ATTACHMENT A

Test Report - STEAM GENERATOR TUBE IN-SITU HYDROSTATIC PRESSURE TEST TOOL HYDRO CHAMBER PRESSURE DETERMINATION

Test Report

Steam Generator Tube

In-Situ Hydrostatic Pressure Test Tool

Hydro Chamber Pressure Determination

Report No. TR-9419-CSE96-1101 Rev. 0

ABB Combustion Engineering Nuclear Operations

Prepared By: R. M. Orsulak, Consulting Engineer Date: 6/12/96

Reviewed By: G. C. Fink, Principal Engineer Date: 6/12/96

Approved By: See attached Sheet J. F. Hall, Principal Consultant Date: ________

Approved By: J. D. Ford, Manager, Field Quality Operations Date: 6/12/96

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1.0 Purpose

The purpose of this test report is to document the results of the test performed to determine the relationship between the hydro pump outlet pressure and the seal bladder pressure under flow conditions for the steam generator localized in-situ pressure test tools. In addition, static testing was performed to establish a baseline relationship under non-flow conditions. The test was performed in accordance with the procedure listed in Reference 2.1. The data under flow conditions will be used to ensure that in the event of a leaking defect indication, the leakage rate is measured at the appropriate pressure(s) within the hydro chamber. Testing was performed on both the axial and circumferential/axial tools.

2.0 References

2.1 Test Procedure, Steam Generator Tube In-Situ Hydrostatic Pressure Test Tool, Hydro Chamber Pressure Determination, TP-9419-CSE96-2104, Rev.0, dated June 10, 1996.

2.2 QAM-100, Fourth Edition, Revison 4.

2.3 Final Test Report for the Steam Generator Tube In-Situ Hydrostatic Test Tool. TR-ESE-1030, Rev. 00, T. R. No. 83D, dated April 5, 1994.

2.4 ABB Combustion Engineering Nuclear Operations Traveler No. PSL-007, In-Situ Hydro Test, Revision 4, dated May 24, 1996.

3.0 Quality Assurance

The test results described herein are to be treated as Safety Related, Quality Class 1, in accordance with the requirements in Reference 2.2.

4.0 Discussion and Background

Reference 2.3 describes the development and qualification testing for the localized in-situ test tool. The tool described in Reference 2.3 was developed to pressure test primarily circumferential defect indications in steam generator tubes at the tubesheet region. It is also used for the testing of axial indications. The designation of 'circumferential tool' used in this report does not preclude its use for axial indications. An additional tool was evolved for the testing of axial defects which are greater in length than those which can be accommodated by the hydro chamber in the original tool. Since the tool design for the circumferential defects has greater restrictions than those for axial defects, the test report is bounding for the axial tool.

The localized test tool contains two pressure circuits; one for seal and gripper bladders (note that the axial tool is not equipped with grippers), and one for the hydro chamber.

The hydro chamber circuit is pressurized by an air operated positive displacement pump. The bladder circuit is pressurized by either an air operated positive displacement pump or a hand pump.

The positive displacement pumps used in the system are able to maintain a precise control at a given static pressure. Under flow conditions, such as those experienced during a tube leak, the pump discharge pressure fluctuates between a high and low limit with each pump pulse. The magnitude of this band is a function of the flow rate and the restrictions within the hose/tool assembly. Due to these dynamic head losses, the actual pressure in the hydro chamber will be less than that observed at the pump discharge.

Reference 2.3 describes testing which was performed under flow conditions to establish the relationship between the hydro pump discharge pressure and the hydro chamber pressure. This test consisted of measuring the swing of the pressure gauge at the discharge of the hydro pump at various leak rates at an initial static hydro chamber pressure of 4,000 psig as directly measured in a controlled leak test fixture. Implementation of this data in an in-situ field test requires an iterative process as the hydro chamber pressure is not directly measurable. The process involves matching the pump discharge pressure swing relative to the desired pressure and observe the pump stroke rate as compared to the data in the test report. In addition, the test report explicitly states that the leak rate correction data apply only to the as-tested configuration.

For the testing at St. Lucie Unit 1, it was requested that the capability be provided to test in the straight tube portions at elevations well above the tubesheet. This necessitated the fabrication of hoses longer than those described in Reference 2.3. For non leaking defect indications, the length of the hose does not affect measuring the desired pressure in the hydro chamber as the system is static and the pressure is equal to that measured at the pump discharge. For leaking defects, the change in system resistance due to the change in hose length does have an effect on the dynamic response of the pump discharge pressure gauge and its subsequent relationship to the hydro chamber pressure. Consequently, for a leaking defect, the actual pressure in the hydro chamber is indeterminate without additional testing.

In order to determine the pressure in the hydro chamber with the current hose configuration, two methods were considered.

1) Hydro pump discharge pressure swing correlation method, and,

2) Seal bladder pressure intensification method.

Method 1 is the method described in Reference 2.3. Method 2 is based upon an observation during laboratory testing and field application. Experience during previous testing has shown that the bladder circuit pressure increases as its initial pre-charge pressure is approached by the increasing pressure in the hydro chamber. This pressure increase has been termed 'intensification.' Once the bladder pre-charge pressure is reached in the hydro chamber, the bladder pressure will increase with increasing hydro chamber pressure. This pressure has been observed to be approximately 200-300 psid under static conditions. It was expected that the relationship would be similar under flow (leak) conditions.

Establishing this relationship will provide an accurate indirect method of measuring the pressure in the hydro chamber under leaking conditions. As the bladder circuit is not in a flow path, there are no head losses to consider. Pulsations were evident in the bladder circuit due to the reciprocating nature of the hydro pump. However, these pulsations reflect the true pressure in the bladder circuit independent of the head losses experienced by the hydro circuit. By inference, the pressure in the hydro chamber can then be determined.

This test focused on establishing method 2 as the method of choice for determining the hydro chamber pressure under flow conditions. However, additional data was recorded in order to provide for the use of method 1. Method 1 is not evaluated in this report, however, the data obtained have been preserved as attachments to this report for any desired future use.

5.0 Limitations

5.1 The evaluation of the test data does not consider method 1. Data were recorded and attached to this report which can support future additional evaluation of method 1. As noted in Section 4, the method 1 correlation is a function of system dynamic resistance. Use of the test results in method 1 correlations is limited to systems with an identical configuration to that tested. The hose configuration in this test was identical to that in Figure 2 of Reference 2.3 with the exception that the length of the 3/16" braided hose has been increased from 30 feet to 50 feet. As a result, the data obtained from this test may be used to qualify method 1 for a 50 ft. length of 3/16" braided hose.

6.0 Test Description

This testing was performed in support of planned steam generator tube in-situ testing at the St. Lucie power plant. The steam generator in-situ test is described in Reference 2.4. Information from the Hydro Chamber Pressure Determination test reported herein will provide the basis for a revision to Reference 2.4 to incorporate lessons learned.

The protocol for the Hydro Chamber Pressure Determination test was provided in Reference 2.1. The target pressures for this test were based upon those anticipated for the in-situ test as described in Reference 2.4. These pressures are listed in the table below under the column headings Circumferential Indications and Axial Indications. Note that the Row titled 'MSLB', was not included in Reference 2.4 but was generated for the Hydro Chamber Pressure Determination test.

Table 1
Test Pressure Basis

Basis	Base Value (psig)	Circumferential Indications (psig)(1)	Axial Indications (psig)(2)
Normal Operating ΔP	1435	1,744	1,622
MSLB Pressure	2,500	3,038	2,825
1.4 x MSLB Pressure(3)	3,500	4,253	3,955
3 x N.O. ΔP	4,305	5,231	4,865

Notes:
1) Pressures were corrected a total of 21.5% from the base values for temperature and locked support influences.
2) Pressures were corrected 13% from the base values for temperature influences.
3) The MSLB base pressure is increased by 40% to account for structural design safety margin.

Regarding the MSLB pressure, initially, the test steam generator tube test plan included only 1.4 x MSLB pressure, corrected for temperature and locked supports. Further review suggests that while this value is an appropriate pressure for testing structural integrity, it is overly conservative with respect to leak rate testing for 10CFR100 release evaluations. As a result, the MSLB value, without the 1.4 x factor was also considered when choosing target pressures for the bladder/hydro chamber correlation tests.

The correlation test was conducted using both the circumferential/axial and long axial localized in-situ test tools. Testing was carried out using a leak rate fixture in conjunction with the spare hydro pump normally used for in-situ testing. Bladder pressure was supplied by a hand operated hydraulic pump. The test equipment is depicted in Figure 1.

Static Test: The static test was conducted at two initial bladder circuit pressures; 1,500 psig, and 2,000 psig. The initial bladder pressure of 2,000 psig was chosen as this is the normal initial bladder circuit pre-charge. As the objective of this test was to provide a comparison of the hydro chamber pressure with that in the bladder circuit for flow conditions, it was necessary to ensure that the initial bladder pressure was below the lowest desired test pressure. Therefore, the static test also was conducted at 1,500 psig as this is less than the lowest target test pressure of 1,622 psig. Performing the static test at the two pressures allows comparison between the traditional bladder pre-charge pressure of 2,000 psig and the planned bladder pre-charge pressure of 1,500 psig.

The static test was conducted at target hydro chamber pressures of 1,500, 1,600, 1,800, 3,000, 4,000 and 5,000 psig for each tool and both bladder pressures. The 1,500 psig value corresponds to the minimum bladder pressure. The remaining pressures are rounded values chosen to approximate the proposed test pressures listed in the above table.

The static test was conducted by pressurizing the hydro circuit to the target pressure ± 100 psig as indicated by the hydro chamber pressure gauge. The system was observed for leaks and steady pressure readings on all gauges. Pressure gauge readings were recorded as 'as read' values on the data sheet. These pressure values were corrected for calibration differences during data reduction in preparation for this report. The test was repeated for each of the target pressures for both tools at both initial bladder circuit pressures.

Dynamic Test: The dynamic leak rate test was conducted for both tools using an initial static bladder circuit pressure of 1,500 psig. The leak rate test was not conducted at an initial bladder pressure of 2,000 psig as this value will not be used at St. Lucie Unit 1.

Target pressures and leak rates were provided in Reference 2.1. The target hydro chamber pressures of 1,700, 3,000, 4,000 and 5,000 psig listed in Reference 2.1 were chosen to approximate the in-situ test pressures for both tools as listed in Table 1. These four values provided a reasonable basis for matching the test pressures while minimizing the number of tests to be conducted. However, during the conduct of the test, substantial pressure fluctuations due to pump pulses were observed. Consequently, the pressures were changed to be tailored to each tool and therefore to more closely approximate the specific target test pressures. In addition, the 3 x NOΔP value was deleted from the leak test as leak testing at this pressure is not a requirement of Regulatory Guide 1.121.

Reference 2.1 listed a series of target leak rates. During the conduct of the test, some difficulty was encountered in achieving these values, particularly at higher leak rates. As a result, the nearest achievable leak rate was used. In addition, the test was expanded to provide additional data at low leak rates.

For the conduct of the test, the bladder circuit was pressurized to 1,500 psig ± 100 psig. The hydro circuit was pressurized to the target pressure ± 100 psig. The test apparatus was observed for leaks and steady pressure readings on all gauges. Subsequently, the leak rate control valve was opened to establish the desired hydro pump stroke rate while maintaining the target pressure as indicated by the hydro chamber pressure gauge. This required iterative adjustment of the hydro pump air control regulator and the leak rate control valve. Due to the pulsing nature of the pump, the pressure gauge readings were fluctuating at a constant amplitude unique to each pressure tap. The adjustments were made such that the target hydro chamber pressure was at approximately the middle of the swing. Once a steady-state condition was achieved, the pressure readings were recorded on the data sheet. This process was repeated for each pump stroke rate tested at each of the hydro chamber test pressures for both tools.

7.0 Test Results

The test procedure and completed data sheets used for this test are included in this report as an attachment. The data were reviewed and compiled in a spreadsheet format in Tables 2 through 5 to show the relationship between the bladder pressure and the hydro chamber pressure. The data were used as the as-read values. The pressure readings were not corrected for calibration variance. The calibration records for the pressure gauges used in this test are attached to this report. For the pressure gauges of interest, those on the hydro chamber and the bladder circuit, the deviation from the standard was identical in the pressure range tested @ + 50 psig. As a result, the true ΔP between these two gauges is identical to the as-read ΔP.

Static Test: The static test was conducted at two initial bladder circuit pressures, 1,500 and 2,000 psig, for both tools. Tables 2 & 3 present the results for the axial and circumferential tools respectively. For both tools it was noted that a large chamber vs. bladder ΔP was evident until the hydro chamber pressure approached the initial bladder pressure. Subsequently, the ΔP was measured to be 150 to 250 psid. The typical variance between these ΔPs for the same tool, at different initial bladder pressures was 50 psi. The variance between the two tools, at the same pressure, also was approximately 50 psi.

Dynamic Test: The dynamic test was conducted at an initial bladder circuit pressure of 1,500 psig for both tools. The tools were tested at three target hydro chamber pressures corresponding approximately to the N.O.ΔP, MSLB pressure and 1.4 x MSLB pressure at a variety of leak rates ranging from 3 to 92 strokes/min (1 pump stroke is equivalent to 0.005 gallons). Note that the target test pressures are different for axial vs. circumferential defects. The results for the axial and circumferential tools are presented in Tables 4 & 5.

Due to the pulsing nature of the reciprocating hydro pump, wide swings in all pressure readings were observed. The hydro pump air inlet pressure and leak rate valve were adjusted such that the midpoint of the swing of the hydro chamber pressure gauge approximated the target test pressure. Both the high and low values were recorded. Additionally, the high and low values for the bladder circuit were recorded. At each pump stroke rate (simulated leak rate) the true mean values of the pressure readings were calculated. These were then used to calculate the ΔP of the average pressures in the hydro chamber and bladder circuit. The ΔP values at each target test pressure were evaluated to calculate a single mean value for the ΔP at a given target pressure.

Axial Tool The results for the axial tool are presented in Table 4. The results show that for a given target pressure the ΔP varied approximately 50 psi with two exceptions. At the highest pump stroke rate for each target pressure, the ΔP was considerably greater than the average of the remaining values. In addition, for the target pressure of 2850 psig, the ΔP at 4 strokes/min was 200 psid while the remaining low to mid-range leak rates ranged from 275 to 325 psid. When comparing the three average ΔP values, one at each target pressure, it was noted that as the target pressure was increased, the average ΔP decreased. The average ΔP for the axial tool ranged from 395 psid @ 1650 psig to 250 psid @ 3950 psig.

Circumferential Tool The results for the circumferential tool are presented in Table 5. The results show that for a given target pressure the ΔP varied approximately 50 psi with one exception. At the highest pump stroke rate @ 1750 psig target pressure, the ΔP was 75 psi greater than the lowest value. This differs from the results observed with the axial tool in that there were no large differences at the higher stroke rate.

Similar to the axial tool, when comparing the three average ΔP values, one at each target pressure, it was noted that as the target pressure was increased, the average ΔP decreased. The average ΔP for the axial tool ranged from 325 psid @ 1750 psig to 215 psid @ 4300 psig.

8.0 Conclusions

8.1 The static test showed that if the initial bladder pre-charge pressure is less than the hydro chamber test pressure, large differences will be observed between the values of these two circuits.

8.2 The static test also showed that as the test pressure is increased, the ΔP between the bladder and hydro chamber decreased.

8.3 Similar to the static test, the dynamic (controlled leak) test showed that as the target pressure was increased, the average ΔP decreased.

8.4 The dynamic test showed that the axial tool had a larger average ΔP than the circumferential tool.

8.5 For the axial tool, a value of 400 psi is a reasonable correction factor for determining the hydro chamber average pressure based on the bladder circuit average pressure. This value is biased high with respect to increasing pressure and somewhat low at high leak rates (approximately 0.5 gpm). Considering the overall pressure swing in the hydro chamber this value is judged to be a reasonable correction factor.

8.6 For the circumferential tool, a value of 300 psi is a reasonable correction factor for determining the hydro chamber average pressure based on the bladder circuit average pressure. This value is applicable for testing both axial as well as circumferential indications. This correction factor is <u>tool</u>-specific, not <u>defect</u>-specific. The value of 300 psi biased high with respect to increasing pressure and slightly low at the normal operating ΔP. Considering the overall pressure swing in the hydro chamber this value is judged to be a reasonable correction factor.

9.0 Recommendations

9.1 Target pressures in the steam generator tube in-situ pressure test as listed in the operating procedure should include a correction factor for pressure gauge deviation from the calibration standard.

9.2 For static, non-leaking defects, the tube test pressure should be directly read from the hydro pump discharge pressure gauge +100, -0 psig.

9.3 For leaking defects using the axial tool, the target test pressure in the tube should be achieved by adding 400 psi to the target pressure and ensuring that the average of the bladder pressure swing matches this pressure within 100 psi.

9.4 For leaking defects using the circumferential /axial tool, the target test pressure in the tube should be achieved by adding 300 psi to the target pressure and ensuring that the average of the bladder pressure swing matches this pressure within 100 psi.

Figure 1
Test Apparatus Configuration

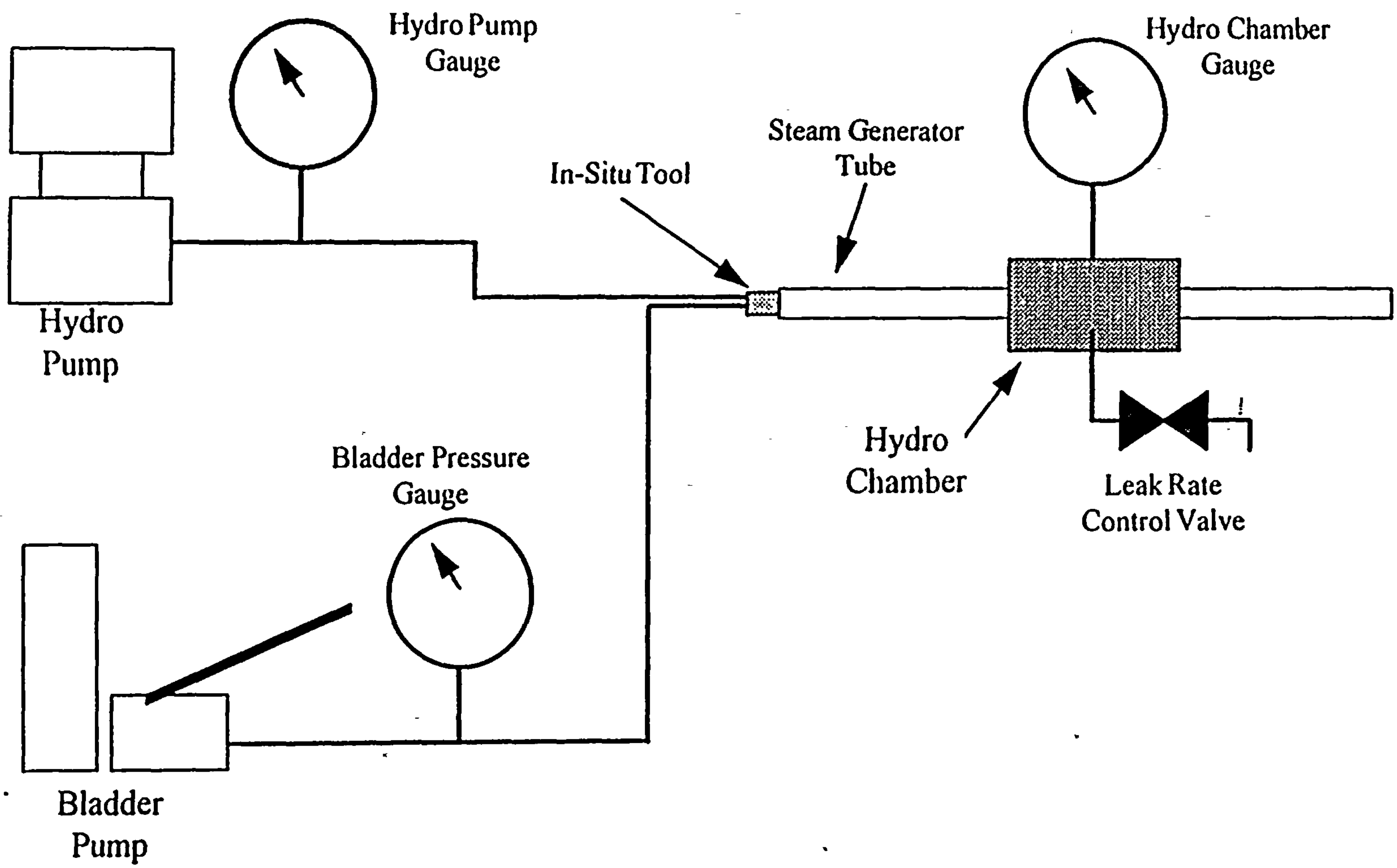

Table 2

Static Pressure Test
Axial Defect Tool

Initial Bladder Pressure - 1500 psig

Hydro Chamber Pressure (psig)	Hydro Pump Pressure(psig)	Bladder Pressure (psig)	Δ Chamber vs Bladder
0	0	1500	1500
1500	1500	1825	325
1600	1600	1875	275
1800	1800	2050	250
3000	3000	3200	200
4000	4050	4250	200
5000	5000	5200	200

Initial Bladder Pressure - 2000 psig

Hydro Chamber Pressure (psig)	Hydro Pump Pressure(psig)	Bladder Pressure (psig)	Δ Chamber vs Bladder
0	0	2000	2000
1500	1500	2150	650
1600	1600	2175	575
1800	1850	2275	425
3000	3050	3250	200
4000	4000	4250	250
5000	5000	5200	200

Table 3

Static Pressure Test
Circumferential/Axial Defect Tool

Initial Bladder Pressure - 1500 psig

Hydro Chamber Pressure (psig)	Hydro Pump Pressure(psig)	Bladder Pressure (psig)	Δ Chamber vs Bladder
0	0	1500	1500
1500	1500	1850	350
1600	1600	1900	300
1750	1800	2050	250
3000	3000	3150	150
4000	4000	4150	150
5000	5000	5150	150

Initial Bladder Pressure - 2000 psig

Hydro Chamber Pressure (psig)	Hydro Pump Pressure(psig)	Bladder Pressure (psig)	Δ Chamber vs Bladder
0	0	2000	2000
1500	1500	2300	800
1550	1600	2300	700
1750	1800	2350	550
2950	3000	3200	200
4000	4000	4200	200
5000	5000	5200	200

Table 4

Dynamic Pressure Test
Axial Defect Tool

Target Pressure 1650 psig

Pump Rate Strokes/min	Hydro Chamber (psi)			Bladder (psi)			Δ
	Max.	Min.	Avg.	Max.	Min.	Avg.	Avg.
5	1700	1600	1650	2050	1950	2000	350
18	1800	1450	1625	2150	1900	2025	400
32	2050	1450	1750	2350	1950	2150	400
53	2300	1400	1850	2500	1900	2200	350
91	2400	1100	1750	2650	1800	2225	475
							395

Target Pressure 2850 psig

Pump Rate Strokes/min	Hydro Chamber (psi)			Bladder (psi)			Δ
	Max.	Min.	Avg.	Max.	Min.	Avg.	Avg.
4	3000	2800	2900	3200	3000	3100	200
22	3150	2600	2875	3400	2900	3150	275
40	3300	2400	2850	3500	2800	3150	300
54	3350	2300	2825	3600	2700	3150	325
92	3800	2200	3000	4100	2800	3450	450
							310

Target Pressure 3950 psig

Pump Rate Strokes/min	Hydro Chamber (psi)			Bladder (psi)			Δ
	Max.	Min.	Avg.	Max.	Min.	Avg.	Avg.
3	4000	3850	3925	4200	4050	4125	200
18	4400	3900	4150	4550	4150	4350	200
38	4500	3500	4000	4600	3700	4150	150
56	4700	3500	4100	4900	3700	4300	200
80	4600	3100	3850	4800	3900	4350	500
							250

Table 5

Dynamic Pressure Test
Circumferential/Axial Defect Tool

Target Pressure 1750 psig

Pump Rate Strokes/min	Hydro Chamber (psi)			Bladder (psi)			Δ
	Max.	Min.	Avg.	Max.	Min.	Avg.	Avg.
3	1800	1700	1750	2100	2050	2075	325
15	1900	1550	1725	2150	1900	2025	300
30	2000	1400	1700	2250	1750	2000	300
60	2300	1200	1750	2450	1700	2075	325
90	2450	1300	1875	2700	1800	2250	375
							325

Target Pressure 3050 psig

Pump Rate Strokes/min	Hydro Chamber (psi)			Bladder (psi)			Δ
	Max.	Min.	Avg.	Max.	Min.	Avg.	Avg.
12	3250	2850	3050	3450	3150	3300	250
19	3350	2800	3075	3550	3000	3275	200
33	3500	2750	3125	3750	3000	3375	250
72	3600	2400	3000	3850	2600	3225	225
86	3800	2200	3000	4000	2500	3250	250
							235

Target Pressure 4300 psig

Pump Rate Strokes/min	Hydro Chamber (psi)			Bladder (psi)			Δ
	Max.	Min.	Avg.	Max.	Min.	Avg.	Avg.
5	4400	4250	4325	4600	4450	4525	200
20	4750	4100	4425	4950	4300	4625	200
42	4950	3800	4375	5100	4100	4600	225
59	4900	3600	4250	5100	3800	4450	200
84	5300	3500	4400	5500	3800	4650	250
							215