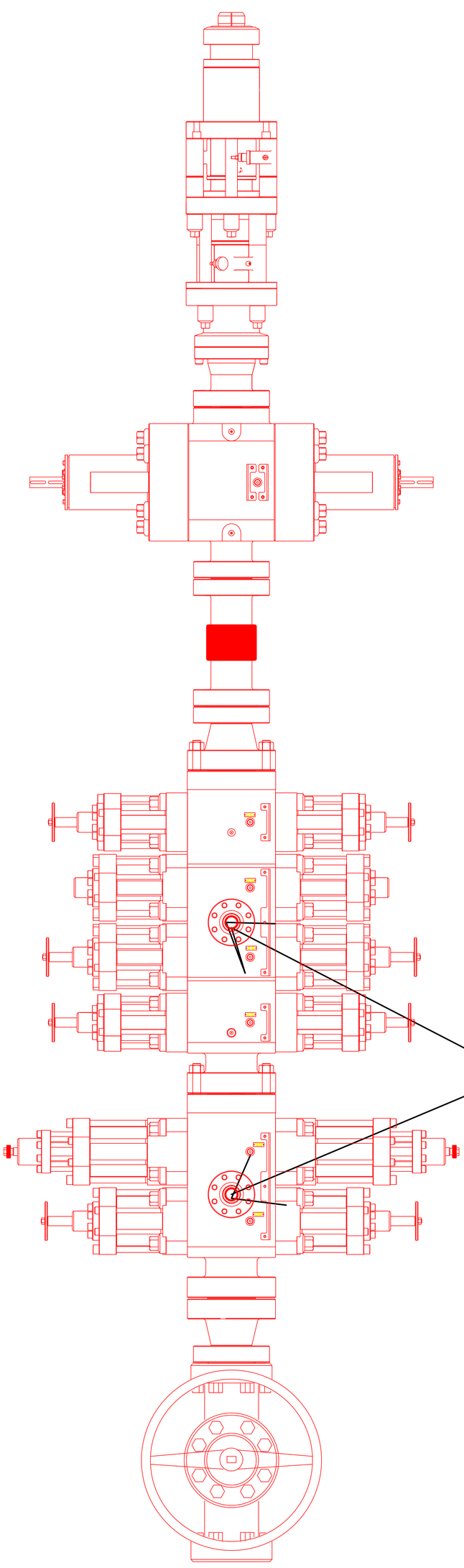


Shear-blind Ram Pressure Test
Conducted Immediately After 1st
Cut of 1.75" OD, 0.203" wall, grade QT 1300

CT Sheared at **1947 (1st Cut)**
Ram Actuator Pressure at 1950 Psig
For Post-Shear Pressure Test

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

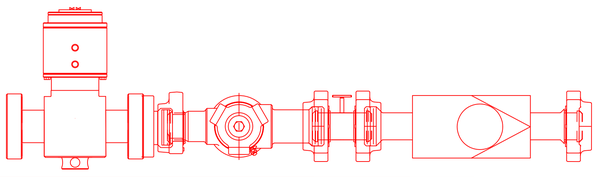
Pipe Rams 5.125-in 15M

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

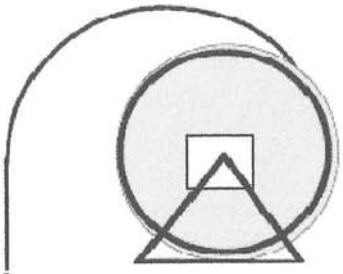


Note: All rams dressed appropriately for 1.75" Coiled Tubing

WELD LOCATION RECORD

NOV Quality Tubing

CUSTOMER	HALLIBURTON ENERGY SERVICES
PO#	EMMEB062513
QTI#	57209
STRING#	404860000
DIAMETER	1.750 INCH
WALL	.134 - .203
GRADE	QT1300
HYDROTESTED TO	15000 PSI
SHIPPING Spool/Reel	
CURRENT Spool/Reel	18363 #MS1800950966N



	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
0	1500051239	.134 - .134	2122	2122	BIAS	651402	2710534	138500	144500	1.04	22.5	31	HRC	34	HRC	0.120	1.450	0.017	0.0010	0.410	0.580	0.220	0.080	0.250	0.064	0.055	
1	1500051240	.134 - .134	2290	4412	BIAS	651402	2710534									0.120	1.450	0.017	0.0010	0.410	0.580	0.220	0.080	0.250	0.064	0.055	
2	1500051241	.134 - .134	2287	6699	BIAS	651402	2710534									0.120	1.450	0.017	0.0010	0.410	0.580	0.220	0.080	0.250	0.064	0.055	
3	1500057909	.134 - .134	2384	9083	BIAS	633874	2C21211	133000	140000	1.05	29.0	28	HRC	27	HRC	0.120	1.470	0.018	0.0010	0.380	0.580	0.220	0.090	0.240	0.066	0.052	
4	1500057910	.134 - .134	2495	11578	BIAS	633874	2C21211									0.120	1.470	0.018	0.0010	0.380	0.580	0.220	0.090	0.240	0.066	0.052	
5	1500057911	.134 - .134	2290	13868	BIAS	633874	2C21211									0.120	1.470	0.018	0.0010	0.380	0.580	0.220	0.090	0.240	0.066	0.052	
6	1500057912	.134 - .134	2400	16268	BIAS	633874	2C21211									0.120	1.470	0.018	0.0010	0.380	0.580	0.220	0.090	0.240	0.066	0.052	
7	1500061785	.134 - .134	1525	17793	BIAS	571964	2C21213	132500	138000	1.04	30.5	26	HRC	27	HRC	0.120	1.460	0.011	0.0010	0.390	0.560	0.220	0.080	0.230	0.065	0.055	
8	1500035615	.134 - .145	1065	18858	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	
9	1500061793	.145 - .145	1797	20655	BIAS	6654241	2922930	141500	147000	1.03	26.5	31	HRC	34	HRC	0.120	1.490	0.017	0.0010	0.380	0.640	0.240	0.080	0.240	0.070	0.060	
10	1500035615	.145 - .156	1156	21811	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	
11	1500006218	.156 - .156	1207	23018	BIAS	651243	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	
12	1500006913	.156 - .175	1530	24548	BIAS	558004	9721832	143500	150500	1.04	22.5	25	HRC	25	HRC	0.120	1.500	0.011	0.0010	0.410	0.590	0.240	0.080	0.250	0.066	0.055	
13	1500041456	.175 - .175	1790	26338	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	1500051075	.175 - .175	940	27278	BIAS	513432	1512513	138000	142500	1.03	22.0	34	HRC	33	HRC	0.130	1.480	0.013	0.0001	0.380	0.600	0.230	0.090	0.250	0.069	0.055	
15	1500056124	.175 - .188	820	28098	BIAS	385551	2922930	141500	147000	1.03	26.5	31	HRC	34	HRC	0.120	1.490	0.017	0.0010	0.380	0.640	0.240	0.080	0.240	0.070	0.060	
16	1500045177	.188 - .188	1570	29668	BIAS	513692	1512512	143500	148000	1.03	26.5	36	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	
17	1500056124	.188 - .203	775	30443	BIAS	385551	2922930	141500	147000	1.03	26.5	31	HRC	34	HRC	0.120	1.490	0.017	0.0010	0.380	0.640	0.240	0.080	0.240	0.070	0.060	
18	1500057096	.203 - .203	1525	31968	BIAS	184930	1B11018									0.120	1.470	0.014	0.0010	0.390	0.560	0.230	0.100	0.250	0.067	0.062	
19	1500057097	.203 - .203	1490	33458	BIAS	184930	1B11018	146000	150000	1.02	23.0	27	HRC	28	HRC	0.120	1.470	0.014	0.0010	0.390	0.560	0.230	0.100	0.250	0.067	0.062	
20	1500057098	.203 - .203	90	33548	END	184930	1B11018	146000	150000	1.02	23.0	27	HRC	28	HRC	0.120	1.470	0.014	0.0010	0.390	0.560	0.230	0.100	0.250	0.067	0.062	

CHEMICAL ANALYSIS, Wt %

Total String: 33548 FT

QUALITY TUBING

By PROFORMA As Current

Date 7/9/2013

String Manufactured: 7/6/2013

ORIENTATION X **BED**

Material Specification:
N.D.E. Tested ASTM E-309

ASTM A1011, Modified
Mechanical Test Method per ASTM A370

Theoretical Shear Ram Performance – Texas Oil Tools Calculation Method

Operator: McMoran **Well:** South Marsh Island Block 234 Well No. 14 **Reported MASP:** 15,000 psig

Coiled Tubing Vendor: B&C Coiled Tubing Services **CT Yield Strength:** 146,000 psi @ 0.203" Wall

Workstring Construction: 1.750" OD, Tapered Wall (0.134" - 0.203"), CT-130 (**QTI String No. 40486**)

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"	146,000 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 (0.70)
(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)

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

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

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

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

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

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:

$$\text{Theoretical Shear} = 0.7854\left(1.750^2 - 1.344^2\right)\left(146{,}000\,psi\right)\left(0.577\right) = 83{,}112\ Lb_f$$

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

Closing Ratio = Infinity (Shear Ram is Pressure Balanced)

P_{Shear} = (83,112 lb_f x **0.70** /54.67 inch^2) = **1,064 psig**

$P_{critical}$ = 1,064 psig + (0) = **1,064 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 ***2,250 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 ***1,064 psig***, and the predicted available accumulator operating pressure of ***2,250 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-Jaworsky P.E.
(TX 79783 04.07.14)

SAS Industries, Inc.

April 07, 2014

Theoretical Shear Ram Performance – Texas Oil Tools Calculation Method

Operator: McMoran **Well:** South Marsh Island Block 234 Well No. 14 **Reported MASP:** 15,000 psig

Coiled Tubing Vendor: B&C Coiled Tubing Services **CT Yield Strength:** 146,000 psi @ 0.203" Wall

Workstring Construction: 1.750" OD, Tapered Wall (0.134" - 0.203"), CT-130 (**QTI String No. 40486**)

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"	146,000 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)

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

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

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

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

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

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:

$$\text{Theoretical Shear} = 0.7854\left(1.750^2 - 1.344^2\right)\left(146{,}000\,psi\right)\left(0.577\right) = 83{,}112\ Lb_f$$

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

Closing Ratio = 208.1 (SBR is Nearly Pressure Balanced)

P_{Shear} = (83,112 lb_f x **0.91** /36.41 inch^2) = **2,077 psig**

$P_{critical}$ = 2,077 psig + (15,000 / 208.1) = **2,149 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 2,920 psig) demonstrated a minimum of ***2,465 psig*** remaining in the system after closure of the ES56 SBR in a simulated well control emergency drill (***second ram to close from the Closing Unit***). Based on the calculated $P_{critical}$ value of ***2,149 psig***, and the predicted available accumulator operating pressure of ***2,465 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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(TX 79783 04.07.14)

SAS Industries, Inc.

April 07, 2014