Enterprise Products

Final Report No. 10-063R5

Final Report

Line P41 Return to Service Hydrostatic Test Plan

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November 11, 2010

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Line P41 Return to Service Hydrostatic Test Plan

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INTRODUCTION

This report presents a hydrostatic test plan for the 164.76-mile P41 Watkins Glen-to-Selkirk Pipeline operated by Enterprise Products. This pipeline is comprised primarily of 8.625-inch OD, 0.203-inch wall, API Grade X42 low-frequency ERW line pipe manufactured by Bethlehem Steel. The test plan presented in this report is intended to demonstrate the immediate integrity of the pipeline for service and to maximize the time before a subsequent reassessment is necessary.

SUMMARY AND CONCLUSIONS

A review of the operational and hydrostatic testing history of P41 indicates that the pipeline has experienced a low number of pressure related failures. Field inspection reports for P41 indicate the presence of selective or preferential seam-weld corrosion associated with the ERW seam and longitudinally oriented stress corrosion cracking (SCC) near the seam. The test plan was developed to target a maximum stress level of 105% to 110% SMYS at relative low point elevations along the pipeline and minimum stress level of 90% to 99% SMYS at high point elevations. The test plan is a viable option for Enterprise to consider given current operational needs.

Table 1 summarizes the minimum time to failure for seam defects that enlarge by pressure-cycle-induced fatigue. Results are contingent upon successful completion of the test parameters outlined in this report. If the proposed test plan is successfully executed, the minimum recommended interval can be calculated; however, that interval will have to accommodate the integrity management requirements under Part 195 of the pipeline safety regulations.

The minimum time to failure outlined in Table 1 is not applicable to longitudinal SCC or preferential seam-weld corrosion. Such defects must be modeled using a different defect growth rate than what is used for fatigue. The fastest averaged crack growth rate for fatigue calculated for the pressure cycle service conditions in P-41 was slightly over 1 mil per year. Growth rates for SCC or preferential seam-weld corrosion can be several times faster. This suggests that, unlike some other liquid pipelines, fatigue is unlikely to take over and extend existing SCC or grooving corrosion at a faster rate. The fact that no prior test or service failures have ever occurred due to longitudinal SCC in the seam could be interpreted to indicate that the discovered occurrences represent either very recent, intermittent, or dormant longitudinal SCC conditions.

A retest interval for longitudinal SCC can be as short as 3 to 6 years for pipe exposed to a stress level of 90% to 110% SMYS during hydrostatic testing[1]. Further analysis of the confirmed longitudinal SCC and preferential seam-weld corrosion will be required before growth rates specific to P41 could be determined. The results of the 2010 hydrostatic test along with previous inspection results will be utilized in the development of these growth rates.

Table 1. Predicted Minimum Times to Failure for Longitudinal Fatigue Defects

Test Segment	Start Location	End Location	Minimum Time to Failure, years	Half the Time to Failure, years
1	0+00 (Watkins Glen)	277+00	38.6	19.32
2	277+00	841+30	70.9	35.43
3	841+30	1425+25	55.9	27.93
4	1425+25 (Landon Rd)	2248+75	59.7	29.85
5	2248+75 (Marathon)	4293+05	100.0	50.00
6	4293+05 (Gilbertsville)	5337+84	73.6	36.79
7	5337+84 (BV 81)	5947+07	100.0	50.00
8	5947+07 (BV 87)	6325+09	100.0	50.00
9	6325+09 (Jefferson)	7386+50	100.0	50.00
10	7386+50 (Oscar Williams)	8011+27	100.0	50.00
11	8011+27	8340+86	100.0	50.00
12	8340+86	8699+50 (Selkirk)	100.0	50.00

BACKGROUND

The P41 Watkins Glen-to-Selkirk Pipeline was constructed in 1963. The pipeline transports liquid propane from Watkins Glen, NY to Selkirk, NY just outside of Albany. The line primarily consists of 8.625-inch OD, 0.203-inch wall, API Grade X42 low-frequency ERW line pipe manufactured by Bethlehem Steel. Also installed at the time of original construction was 8.625-inch OD, 0.203-inch wall, API Grade X42 low-frequency ERW line pipe manufactured by Jones & Laughlin (J&L) and 8.625-inch OD, 0.375-inch wall, API Grade B low-frequency ERW line pipe manufactured by Bethlehem Steel. The line was last hydrostatically tested in 1990 to a range of 42% to 102% of the specified minimum yield strength (SMYS). The maximum

[1] Estimate based on a 4-inch long defect and 10-inch long defect in 8.625 inch OD, 0.203 inch wall, Grade X42 pipe with a growth rate of 12 mils per year. According to TTO-8 “Stress Corrosion Cracking Study” prepared by Michael Baker Jr., Inc., 12 mils per year is a “typical growth rate for a growing SCC defect”. Average SCC growth rates much slower than this have also been established based on extensive field investigations. Grooving rates for selective seam corrosion are probably in about the same range as SCC.

operating pressure of the pipeline ranges from 1,320 psig to 1,423 psig corresponding to a hoop stress range of 67% to 72% of SMYS for the 8.625-inch OD, 0.203-inch wall, X42 pipe (the limiting pipe for the system).

Four in-service failures have occurred since the line was commissioned in 1964 (see Table 2 below). On August 27, 2010 an in-service failure occurred at mile post 133.87. P41 is currently shutdown due to this recent failure located downstream of the Jefferson Valve in the Gilbertsville-to-Selkirk pumping segment. The failure was a circumferential break at a girth weld and the investigation into the root cause is ongoing.

Table 2. Summary of In-Service Failures

Pipe Segment	Date of Failure	Failure Location	Pressure at Failure Location, psig (%SMYS)	Cause
Watkins Glen to Marathon	2/12/1980	1618+65	1,235 (62%)	Selective Seam Weld Corrosion
Gilbertsville to Selkirk	3/19/1990	6776+00	1,682 (85%)	Circumferential Break – Brittle Fracture/Transverse SCC
Gilbertsville to Selkirk	1/25/2004	5947+03	588 (30%)	Frost Heave – Branch Fitting
Gilbertsville to Selkirk	8/27/2010	7068+67	279 (14%)	Circumferential Break – Investigation Pending

LINE DESCRIPTION

There are three active pump stations on P41: Watkins Glen, Marathon and Gilbertsville. Between Gilbertsville and Selkirk Terminal are three valve sites with pressure transmitters, Jefferson, Blenheim and Oscar Williams. Table 3 outlines these station and valve locations and their current maximum operating pressure (MOP). These locations were critical to the study for minimum hydrostatic testing requirements and reassessment interval calculations.

Table 3. Locations of Pump Stations and Control Valves

Location	Station	Mile Post	MOP, psig	Elevation, ft
Watkins Glen Station	0+00	0.00	1,372	1,262
Marathon Station	2248+75	42.59	1,423	1,395
Gilbertsville Station	4293+03	81.31	1,320	1,649
Jefferson Valve	6325+09	119.79	1,359	2,062
Blenheim Valve	6846+45	129.66	1,359	1,077
Oscar Williams Valve	7386+50	139.90	1,359	1,727
Selkirk Station	8699+50	164.76	1,359	164

ANALYSIS OF PRIOR HYDROSTATIC TESTS

P41 was originally tested prior to commissioning the pipeline in 1964. The line was tested in 34 segments during the months of June through September. Test pressures ranged from 70% to 104% SMYS. A total of three failures occurred during the construction hydrostatic test. The three failures were likely attributed to manufacturing type defects, two in the longitudinal seam-weld and one recorded as only a leak. A second hydrostatic test was performed on P41 in 1990 and results are outlined in Table 4. Two ruptures occurred during testing, one in the seam and one in the pipe body. Table 5 summarizes the hydrostatic test failures experienced on P41 to date. Note that the failures during the 1990 tests were at higher stress levels than the previous 1964 failures.

Table 4. Summary of 1990 Hydrostatic Test

Test Segment	Date of Test	Start Station	End Station	Miles	Minimum Deadweight Pressure, psig	Range of Test Stresses[2], % SMYS
1	4/12/1990	0+00	281+50	5.3	1,715	86-101
2	4/10/1990	281+50	841+30	10.6	1,977	83-101
3	4/9/1990	841+30	1426+00	11.1	1,786	87-102
4	4/9/1990	1426+00	2248+75	15.6	1,826	81-101
5	4/11/1990	2248+75	4296+34	38.7	1,791	84-101
6	4/7/1990	4296+34	5023+50	13.7	1,930	81-100
7	4/5/1990	5023+50	5811+70	15.0	1,962	82-100
8	4/3/1990	5811+70	6324+91	9.7	1,640	83-101
9	4/4/1990	6324+91	7388+50	20.1	1,763	86-101
10	4/2/1990	7388+50	8012+79	11.8	1,899	81-100
11	4/2/1990	8012+79	8698+80	13.0	1,689	84-100

[2] For 8.6265-inch OD, 0.203-inch wall, Grade X42 pipe.

Table 5. Summary of 1964 and 1990 Hydrostatic Test Failures

Test Segment	Date of Failure	Failure Location	Pressure at Failure Location, psig (%SMYS)	Manufacturer	Description
1	7/14/1964	27+80	1,557 (80%)	Jones & Laughlin	Leak
4	8/4/1964	513+55	1,609 (81%)	Bethlehem	Long Seam Rupture
15B	8/16/1964	3107+59	1,385 (70%)	Bethlehem	Long Seam Rupture
TS 5	4/8/1990	2898+72	1,798 (91%)	Bethlehem	Lamination Rupture
TS 6	4/4/1990	4961+03	1,818 (80%)	Bethlehem	Long Seam Rupture

HYDROSTATIC TEST PLAN

The hydrostatic test plan was developed with the objective of satisfying the 49 CFR 195 Subpart E test requirements and to maximize the re-inspection interval for seam integrity assessments. The plan recommends test pressure levels near or exceeding the last hydrostatic test performed in 1990. The proposed hydrostatic test will address integrity threats associated with longitudinally-oriented defects, including metal-loss, longitudinal seam-weld defects and mechanical damage. Also, a spike test is recommended to address the threat of any longitudinally-oriented defects susceptible to time dependant growth mechanisms (i.e. fatigue cracks, longitudinal SCC or preferential seam corrosion). The following spike test plan is proposed for consideration and has been written to be excerpted as a stand-alone Test Plan document.

Spike Test Plan

The spike test involves subjecting the pipe to a 30-minute test to a pressure level above the minimum level of 1.25 times MOP required by federal regulations. The spike test verifies the integrity of the pipeline at the level achieved even if a leak exists (assuming that the leak is located and repaired). The spike will be conducted prior to the Subpart E test. The latter is used to verify leak tightness. According to industry studies pressures above 100% SMYS are beneficial for the mitigation of longitudinally oriented SCC and pressures between 105% and 110% SMYS are considered optimal from the standpoint of test effectiveness without inducing additional damage to surviving defects.[i,ii, iii] Details for the spike test segmentation and target test pressures are provided in Table 6. Because the Start and End locations were determined utilizing alignment sheets and previous test records, slight variations to the Start and End locations may be necessary to accommodate actual field conditions. The stress levels range from 90% to 111% SMYS and are considerably higher than the pipeline has ever been subjected to. Testing to pressure levels higher than the pipe has previously been exposed to increases the potential for manufacturing related failures to occur during testing. To limit the amount of yielding, a pressure-volume plot will be made during testing, to ensure the slope of the pressure-volume plot does not decline to less than half the elastic slope.

For the purpose of this plan, a “rupture” means the breaking open or bursting of the pipe or pipeline component. A “leak” means the escape of product through a crack or flaw in the pipe or pipeline component.

The following are important considerations for the proposed spike test:

1. The final spike test pressure must be achieved and the pressure reduced gradually even if prior test failures (leaks or ruptures) have occurred during an attempt to achieve the spike test. The spike test will not be terminated with a test failure.
2. The proposed spike test will be achieved if a pressure level corresponding to 105% to 111% SMYS at the relative low point elevation is reached in each of the twelve proposed test segments. Also, the spike testing will achieve a minimum hydrostatic test pressure (HTP) to MOP ratio equal to 1.39.
3. For test segments greater than 24 miles in length (segments 5, 6, 9): See Table 6
    a. If the number of spike test failures approaches or exceeds 5 per test segment (the test segments are defined in Table 6) and the pressure of each successive failure is less than the previous (pressure reversals), a determination shall be made as to whether spike testing to the current proposed test pressure should be continued. If the number of spike test failures exceeds 5 successive pressure reversals per test segment, the determination to continue at that pressure must receive the approval of the Director, Eastern Region, PHMSA. The determination shall consider the properties of the failed pipe, failure pressures, and the failure mechanism(s). Any reductions made to the current proposed spike test pressures will result in a proportionate reduction in MOP such that the final successful spike test pressure provides a minimum spike test pressure-to-MOP ratio of 1.39.
    b. If there is no consistent pattern of pressure reversal and the number of spike test failures on a test segment approaches or exceeds 10, a determination shall be made as to whether spike testing to the current proposed test pressure should be continued. If the number of spike test failures exceeds 10 per test segment, the determination to continue at that pressure must receive the approval of the Director, Eastern Region, PHMSA. The determination shall consider the properties of the failed pipe, failure pressures, and the failure mechanism(s). Any reductions made to the current proposed spike test pressures will result in a proportionate reduction in MOP such that the final successful spike test pressure provides a minimum spike test pressure-to-MOP ratio of 1.39.

4. For test segments less than or equal to 24 miles in length (segments 1,2,3,4,7,8,10,11,12): See Table 6
   a. If the number of spike test failures approaches or exceeds 3 per test segment (the test segments are defined in Table 6) and the pressure of each successive failure is less than the previous (pressure reversals), a determination shall be made as to whether spike testing to the current proposed test pressure should be continued. If the number of spike test failures exceeds 3 successive pressure reversals per test segment, the determination to continue at that pressure must receive the approval of the Director, Eastern Region, PHMSA. The determination shall consider the properties of the failed pipe, failure pressures, and the failure mechanism(s). Any reductions made to the current proposed spike test pressures will result in a proportionate reduction in MOP such that the final successful spike test pressure provides a minimum spike test pressure-to-MOP ratio of 1.39.
   b. If there is no consistent pattern of pressure reversal and the number of spike test failures on a test segment approaches or exceeds 6, a determination shall be made as to whether spike testing to the current proposed test pressure should be continued. If the number of spike test failures exceeds 6 per test segment, the determination to continue at that pressure must receive the approval of the Director, Eastern Region, PHMSA. The determination shall consider the properties of the failed pipe, failure pressures, and the failure mechanism(s). Any reductions made to the current proposed spike test pressures will result in a proportionate reduction in MOP such that the final successful spike test pressure provides a minimum spike test pressure-to-MOP ratio of 1.39.
5. In the event that a spike test at the target level cannot be successfully completed, the implications of having to accept a lower test-pressure-to-operating-pressure ratio (in terms of a shorter retest interval) must be determined.
6. The final successful spike test pressure is used to calculate the retest interval. The higher the successful spike test pressure the longer the re-test interval.
7. All test ruptures will be examined in the field as soon as feasible in order to see if the rupture is associated with a seam defect. Should a non-seam failure occur an attempt will be made in the field to determine the cause. A non-seam failure might indicate the existence of mechanical damage or an unexpected degradation phenomenon. All seam ruptures will be examined both in the field, and subsequently in a metallurgical laboratory. It is important to preserve fracture surfaces from damage and degradation.
8. In the event of a hydrostatic test segment failure caused by something other than a pipe defect such as a hydrostatic test equipment leak, leaking valve packing, leaking flange gasket, etc. the cause of the failure shall be remediated and the hydrostatic test

immediately restarted. These failures will not be considered in pressure reversal calculations and will not be considered as meeting the criteria of 3(a), 3(b), 4(a) and 4(b) of the Spike Test Plan.

9. A Type B sleeve may be installed at Enterprise’s choice to repair a hydrostatic test segment failure caused by an internal or external corrosion leak in the pipe body, longitudinal seam preferential corrosion leak, leak associated with a dent, leak associated with a gouge, or a leak associated with cracking in the pipe body. If a Type B sleeve repair is utilized, the pipe area 3 feet upstream and downstream of the failed portion shall be non-destructively examined including, but not limited to, magnetic particle examination. All anomalies, including those in both high consequence areas and non-high consequence areas, that are: identified as cracking, or equal to or greater than 50-percent wall loss, or have a failure pressure ratio (FPR) of less than 1.39, or do not meet 49 C.F.R. § 195.452(h)(4)(i), (ii), and (iii) must be remediated and/or repaired. All Type B sleeves shall be installed in accordance with Enterprise’s Pipeline Defect Evaluation and Repair Procedure and Section 12.0 of the ES-40 General Piping Specifications.
10. Pipe replacement shall be utilized to repair a hydrostatic test segment failure caused by a leak or rupture associated with cracking or corrosion of a girth weld, internal or external corrosion rupture in the pipe body, rupture associated with a dent, rupture associated with a gouge, longitudinal seam preferential corrosion rupture, or a rupture associated with cracking in the pipe body. If pipe replacement is utilized, the area of tie-in points shall be non-destructively examined, including magnetic particle examination, for cracking 3 feet upstream and downstream of the "failed defect" area. The pipe replacement shall be extended such that it contains all anomalies, including those in both high consequence areas and non-high consequence areas, that are: identified as cracking, or equal to or greater than 50-percent wall loss, or have a failure pressure ratio (FPR) of less than 1.39, or do not meet 49 C.F.R. § 195.452(h)(4)(i), (ii), and (iii). All pipe replacements shall be implemented in accordance with Enterprise’s Pipeline Defect Evaluation and Repair Procedure and Section 12.0 of the ES-40 General Piping Specifications.
11. Replacement of the entire joint of pipe which contains the hydrostatic test failure shall be utilized to repair a hydrostatic test segment failure caused by a leak or rupture associated with a lamination or cracking in the longitudinal seam.
12. All hydrostatic test failure cut outs shall be sent to a metallurgical laboratory to determine the cause of the test failure. Fracture surfaces shall be protected from damage and degradation through the application of the attached Pipe Failure Inspection and Analysis guideline and shall be transferred to the metallurgical laboratory utilizing the attached Chain of Custody form.

Table 6. Summary of Spike Test Plan

Test Segment	Start Location	End Location	Target Spike Pressure at Start Location, psig	Min Spike Pressure in Test Segment, psig	Max Spike Pressure in Test Segment, psig	Range of Spike HTP/MOP	Range of Test Stresses[3], % SMYS
1	0+00 (Watkins Glen)	277+00	1,907	1,889	2,261	1.39 - 1.53	96 - 110
2	277+00	841+30	2,119	1,827	2,175	1.39 - 1.53	92 - 110
3	841+30	1425+25	1,985	1,870	2,302	1.39 - 1.54	96 - 111
4	1425+25 (Landon Rd)	2248+75	2,118	1,781	2,175	1.39 - 1.53	90 - 110
5	2248+75 (Marathon)	4293+05	1,981	1,830	2,166	1.39 - 1.52	93 - 109
6	4293+05 (Gilbertsville)	5337+84	1,891	1,780	2,155	1.39 - 1.51	90 - 108
7	5337+84 (BV 81)	5947+07	2,157	1,779	2,189	1.39 - 1.53	90 - 110
8	5947+07 (BV 87)	6325+09	1,973	1,944	2,077	1.45 – 1.47	98 - 105
9	6325+09 (Jefferson)	7386+50	1,959	1,879	2,519	1.39 - 1.52	95 - 110
10	7386+50 (Oscar Williams)	8011+27	1,773	1,771	2,151	1.39 - 1.58	90 - 109
11	8011+27	8340+86	1,878	1,833	2,138	1.39 - 1.50	93 - 108
12	8340+86	8699+50 (Selkirk)	2,148	1,960	2,300	1.39 - 1.53	99 - 110

Subpart E Test Plan

Target test pressures for the Subpart E Test Plan meet minimum requirements to certify MOP. The target pressures correspond to a maximum of 90% of the proposed spike test pressures, which permits a minimum spike test pressure-to-MOP ratio of 1.39. Stress levels range from 79% to 100% SMYS for the 0.203-inch wall, X42 pipe. In the event of a Subpart E Test Plan hydrostatic test failure, the repair plan described in the Spike Test Plan section above shall be applied. Details for the test plan are provided in Table 7. Because the Start and End locations were determined utilizing alignment sheets and previous test records, slight variations to the Start and End locations may be necessary to accommodate actual field conditions.

[3] For 8.6265-inch OD, 0.203-inch wall, Grade X42 pipe manufactured by Bethlehem Steel.

Table 7. Summary of Subpart E Test Plan

Test Segment	Start Location	End Location	Target Pressure at Start Location, psig	Min Pressure in Test Segment, psig	Max Pressure in Test Segment, psig	Range of HTP/MOP	Range of Test Stresses[4], % SMYS
1	0+00 (Watkins Glen)	277+00	1,716	1,699	2,070	1.25 - 1.40	86 - 100
2	277+00	841+30	1,907	1,615	1,963	1.25 - 1.38	82 - 100
3	841+30	1425+25	1,786	1,672	2,104	1.25 - 1.40	86 - 100
4	1425+25 (Landon Rd)	2248+75	1,906	1,569	1,963	1.25 - 1.38	79 - 99
5	2248+75 (Marathon)	4293+05	1,783	1,632	1,967	1.25 - 1.38	83 - 99
6	4293+05 (Gilbertsville)	5337+84	1,702	1,591	1,965	1.25 - 1.37	80 - 99
7	5337+84 (BV 81)	5947+07	1,941	1,564	1,973	1.25 - 1.38	79 - 100
8	5947+07 (BV 87)	6325+09	1,685	1,656	1,790	1.25 - 1.26	84 - 91
9	6325+09 (Jefferson)	7386+50	1,763	1,683	2,323	1.25 - 1.39	85 - 100
10	7386+50 (Oscar Williams)	8011+27	1,595	1,594	1,974	1.25 - 1.42	81 - 100
11	8011+27	8340+86	1,690	1,645	1,950	1.25 - 1.37	83 - 99
12	8340+86	8699+50 (Selkirk)	1,934	1,745	2,085	1.25 - 1.38	88 - 99

Figure 1 through Figure 3 are plots of the achieved 1990 hydrostatic test pressures compared to the 2010 proposed spike test and Subpart E test. Included are previous hydrostatic failures plotted by location and failure pressure. The Watkins Glen-to-Marathon portion of P41 is broken up into 4 test segments and has not experienced a failure since the original construction hydrostatic test. The Marathon-to-Gilbertsville portion experienced one test failure in 1964 and one in 1990. The Gilbertsville-to-Selkirk portion is broken up into 7 test segments (TS 6 through 12). Only one seam related failure has occurred in this portion from the 1990 test. All test segments will target pressures exceeding the 1990 test during the spike portion of the planned test. The longer duration portion of the test plan (Subpart E) for stress and leak testing is similar to the 1990 test plan. However in order to achieve a minimum spike test pressure-to-MOP ratio

[4] For 8.6265-inch OD, 0.203-inch wall, Grade X42 pipe manufactured by Bethlehem Steel.

of 1.39 and not over pressure the pipeline, the proposed test plan has an additional test segment (1990 TS 11 split into TS 11 and TS 12).

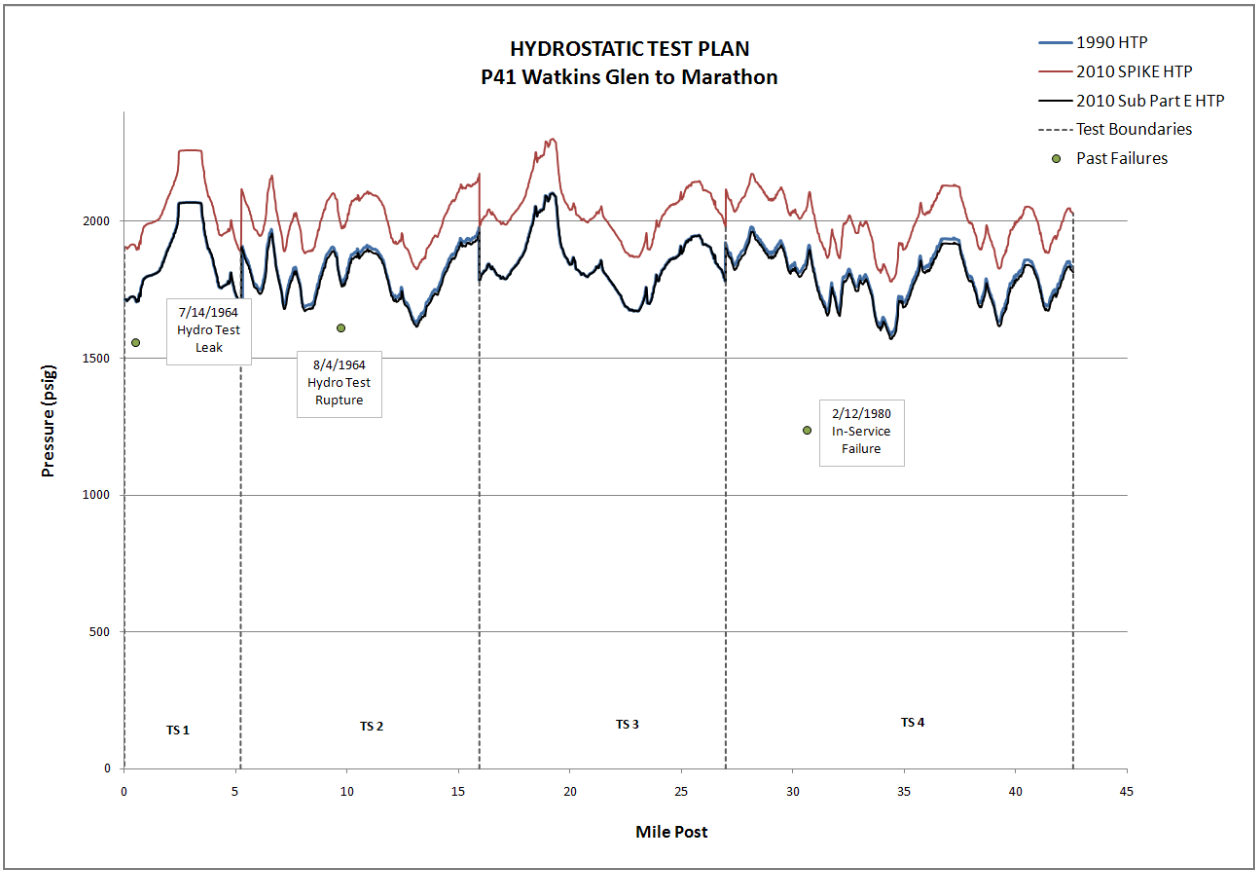


Figure 1. Hydrostatic Test Plan for Watkins Glen-to-Marathon (Test Segments 1 - 4)

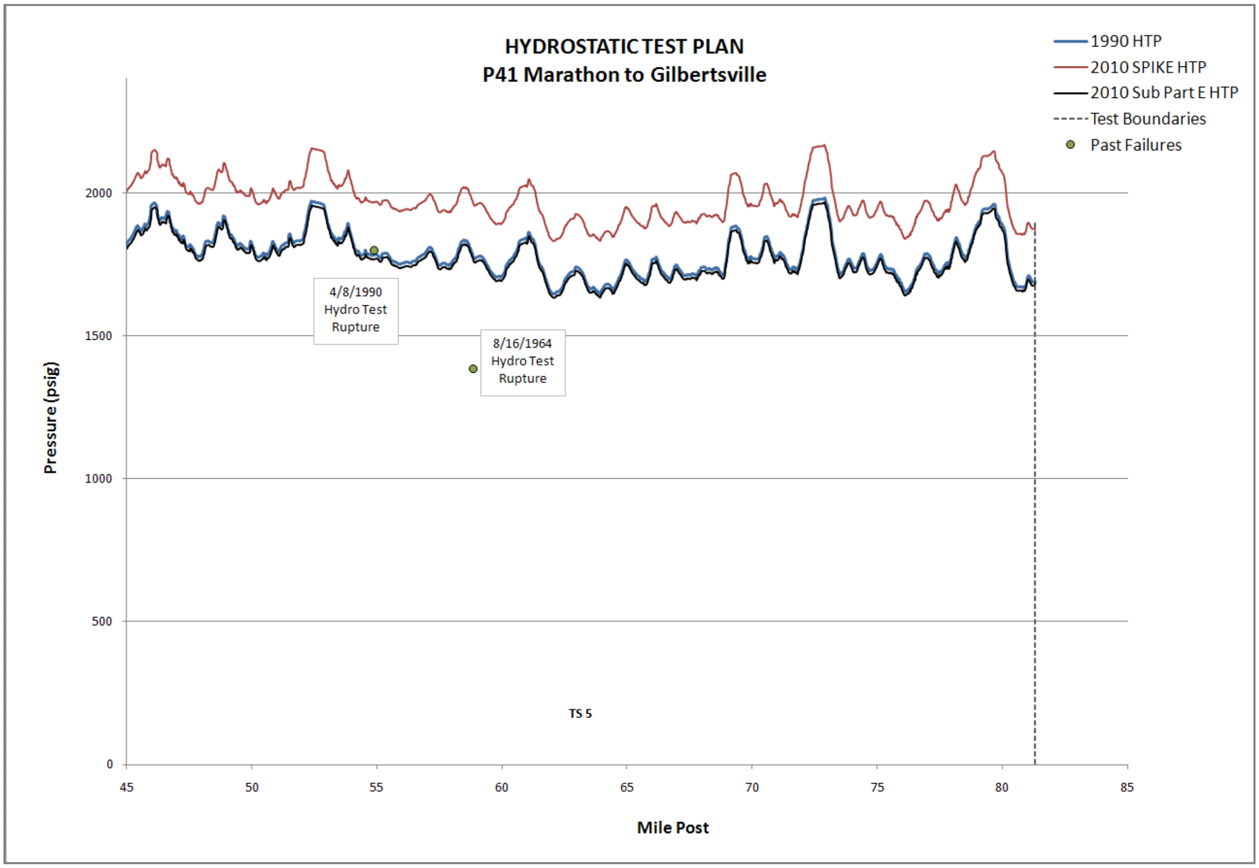


Figure 2. Hydrostatic Test Plan for Marathon-to-Gilbertsville (Test Segment 5)

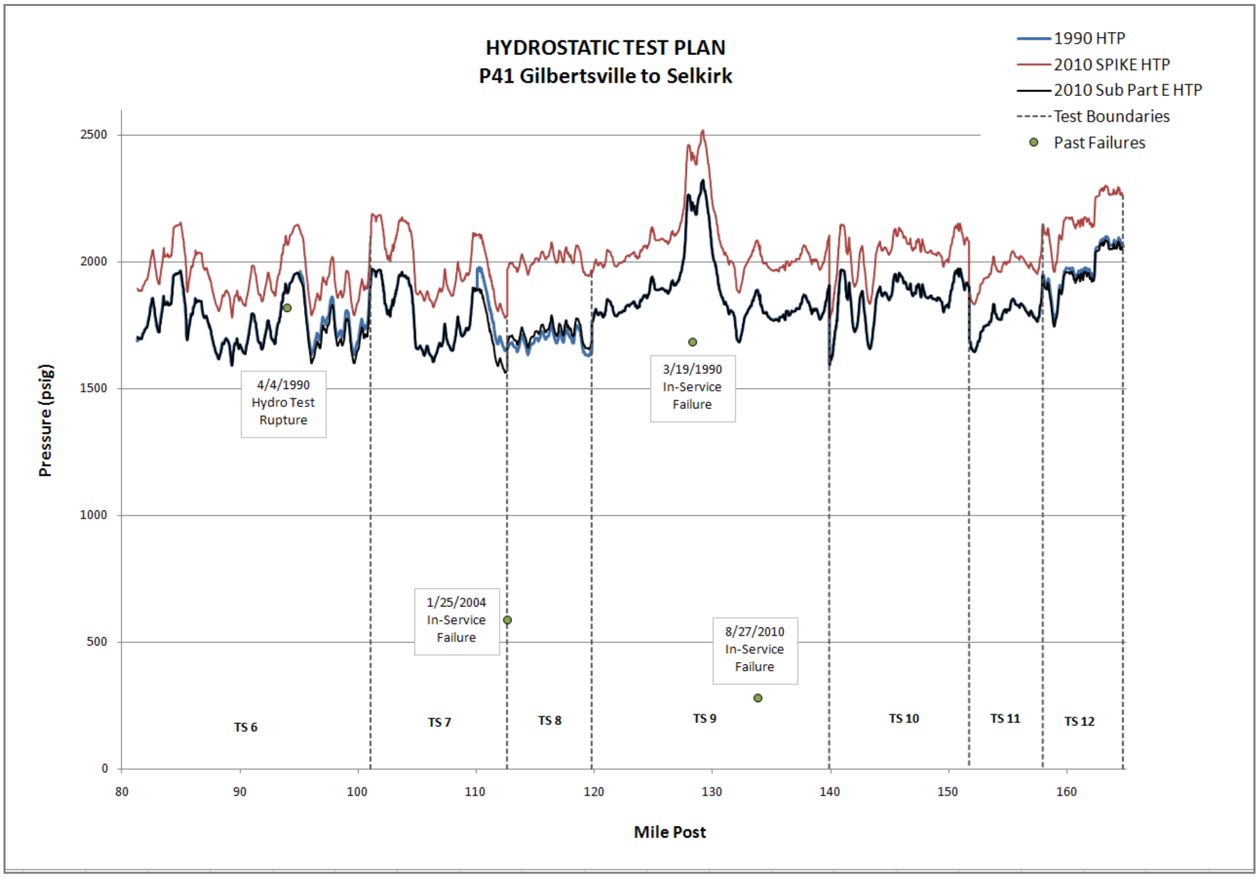


Figure 3. Hydrostatic Test Plan for Gilbertsville-to-Selkirk (Test Segments 6 - 12)

Figure 4 demonstrates the certified MOP for P41 upon successful completion of the proposed hydrostatic test plan. The subpart E test plan will achieve a HTP/MOP range of 1.25 to 1.42.

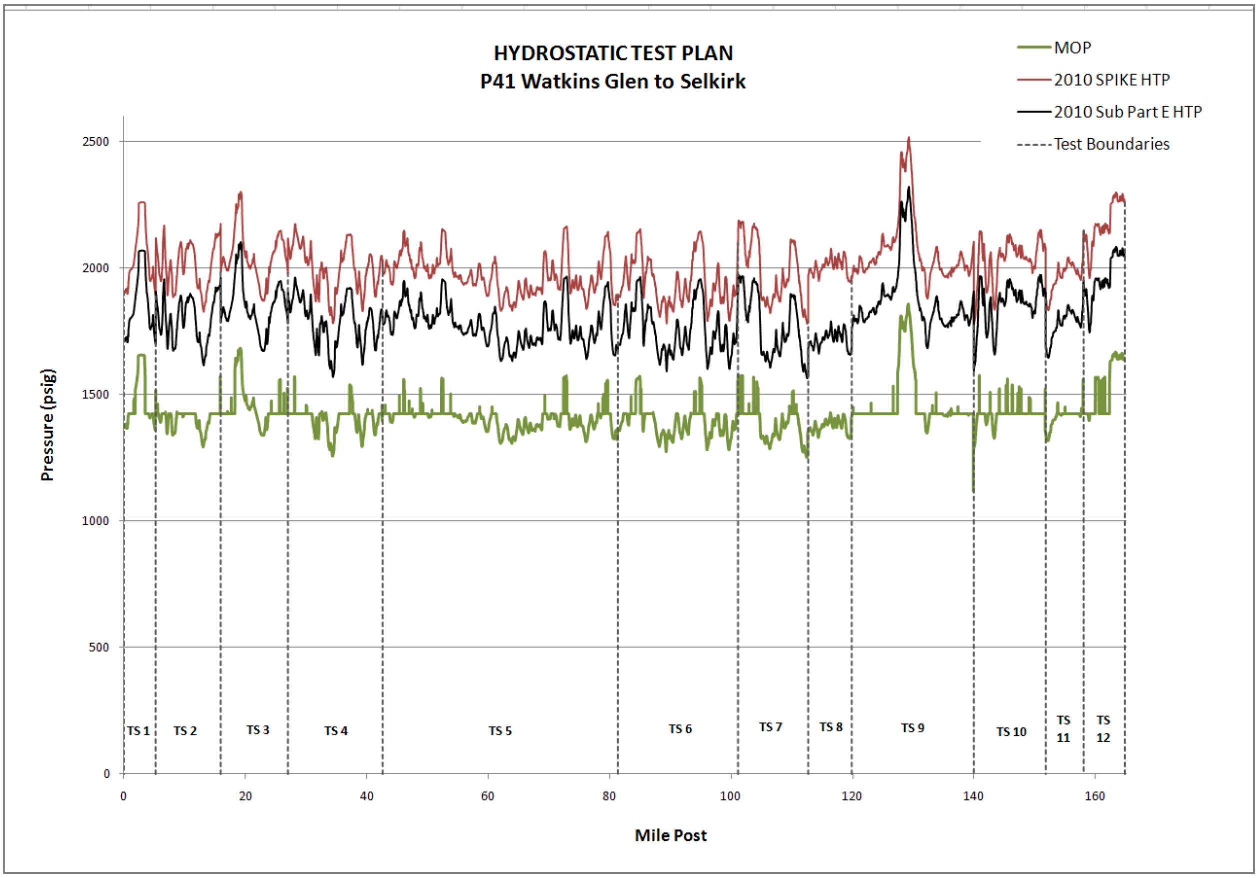


Figure 4. MOP based on Successful Execution of Hydrostatic Test Plan

RE-ASSESSMENT OF LONG SEAM-WELD INTEGRITY

The following analyses were carried out to establish prudent times for re-assessment of the seam integrity of the P41 based on the proposed test plan outlined in the previous section of this report.

Hydrostatic testing to a level in excess of the MOP provides a positive verification of the ability of a pipeline to be operated safely at the MOP. The margin of safety is embodied in the ratio of test pressure to operating pressure. The higher the ratio, the larger will be the margin of safety. The margin of safety will be eroded with the passage of time if defects that survive the test can become larger in service. The most common mode of seam defect enlargement for many liquid pipelines is pressure-cycle-induced fatigue. The analysis presented herein is based on the assumption that pressure-cycle-induced fatigue is the sole means of enlargement and the results should only be considered valid for the mitigation of seam defects that primarily exhibit this mode of growth (like hook cracks). It should be noted that no direct evidence of fatigue having caused a seam failure in the P41 pipeline exists. Occurrences of preferential seam-weld corrosion and longitudinal SCC near the seam have been confirmed. Further analysis is required for the development of a prudent retest interval for axial SCC and preferential seam-weld corrosion.

A process for determining re-inspection intervals for seam defects that may become enlarged by pressure-cycle-induced fatigue is described in TTO-5[iv]. The process consists of using the hydrostatic test pressure to establish the sizes of defects that might have barely survived the test, the MOP to establish the sizes of defects that can be expected to fail at the MOP, and repeatedly applying the actual pressure cycle spectrum characteristic of the operation of the pipeline via a Paris-law fatigue-crack-growth analysis until the worst-case, just-surviving defect becomes large enough to fail at the MOP. Since the number of times the actual pressure spectrum is applied corresponds to actual time in years of operation, the time to failure can be established. Re-assessment is required before the time to failure is reached and it has become a wide-spread practice to schedule re-assessment when half the time to failure has expired.

Analysis Locations

To establish the minimum time to failure after a hydrostatic test for each segment of the pipeline on which a hydrostatic test is conducted, it is necessary to perform the analysis at only a few critical locations having specific characteristics. The critical locations are characterized by combinations of minimum test-pressure-to-operating-pressure ratio and maximum-range service pressure cycles. Within the region between any two pump stations, the critical locations will typically lie closer to the discharge of the upstream station because the maximum pressure decreases with the distance downstream from the discharge. Usually an analysis is conducted for the location of the discharge itself where the largest pressure range is to be expected. Other locations are chosen based on the locations of high elevations near the pump station discharge where the pressure range will still be large, but the test-pressure-to-operating-pressure ratio may be significantly less than that at the discharge. In some cases for this pipeline the elevation change is so drastic that low point elevations were considered as well because the operating pressures were higher than at discharge locations. The low-frequency ERW 0.203-inch wall, X42 pipe and the low-frequency ERW 0.375-inch wall, Grade B pipe were the primary focus of this analysis. The characteristics of the analysis locations are given in Table 8.

Table 8. Analysis Locations

TS	Station	WT, inch	Elevation, ft	Pressure Cycles	Reason for Selection
1	0+00	0.375	1261.5	Watkins Glen Discharge	Near Discharge
1	6+61	0.203	1275.6	Watkins Glen Discharge	Near Discharge
2	691+00	0.203	1982.6	Intermediate - Watkins Glen & Marathon	High Point
3	1207+00	0.375	1442.3	Intermediate - Watkins Glen & Marathon	High Point
4	1817+00	0.203	1967.5	Intermediate - Watkins Glen & Marathon	High Point
4	1988+00	0.375	1316.3	Intermediate - Watkins Glen & Marathon	High Point
5	2251+92	0.375	1404.2	Marathon Discharge	Near Discharge
5	2255+51	0.203	1404.9	Marathon Discharge	Near Discharge
5	2963+84	0.375	1489.2	Marathon Discharge	High Point
6	4300+02	0.375	1663.4	Gilbertsville Discharge	Near Discharge
6	4716+02	0.203	1905.5	Gilbertsville Discharge	High Point
7	5609+00	0.375	1897.3	Intermediate - Gilbertsville & Jefferson	High Point
7	5947+00	0.203	2025.6	Intermediate - Gilbertsville & Jefferson	High Point
8	6311+00	0.203	2092.5	Intermediate - Gilbertsville & Jefferson	High Point
9	6326+00	0.375	2064.0	Jefferson	High Point
9	6983+00	0.203	2246.7	Blenheim	High Point
10	7387+00	0.203	1730.3	Preston Hollows	High Point
10	7883+00	0.375	1141.4	Intermediate - Preston Hollows & Selkirk	High Point
11	8118+16	0.375	713.3	Intermediate - Preston Hollows & Selkirk	High Point
12	8391+00	0.203	854.0	Intermediate - Preston Hollows & Selkirk	High Point
12	8510+91	0.375	426.5	Intermediate - Preston Hollows & Selkirk	High Point
12	8527+11	0.375	355.3	Intermediate - Preston Hollows & Selkirk	New Grade X42

Pressure Data

The pressure data used in this analysis were recorded at Watkins Glen Pump Station, Marathon Pump Station, Gilbertsville Pump Station, Jefferson, Blenheim, Preston Hollows and Selkirk Terminal. A year of data from September 2009 through August 2010 was recorded at 15-minute intervals. Pressure cycles for intermediate points between pump stations or valve locations were determined by matching simultaneous pressures at each source and calculating the instantaneous pressure by assuming a linear gradient between locations. The actual gradient for propane is slightly non-linear, but the difference this makes is believed to be negligible. The pressure data are assumed representative of ongoing operation. If the magnitude or frequency of the pressure cycles change, then the results of the analysis will be affected. Plots of the pressure data are provided in Appendix A.

Material Toughness

The toughness of the pipe material determines the sizes of cracks that can survive a given level of hydrostatic test pressure and the sizes of cracks that will cause the pipe to fail at the MOP. The initial flaw sizes established by the test pressure and the toughness have a significant effect on fatigue life whereas the final crack sizes established by the MOP and the toughness do not. Crack growth per pressure cycle is a function of both pressure-cycle magnitude and crack size. A small starting size, therefore, results in an initially slow growing crack, and a large starting size results in an initially more rapid growing crack. By the same rationale, when the crack is near failure, the steps of growth per cycle become so large that the level of maximum pressure is not that important. That is, the failure pressure will be reached within a few cycles even if the actual maximum level is well below the MOP.

A toughness of 25 ft-lb was used in this analysis. This value is considered representative of the ERW pipe including the portion of the seam that is capable of supporting stable crack growth by fatigue. A value as high as 40 ft-lb would be at the technologically achievable limit for the time of manufacture, and it would not result in a significantly shorter predicted fatigue life because 25 ft-lb is close to the level needed to assure the largest possible starting crack size for this size of pipe.

Crack-Growth Rate

The crack-growth rate is used to calculate the effects of each pressure cycle on a flaw using the Paris Law[v] equation which is given as:

$$\frac{da}{dN} = C(\Delta K)^n$$

where

da/dN	=	Increment of crack growth for a given cycle, $in/cycle$
C	=	Material parameter, *units vary depending on "units of ΔK" value*
n	=	Material parameter, *no units*
ΔK	=	Change in stress intensity factor, $psi \cdot \sqrt{in}$.

The exact crack-growth rate applicable to the P41 Pipeline is unknown. Therefore, we have used the rate recommended by API Recommended Practice 579 for use in ferritic and austenitic steels in air or other non-aggressive service environments.[vi] For the fatigue model we used a crack-growth rate value for "C" of 8.6E-19 (for ΔK in $psi\sqrt{in}$ units) and a value for "n" of 3.0 in the Paris equation.

It is noted that the API 579 crack-growth rate is 2.4 times faster than the upper-bound of published data for ferritic-pearlitic steel, which in turn is 1.5 times faster than average crack-growth rates for such materials.[vii] Effects such as retardation were also ignored. Hence the analysis incorporates many conservative factors.

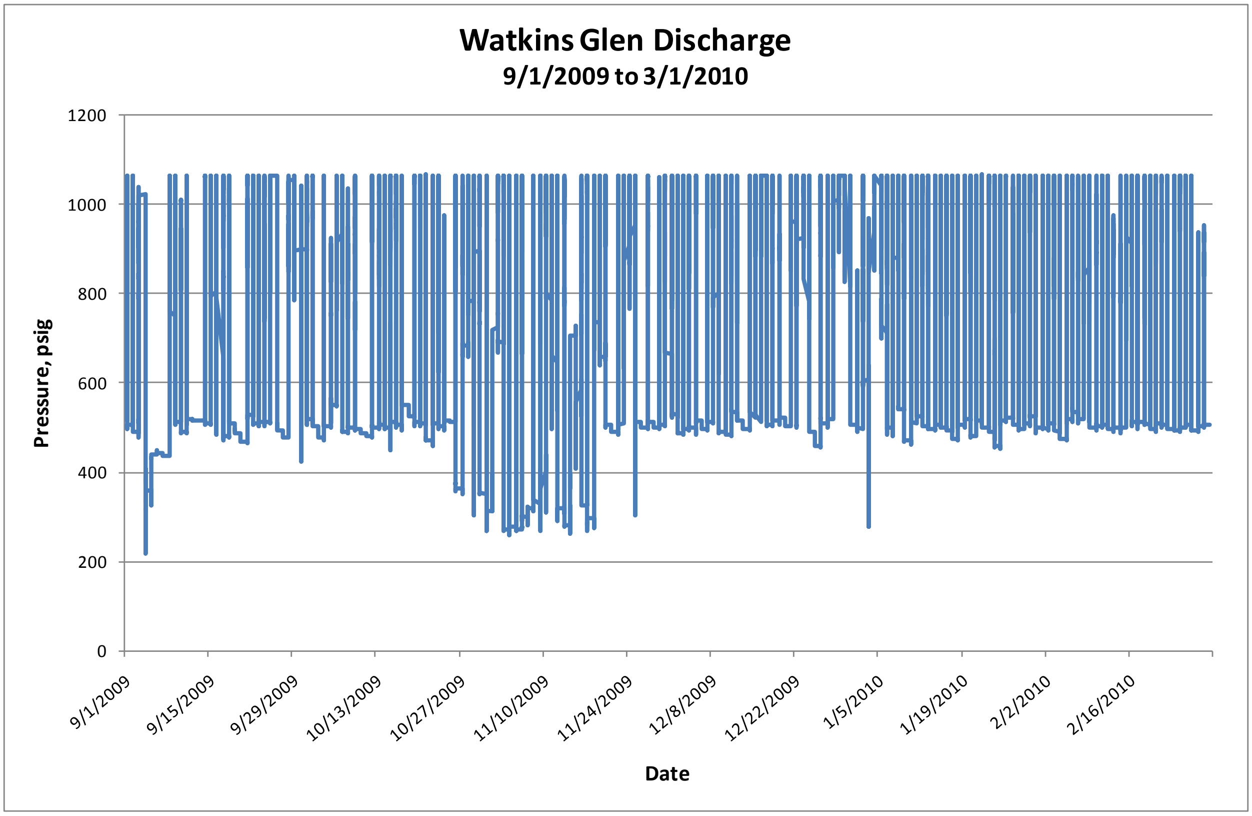
Fatigue Life Calculation

The times to failure given in this analysis were calculated using our PIPELIFE software. This program uses operational pressure-cycle data to evaluate the remaining lives of flaws that are affected by pressure-cycle-induced fatigue. The methodology used by the PIPELIFE program is described by Kiefner, et al.[viii] A summary of the PIPELIFE results for each case conducted is given in Appendix B. Appendix C explains the sections of the results page. The minimum time to failure for each analysis location are summarized in Table 9.

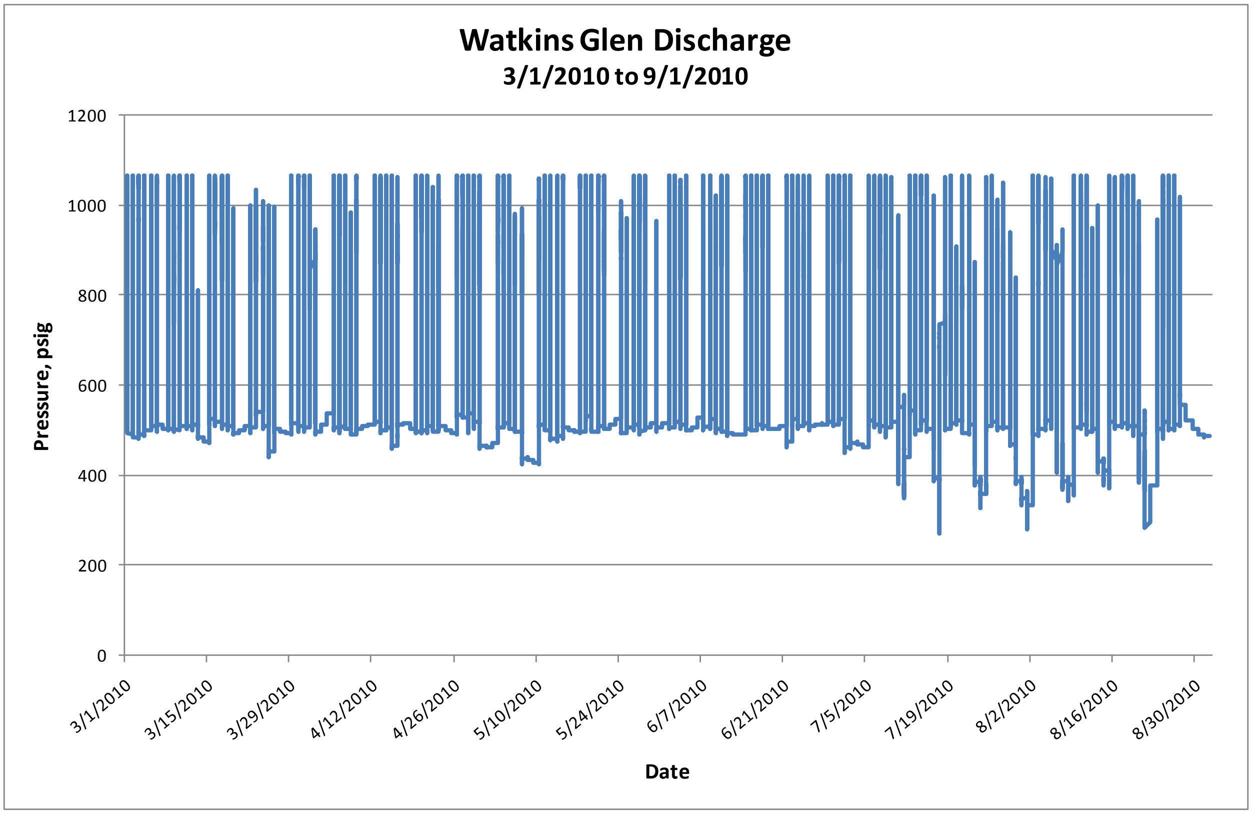
Table 9. Estimated Times to Failure

TS	Station	HTP, psig	HTP, % SMYS	Minimum Time to Failure, years	Half the Time to Failure, years
1	0+00	1,907	63%	38.6	19.32
1	6+61	1,904	96%	51.1	25.53
2	691+00	1,827	92%	70.9	35.43
3	1207+00	1,870	61%	55.9	27.93
4	1817+00	1,781	90%	59.7	29.85
4	1988+00	2,062	68%	96.3	48.17
5	2251+92	1,975	95%	100.0	50.00
5	2255+51	1,977	100%	100.0	50.00
5	2963+84	1,941	64%	100.0	50.00
6	4300+02	1,885	62%	73.6	36.79
6	4716+02	1,780	90%	73.9	36.97
7	5609+00	1,843	61%	100.0	50.00
7	5947+00	1,973	100%	100.0	50.00
8	6311+00	1,944	98%	100.0	50.00
9	6326+00	1,958	64%	100.0	50.00
9	6983+00	1,879	95%	100.0	50.00
10	7387+00	1,771	90%	100.0	50.00
10	7883+00	2,026	67%	100.0	50.00
11	8118+16	2,011	66%	100.0	50.00
12	8391+00	1,960	99%	100.0	50.00
12	8510+91	2,160	71%	100.0	50.00
12	8527+11	2,176	60%	100.0	50.00

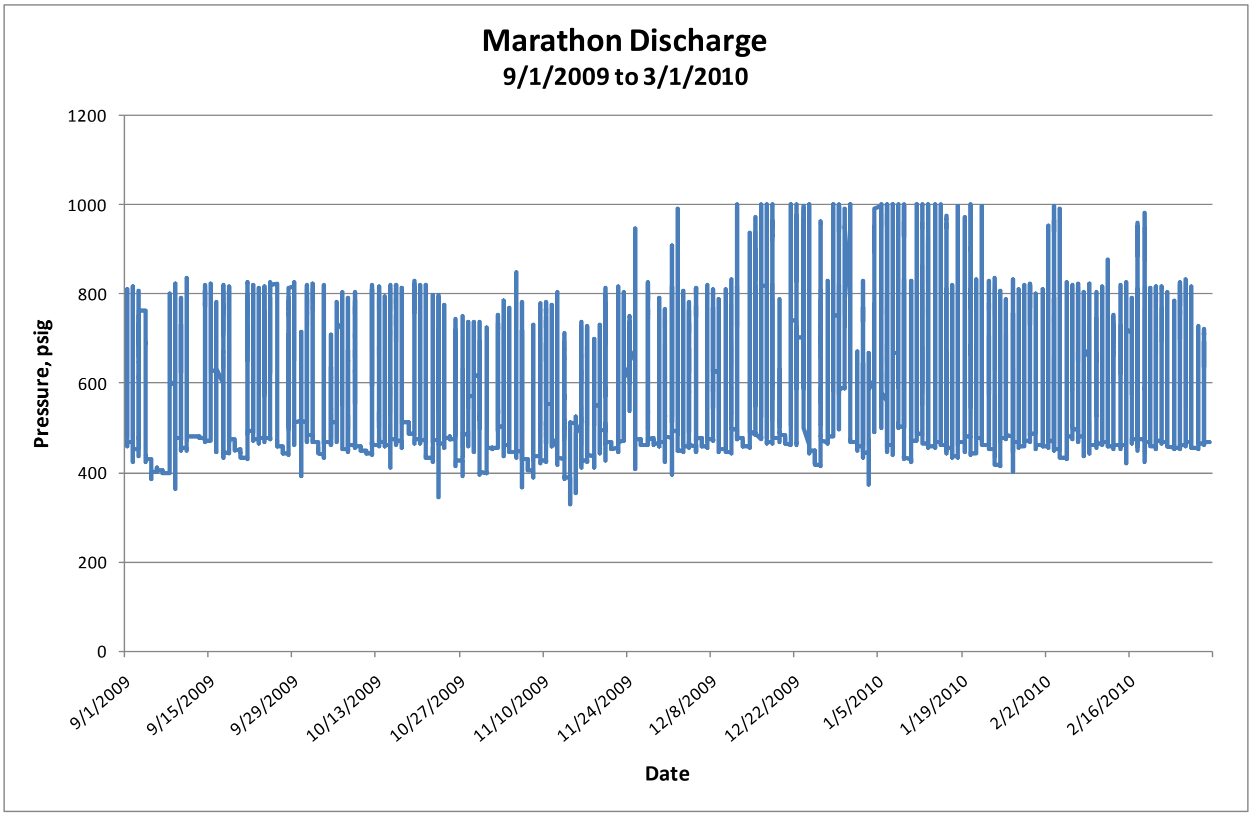
APPENDIX A – PRESSURE SPECTRA USED IN ANALYSIS

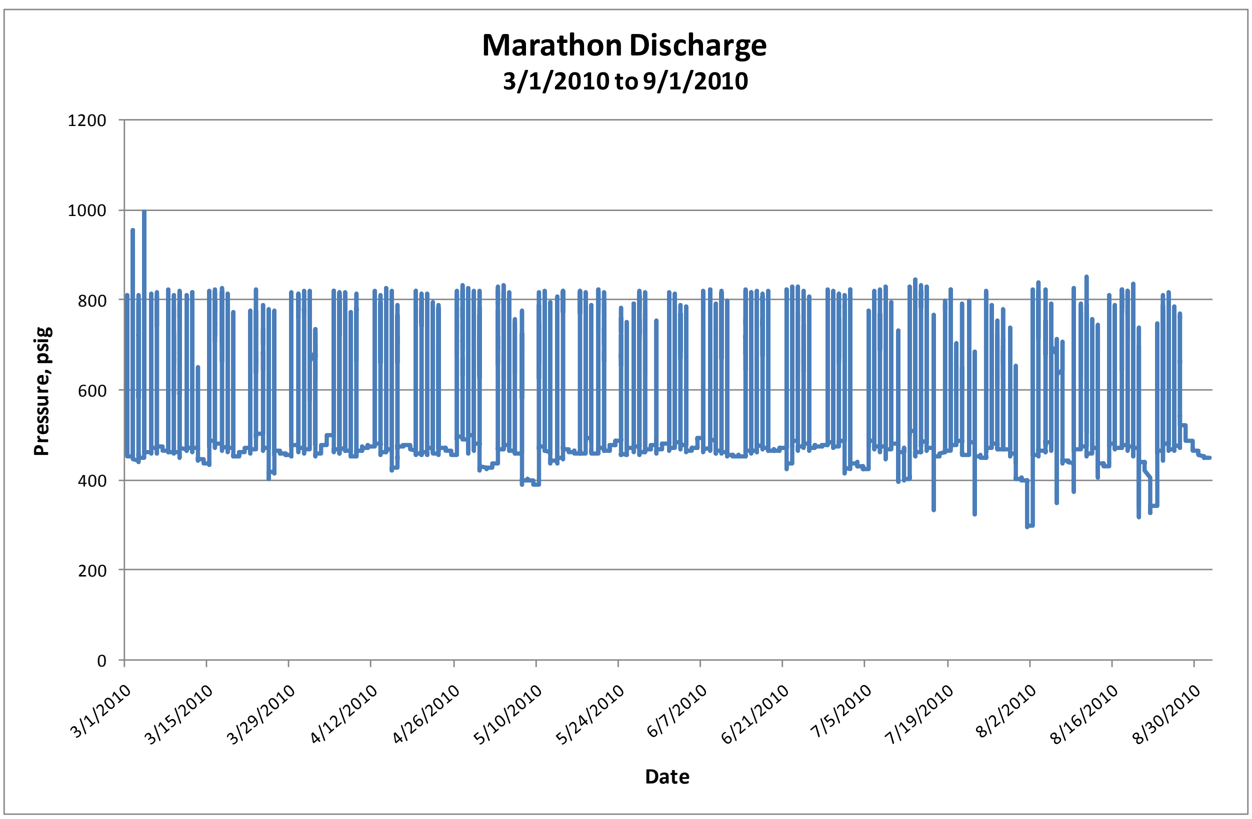


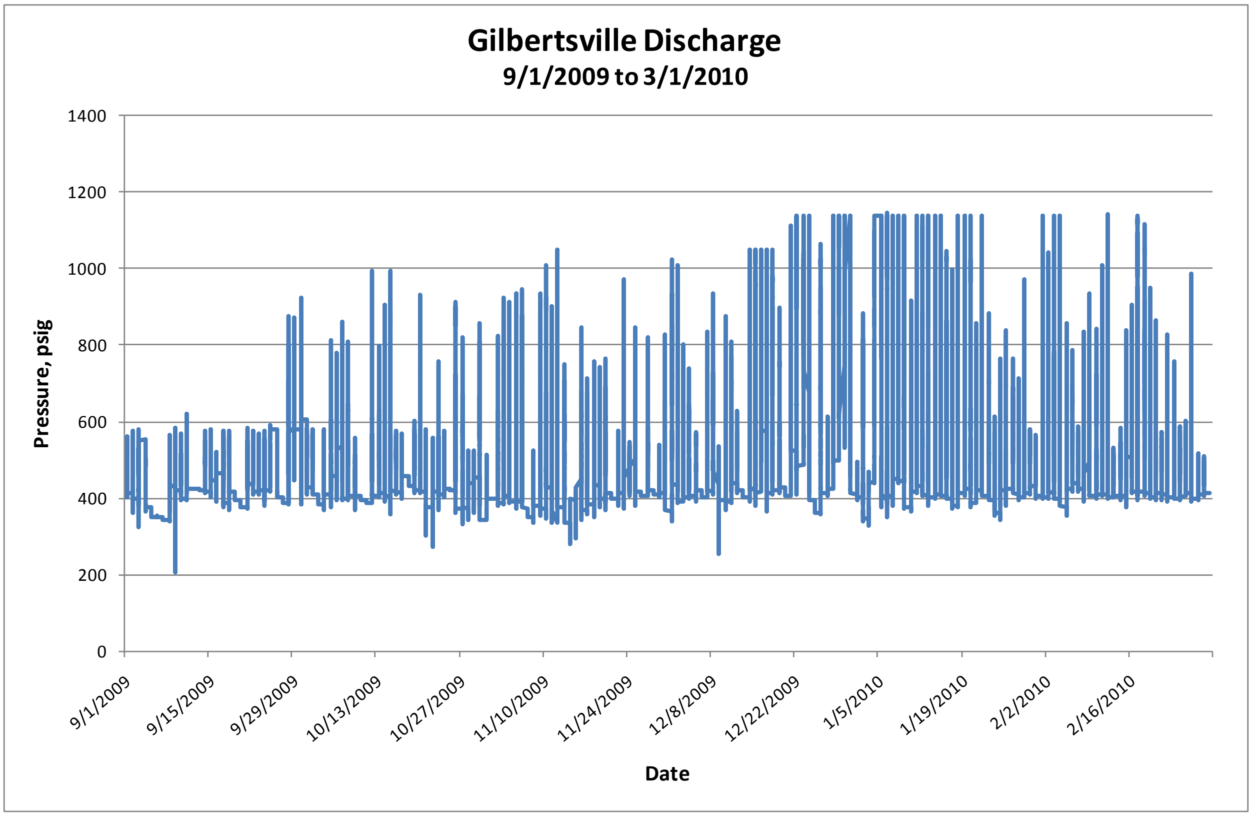
Watkins Glen Discharge
9/1/2009 to 3/1/2010
Pressure, psig
1200
1000
800
600
400
200
0
9/1/2009
9/15/2009
9/29/2009
10/13/2009
10/27/2009
11/10/2009
11/24/2009
12/8/2009
12/22/2009
1/5/2010
1/19/2010
2/2/2010
2/16/2010
Date

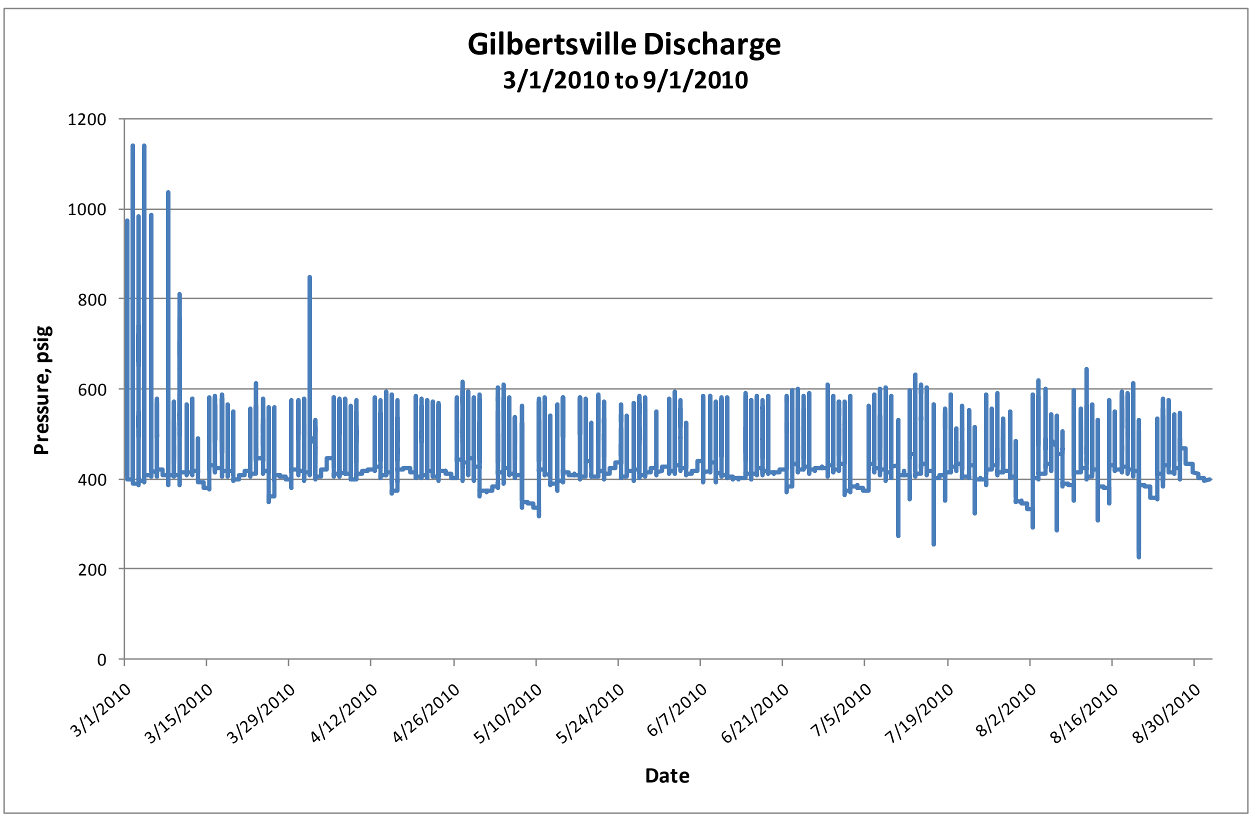


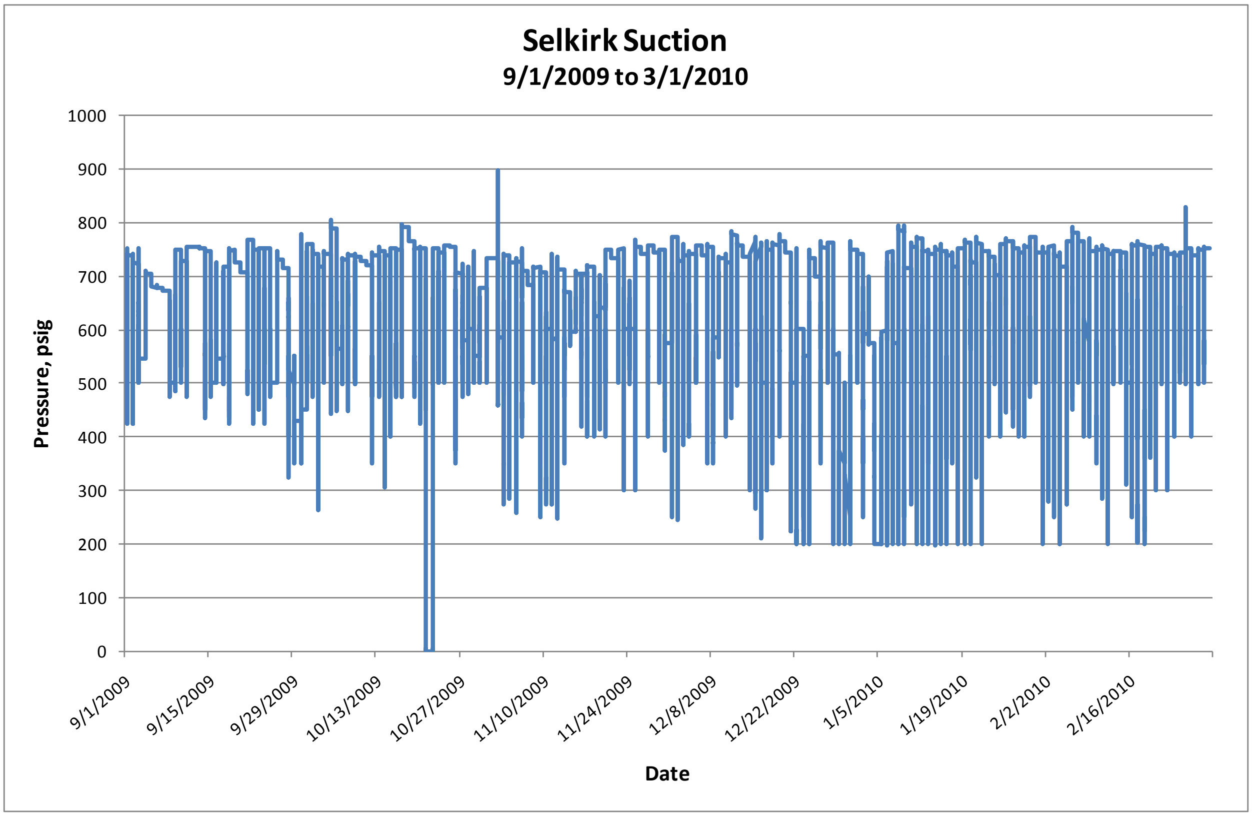
Watkins Glen Discharge
3/1/2010 to 9/1/2010
Pressure, psig
1200
1000
800
600
400
200
0
3/1/2010
3/15/2010
3/29/2010
4/12/2010
4/26/2010
5/10/2010
5/24/2010
6/7/2010
6/21/2010
7/5/2010
7/19/2010
8/2/2010
8/16/2010
8/30/2010
Date

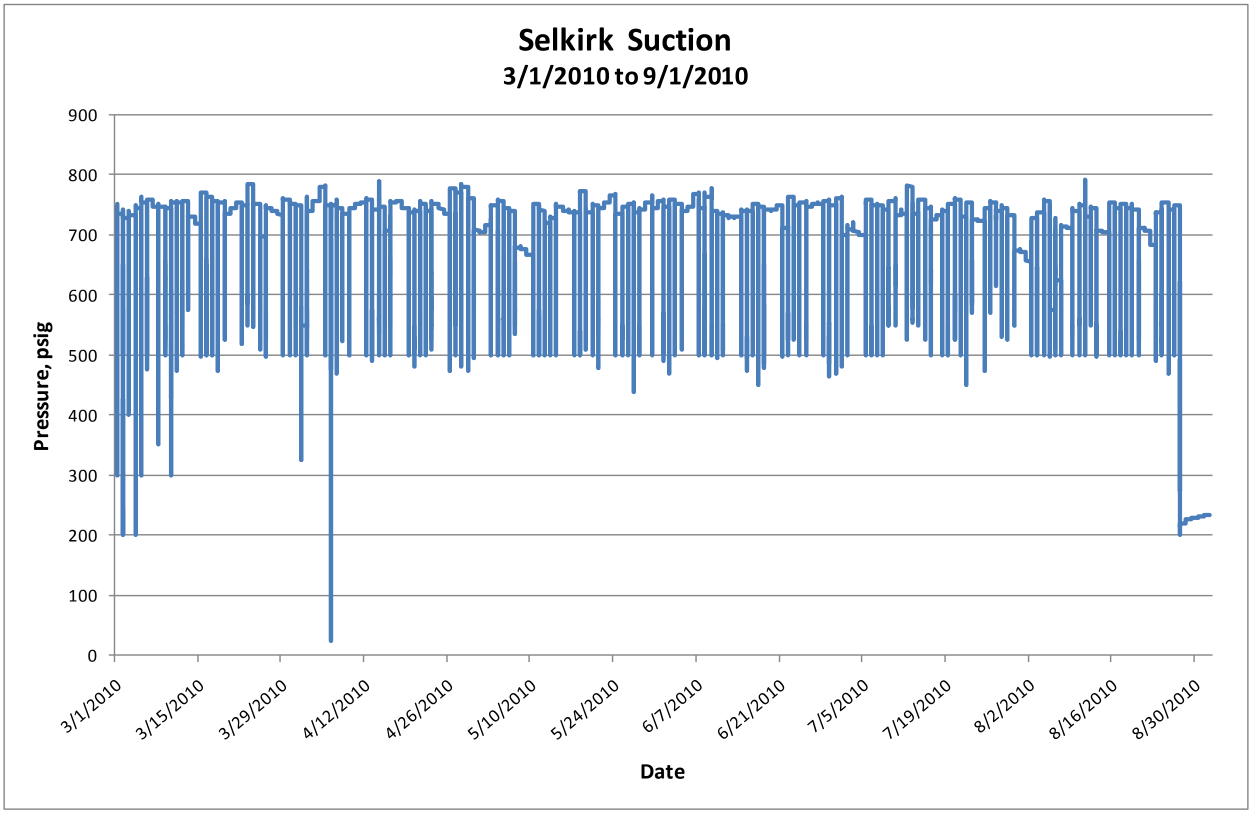

Marathon Discharge
9/1/2009 to 3/1/2010
Pressure, psig
0
200
400
600
800
1000
1200
9/1/2009
9/15/2009
9/29/2009
10/13/2009
10/27/2009
11/10/2009
11/24/2009
12/8/2009
12/22/2009
1/5/2010
1/19/2010
2/2/2010
2/16/2010
Date


Marathon Discharge
3/1/2010 to 9/1/2010
Pressure, psig
0
200
400
600
800
1000
1200
3/1/2010
3/15/2010
3/29/2010
4/12/2010
4/26/2010
5/10/2010
5/24/2010
6/7/2010
6/21/2010
7/5/2010
7/19/2010
8/2/2010
8/16/2010
8/30/2010
Date


Gilbertsville Discharge
9/1/2009 to 3/1/2010
Pressure, psig
0
200
400
600
800
1000
1200
1400
9/1/2009
9/15/2009
9/29/2009
10/13/2009
10/27/2009
11/10/2009
11/24/2009
12/8/2009
12/22/2009
1/5/2010
1/19/2010
2/2/2010
2/16/2010
Date


Gilbertsville Discharge
3/1/2010 to 9/1/2010
Pressure, psig
0
200
400
600
800
1000
1200
3/1/2010
3/15/2010
3/29/2010
4/12/2010
4/26/2010
5/10/2010
5/24/2010
6/7/2010
6/21/2010
7/5/2010
7/19/2010
8/2/2010
8/16/2010
8/30/2010
Date


Selkirk Suction
9/1/2009 to 3/1/2010
Pressure, psig
0
100
200
300
400
500
600
700
800
900
1000
9/1/2009
9/15/2009
9/29/2009
10/13/2009
10/27/2009
11/10/2009
11/24/2009
12/8/2009
12/22/2009
1/5/2010
1/19/2010
2/2/2010
2/16/2010
Date


Selkirk Suction
3/1/2010 to 9/1/2010
Pressure, psig
0
100
200
300
400
500
600
700
800
900
3/1/2010
3/15/2010
3/29/2010
4/12/2010
4/26/2010
5/10/2010
5/24/2010
6/7/2010
6/21/2010
7/5/2010
7/19/2010
8/2/2010
8/16/2010
8/30/2010
Date

APPENDIX B – PIPELIFE CASE RESULTS

Analysis Performed by Kiefner & Associates, Inc.
Software by Kiefner & Associates, Inc.
PipeLife 3 - Excel 2007

File Copy (Formulas and graphs are not linked)

Program Run Date and Time 9/25/10 9:41

Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 1 - Sta 0+00
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.375

Section 3. Material

Material	Grade B
Yield Stress	35,000
Flow Stress	45,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,372 psig
Hydrostatic Test Pressure	1,907 psig
Max. Press. in Original Spectrum	1,068 psig
Min. Press. in Original Spectrum	218 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	1094
# of Days Cycles Occurred	365 Days
Number of Cycles	1090
Conversion Factor (Cycles/Year)	1,090.7

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	19.32 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.3375	0.7700	109,075	100.0	95.4%	0.3579	0.7883	1,104	901
80.0%	0.3000	1.3350	93,708	85.9	90.9%	0.3409	1.3480	1,065	1,065
70.0%	0.2625	2.2250	71,805	65.8	85.5%	0.3207	2.2318	1,065	1,065
60.0%	0.2250	4.5450	42,145	38.6	79.3%	0.2975	4.5472	1,065	1,065
50.0%	0.1875	10.5400	49,340	45.2	72.9%	0.2735	10.5406	1,065	1,065
40.0%	0.1500	25.8750	109,075	100.0	56.3%	0.2109	25.8751	1,302	901
30.0%	0.1125	25.8750	109,075	100.0	32.6%	0.1222	25.8750	2,237	901
20.0%	0.0750	25.8750	109,075	100.0	20.8%	0.0779	25.8750	2,777	901
10.0%	0.0375	25.8750	109,075	100.0	10.2%	0.0383	25.8750	3,309	901

Analysis Performed by Kiefner & Associates, Inc.
Software by Kiefner & Associates, Inc.
PipeLife 3 - Excel 2007

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Program Run Date and Time 9/25/10 9:51

Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 1 - Sta 6+61
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.203

Section 3. Material

Material	X42
Yield Stress	42,000
Flow Stress	52,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,372 psig
Hydrostatic Test Pressure	1,904 psig
Max. Press. in Original Spectrum	1,068 psig
Min. Press. in Original Spectrum	218 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	1094
# of Days Cycles Occurred	365 Days
Number of Cycles	1090
Conversion Factor (Cycles/Year)	1,090.7

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	25.53 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.1827	0.2750	67,579	62.0	97.2%	0.1973	0.2996	1,066	1,068
80.0%	0.1624	0.4300	57,005	52.3	94.2%	0.1913	0.4510	1,065	1,065
70.0%	0.1421	0.5850	55,691	51.1	91.0%	0.1846	0.6011	1,065	1,065
60.0%	0.1218	0.7750	57,921	53.1	86.9%	0.1765	0.7859	1,065	1,065
50.0%	0.1015	1.0500	62,781	57.6	81.8%	0.1660	1.0564	1,065	1,065
40.0%	0.0812	1.5400	75,935	69.6	75.2%	0.1526	1.5430	1,065	1,065
30.0%	0.0609	2.9300	109,075	100.0	53.2%	0.1079	2.9304	1,400	901
20.0%	0.0406	7.8850	109,075	100.0	24.2%	0.0491	7.8850	1,800	901
10.0%	0.0203	25.8750	109,075	100.0	11.0%	0.0223	25.8750	2,028	901

Analysis Performed by Kiefner & Associates, Inc.
Software by Kiefner & Associates, Inc.
PipeLife 3 - Excel 2007

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Program Run Date and Time 9/25/10 10:03
Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 2 - Sta 691+00
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.203

Section 3. Material

Material	X42
Yield Stress	42,000
Flow Stress	52,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,372 psig
Hydrostatic Test Pressure	1,827 psig
Max. Press. in Original Spectrum	852 psig
Min. Press. in Original Spectrum	120 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	1056
# of Days Cycles Occurred	365 Days
Number of Cycles	1050
Conversion Factor (Cycles/Year)	1,050.7

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	35.43 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.1827	0.3050	84,984	80.9	97.7%	0.1983	0.3279	849	851
80.0%	0.1624	0.4700	76,584	72.9	95.3%	0.1935	0.4902	851	851
70.0%	0.1421	0.6500	74,447	70.9	92.6%	0.1879	0.6652	847	848
60.0%	0.1218	0.8750	76,385	72.7	89.2%	0.1810	0.8853	844	845
50.0%	0.1015	1.2200	79,734	75.9	84.6%	0.1718	1.2259	849	851
40.0%	0.0812	1.9150	94,397	89.8	78.8%	0.1599	1.9176	846	848
30.0%	0.0609	4.0500	105,072	100.0	40.3%	0.0817	4.0501	1,605	587
20.0%	0.0406	11.8750	105,072	100.0	22.6%	0.0458	11.8750	1,756	587
10.0%	0.0203	25.8750	105,072	100.0	10.6%	0.0216	25.8750	2,039	587

Analysis Performed by Kiefner & Associates, Inc.
Software by Kiefner & Associates, Inc.
PipeLife 3 - Excel 2007

File Copy (Formulas and graphs are not linked)

Program Run Date and Time 9/25/10 10:08

Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 3 - Sta 1207+00
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.375

Section 3. Material

Material	Grade B
Yield Stress	35,000
Flow Stress	45,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,372 psig
Hydrostatic Test Pressure	1,870 psig
Max. Press. in Original Spectrum	1,108 psig
Min. Press. in Original Spectrum	398 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	1023
# of Days Cycles Occurred	365 Days
Number of Cycles	1017
Conversion Factor (Cycles/Year)	1,017.7

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	27.93 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.3375	0.7900	101,770	100.0	93.4%	0.3504	0.8006	1,406	1,097
80.0%	0.3000	1.3750	101,770	100.0	87.8%	0.3292	1.3834	1,311	1,097
70.0%	0.2625	2.3300	97,631	95.9	84.4%	0.3163	2.3357	1,108	1,108
60.0%	0.2250	4.9350	56,851	55.9	78.0%	0.2925	4.9368	1,099	1,102
50.0%	0.1875	11.3500	72,886	71.6	71.2%	0.2672	11.3505	1,099	1,100
40.0%	0.1500	25.8750	101,770	100.0	46.0%	0.1723	25.8750	1,686	1,097
30.0%	0.1125	25.8750	101,770	100.0	31.5%	0.1181	25.8750	2,286	1,097
20.0%	0.0750	25.8750	101,770	100.0	20.5%	0.0768	25.8750	2,791	1,097
10.0%	0.0375	25.8750	101,770	100.0	10.1%	0.0380	25.8750	3,313	1,097

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Program Run Date and Time 9/25/10 10:11

Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 4 - Sta 1817+00
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.203

Section 3. Material

Material	X42
Yield Stress	42,000
Flow Stress	52,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,372 psig
Hydrostatic Test Pressure	1,781 psig
Max. Press. in Original Spectrum	1,108 psig
Min. Press. in Original Spectrum	398 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	1023
# of Days Cycles Occurred	365 Days
Number of Cycles	1017
Conversion Factor (Cycles/Year)	1,017.7

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	29.85 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.1827	0.3200	68,901	67.7	96.3%	0.1955	0.3373	1,100	1,100
80.0%	0.1624	0.5000	60,919	59.9	92.5%	0.1878	0.5144	1,099	1,102
70.0%	0.1421	0.6900	60,765	59.7	88.2%	0.1790	0.7004	1,099	1,100
60.0%	0.1218	0.9400	62,036	61.0	82.8%	0.1681	0.9464	1,106	1,108
50.0%	0.1015	1.3350	66,518	65.4	76.6%	0.1555	1.3384	1,098	1,100
40.0%	0.0812	2.2050	83,056	81.6	68.7%	0.1394	2.2062	1,098	1,100
30.0%	0.0609	4.8850	101,770	100.0	39.3%	0.0797	4.8851	1,576	1,097
20.0%	0.0406	16.2000	101,770	100.0	22.3%	0.0453	16.2000	1,713	1,097
10.0%	0.0203	25.8750	101,770	100.0	10.6%	0.0215	25.8750	2,041	1,097

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Program Run Date and Time 9/25/10 10:15

Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 4 - Sta 1988+00
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.375

Section 3. Material

Material	Grade B
Yield Stress	35,000
Flow Stress	45,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,372 psig
Hydrostatic Test Pressure	2,062 psig
Max. Press. in Original Spectrum	1,108 psig
Min. Press. in Original Spectrum	398 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	1023
# of Days Cycles Occurred	365 Days
Number of Cycles	1017
Conversion Factor (Cycles/Year)	1,017.7

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	48.17 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.3375	0.7000	101,770	100.0	92.8%	0.3479	0.7101	1,690	1,097
80.0%	0.3000	1.1800	101,770	100.0	86.2%	0.3231	1.1881	1,623	1,097
70.0%	0.2625	1.8700	101,770	100.0	79.9%	0.2998	1.8751	1,540	1,097
60.0%	0.2250	3.3400	101,770	100.0	78.6%	0.2949	3.3434	1,222	1,097
50.0%	0.1875	7.6100	98,045	96.3	74.9%	0.2808	7.6110	1,098	1,100
40.0%	0.1500	16.9950	101,770	100.0	45.5%	0.1706	16.9950	1,850	1,097
30.0%	0.1125	25.8750	101,770	100.0	31.5%	0.1181	25.8750	2,286	1,097
20.0%	0.0750	25.8750	101,770	100.0	20.5%	0.0768	25.8750	2,791	1,097
10.0%	0.0375	25.8750	101,770	100.0	10.1%	0.0380	25.8750	3,313	1,097

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Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 5 - Sta 2251+92
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.375

Section 3. Material

Material	Grade B
Yield Stress	35,000
Flow Stress	45,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,423 psig
Hydrostatic Test Pressure	1,975 psig
Max. Press. in Original Spectrum	1,001 psig
Min. Press. in Original Spectrum	296 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	1001
# of Days Cycles Occurred	365 Days
Number of Cycles	994
Conversion Factor (Cycles/Year)	994.7

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	50.00 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.3375	0.7400	99,469	100.0	91.9%	0.3445	0.7459	1,734	827
80.0%	0.3000	1.2650	99,469	100.0	84.0%	0.3148	1.2694	1,704	827
70.0%	0.2625	2.0550	99,469	100.0	76.3%	0.2863	2.0576	1,657	827
60.0%	0.2250	3.9400	99,469	100.0	71.4%	0.2679	3.9414	1,486	827
50.0%	0.1875	9.1850	99,469	100.0	59.8%	0.2243	9.1852	1,612	827
40.0%	0.1500	21.7150	99,469	100.0	42.9%	0.1609	21.7150	1,859	827
30.0%	0.1125	25.8750	99,469	100.0	30.9%	0.1157	25.8750	2,313	827
20.0%	0.0750	25.8750	99,469	100.0	20.3%	0.0761	25.8750	2,800	827
10.0%	0.0375	25.8750	99,469	100.0	10.1%	0.0378	25.8750	3,315	827

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Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 5 - Sta 2255+51
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.203

Section 3. Material

Material	X42
Yield Stress	42,000
Flow Stress	52,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,423 psig
Hydrostatic Test Pressure	1,977 psig
Max. Press. in Original Spectrum	1,001 psig
Min. Press. in Original Spectrum	296 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	1001
# of Days Cycles Occurred	365 Days
Number of Cycles	994
Conversion Factor (Cycles/Year)	994.7

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	50.00 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.1827	0.2500	99,469	100.0	93.3%	0.1893	0.2620	1,746	827
80.0%	0.1624	0.3850	99,469	100.0	87.6%	0.1777	0.3968	1,696	827
70.0%	0.1421	0.5250	99,469	100.0	81.2%	0.1648	0.5335	1,679	827
60.0%	0.1218	0.6850	99,469	100.0	72.6%	0.1473	0.6897	1,718	827
50.0%	0.1015	0.9100	99,469	100.0	61.3%	0.1245	0.9119	1,773	827
40.0%	0.0812	1.2750	99,469	100.0	47.6%	0.0965	1.2755	1,849	827
30.0%	0.0609	2.1650	99,469	100.0	33.5%	0.0680	2.1651	1,912	827
20.0%	0.0406	5.4700	99,469	100.0	21.2%	0.0431	5.4700	1,949	827
10.0%	0.0203	25.8750	99,469	100.0	10.3%	0.0210	25.8750	2,050	827

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Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 5 - Sta 2963+84
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.375

Section 3. Material

Material	Grade B
Yield Stress	35,000
Flow Stress	45,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,423 psig
Hydrostatic Test Pressure	1,941 psig
Max. Press. in Original Spectrum	1,001 psig
Min. Press. in Original Spectrum	296 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	1001
# of Days Cycles Occurred	365 Days
Number of Cycles	994
Conversion Factor (Cycles/Year)	994.7

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	50.00 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.3375	0.7550	99,469	100.0	91.9%	0.3448	0.7609	1,694	827
80.0%	0.3000	1.2950	99,469	100.0	84.1%	0.3154	1.2995	1,666	827
70.0%	0.2625	2.1350	99,469	100.0	76.8%	0.2879	2.1377	1,603	827
60.0%	0.2250	4.2250	99,469	100.0	73.2%	0.2745	4.2265	1,376	827
50.0%	0.1875	9.8450	99,469	100.0	60.5%	0.2268	9.8452	1,556	827
40.0%	0.1500	24.3250	99,469	100.0	42.9%	0.1610	24.3250	1,822	827
30.0%	0.1125	25.8750	99,469	100.0	30.9%	0.1157	25.8750	2,313	827
20.0%	0.0750	25.8750	99,469	100.0	20.3%	0.0761	25.8750	2,800	827
10.0%	0.0375	25.8750	99,469	100.0	10.1%	0.0378	25.8750	3,315	827

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Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 6 - Sta 4300+02
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.375

Section 3. Material

Material	Grade B
Yield Stress	35,000
Flow Stress	45,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,320 psig
Hydrostatic Test Pressure	1,885 psig
Max. Press. in Original Spectrum	1,146 psig
Min. Press. in Original Spectrum	209 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	1103
# of Days Cycles Occurred	365 Days
Number of Cycles	1098
Conversion Factor (Cycles/Year)	1,098.8

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	36.79 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.3375	0.7800	109,876	100.0	92.7%	0.3475	0.7882	1,540	711
80.0%	0.3000	1.3550	109,876	100.0	85.9%	0.3221	1.3613	1,478	711
70.0%	0.2625	2.2850	109,876	100.0	80.7%	0.3027	2.2891	1,334	711
60.0%	0.2250	4.7700	80,840	73.6	77.4%	0.2902	4.7718	1,139	1,139
50.0%	0.1875	11.0150	101,489	92.4	70.4%	0.2642	11.0154	1,140	1,140
40.0%	0.1500	25.8750	109,876	100.0	44.3%	0.1659	25.8750	1,753	711
30.0%	0.1125	25.8750	109,876	100.0	31.1%	0.1168	25.8750	2,300	711
20.0%	0.0750	25.8750	109,876	100.0	20.4%	0.0764	25.8750	2,796	711
10.0%	0.0375	25.8750	109,876	100.0	10.1%	0.0379	25.8750	3,314	711

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Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 6 - Sta 4716+02 Spike Test P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.203

Section 3. Material

Material	X42
Yield Stress	42,000
Flow Stress	52,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,320 psig
Hydrostatic Test Pressure	1,780 psig
Max. Press. in Original Spectrum	1,146 psig
Min. Press. in Original Spectrum	209 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	1103
# of Days Cycles Occurred	365 Days
Number of Cycles	1098
Conversion Factor (Cycles/Year)	1,098.8

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	36.97 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.1827	0.3200	92,693	84.4	96.1%	0.1951	0.3366	1,140	1,140
80.0%	0.1624	0.5000	82,349	74.9	92.0%	0.1868	0.5137	1,142	1,146
70.0%	0.1421	0.6950	81,251	73.9	87.3%	0.1773	0.7047	1,142	1,146
60.0%	0.1218	0.9450	84,135	76.6	81.9%	0.1663	0.9510	1,140	1,140
50.0%	0.1015	1.3400	90,908	82.7	75.3%	0.1529	1.3431	1,139	1,140
40.0%	0.0812	2.2100	109,876	100.0	63.4%	0.1288	2.2109	1,240	711
30.0%	0.0609	4.9050	109,876	100.0	36.1%	0.0734	4.9050	1,644	711
20.0%	0.0406	16.3250	109,876	100.0	21.7%	0.0441	16.3250	1,729	711
10.0%	0.0203	25.8750	109,876	100.0	10.4%	0.0212	25.8750	2,046	711

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Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 7 - Sta 5609+00
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.375

Section 3. Material

Material	Grade B	
Yield Stress	35,000	
Flow Stress	45,000	psi
Charpy V-Notch	25	ft-lbs
Charpy V-Notch Area	0.124	sq-in
Young's Modulus (E)	3.00E+07	psi

Section 4. Pressure History

Max Operating Pressure	1,320	psig
Hydrostatic Test Pressure	1,843	psig
Max. Press. in Original Spectrum	972	psig
Min. Press. in Original Spectrum	364	psig
Amplitude Filter	25	psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	1086	
# of Days Cycles Occurred	365	Days
Number of Cycles	1080	
Conversion Factor (Cycles/Year)	1,080.7	

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	50.00	Years
Based on a Safety Factor of	2.000	

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.3375	0.8000	108,074	100.0	90.9%	0.3408	0.8021	1,739	641
80.0%	0.3000	1.4050	108,074	100.0	81.7%	0.3064	1.4065	1,733	641
70.0%	0.2625	2.4100	108,074	100.0	72.8%	0.2729	2.4108	1,712	641
60.0%	0.2250	5.2500	108,074	100.0	64.6%	0.2423	5.2503	1,656	641
50.0%	0.1875	11.9800	108,074	100.0	52.9%	0.1982	11.9800	1,739	641
40.0%	0.1500	25.8750	108,074	100.0	41.0%	0.1537	25.8750	1,884	641
30.0%	0.1125	25.8750	108,074	100.0	30.3%	0.1138	25.8750	2,336	641
20.0%	0.0750	25.8750	108,074	100.0	20.1%	0.0755	25.8750	2,808	641
10.0%	0.0375	25.8750	108,074	100.0	10.0%	0.0377	25.8750	3,317	641

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Program Run Date and Time 9/25/10 10:43

Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 7 - Sta 5947+00 Spike Test P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.203

Section 3. Material

Material	X42
Yield Stress	42,000
Flow Stress	52,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,320 psig
Hydrostatic Test Pressure	1,973 psig
Max. Press. in Original Spectrum	972 psig
Min. Press. in Original Spectrum	364 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	1086
# of Days Cycles Occurred	365 Days
Number of Cycles	1080
Conversion Factor (Cycles/Year)	1,080.7

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	50.00 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.1827	0.2550	108,074	100.0	91.3%	0.1853	0.2591	1,885	641
80.0%	0.1624	0.3900	108,074	100.0	82.8%	0.1680	0.3938	1,885	641
70.0%	0.1421	0.5250	108,074	100.0	73.8%	0.1498	0.5275	1,894	641
60.0%	0.1218	0.6900	108,074	100.0	64.0%	0.1299	0.6912	1,903	641
50.0%	0.1015	0.9150	108,074	100.0	53.4%	0.1084	0.9155	1,918	641
40.0%	0.0812	1.2900	108,074	100.0	42.3%	0.0859	1.2901	1,935	641
30.0%	0.0609	2.2000	108,074	100.0	31.2%	0.0632	2.2000	1,951	641
20.0%	0.0406	5.5850	108,074	100.0	20.4%	0.0415	5.5850	1,963	641
10.0%	0.0203	25.8750	108,074	100.0	10.1%	0.0206	25.8750	2,056	641

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Program Run Date and Time 9/25/10 10:46

Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 8 - Sta 6311+00 Spike Test P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.203

Section 3. Material

Material	X42
Yield Stress	42,000
Flow Stress	52,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,320 psig
Hydrostatic Test Pressure	1,944 psig
Max. Press. in Original Spectrum	972 psig
Min. Press. in Original Spectrum	364 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	1086
# of Days Cycles Occurred	365 Days
Number of Cycles	1080
Conversion Factor (Cycles/Year)	1,080.7

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	50.00 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.1827	0.2650	108,074	100.0	91.4%	0.1855	0.2692	1,848	641
80.0%	0.1624	0.4050	108,074	100.0	82.9%	0.1684	0.4088	1,850	641
70.0%	0.1421	0.5500	108,074	100.0	74.0%	0.1502	0.5525	1,854	641
60.0%	0.1218	0.7250	108,074	100.0	64.2%	0.1304	0.7262	1,866	641
50.0%	0.1015	0.9700	108,074	100.0	53.6%	0.1088	0.9705	1,882	641
40.0%	0.0812	1.3900	108,074	100.0	42.4%	0.0861	1.3901	1,902	641
30.0%	0.0609	2.4750	108,074	100.0	31.2%	0.0633	2.4750	1,921	641
20.0%	0.0406	6.4700	108,074	100.0	20.4%	0.0415	6.4700	1,933	641
10.0%	0.0203	25.8750	108,074	100.0	10.1%	0.0206	25.8750	2,056	641

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Program Run Date and Time 9/25/10 10:50

Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 9 - Sta 6326+00
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.375

Section 3. Material

Material	Grade B
Yield Stress	35,000
Flow Stress	45,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,359 psig
Hydrostatic Test Pressure	1,958 psig
Max. Press. in Original Spectrum	564 psig
Min. Press. in Original Spectrum	0 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	1110
# of Days Cycles Occurred	365 Days
Number of Cycles	1104
Conversion Factor (Cycles/Year)	1,104.8

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	50.00 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.3375	0.7500	110,477	100.0	90.4%	0.3388	0.7505	1,907	328
80.0%	0.3000	1.2800	110,477	100.0	80.5%	0.3019	1.2803	1,925	328
70.0%	0.2625	2.0950	110,477	100.0	70.6%	0.2649	2.0952	1,926	328
60.0%	0.2250	4.0800	110,477	100.0	60.8%	0.2281	4.0801	1,924	328
50.0%	0.1875	9.5100	110,477	100.0	50.6%	0.1899	9.5100	1,935	328
40.0%	0.1500	22.9450	110,477	100.0	40.3%	0.1511	22.9450	1,946	328
30.0%	0.1125	25.8750	110,477	100.0	30.1%	0.1130	25.8750	2,345	328
20.0%	0.0750	25.8750	110,477	100.0	20.1%	0.0753	25.8750	2,811	328
10.0%	0.0375	25.8750	110,477	100.0	10.0%	0.0376	25.8750	3,318	328

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Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 9 - Sta 6983+00
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625	
Wall Thickness	0.203	

Section 3. Material

Material	X42	
Yield Stress	42,000	
Flow Stress	52,000	psi
Charpy V-Notch	25	ft-lbs
Charpy V-Notch Area	0.124	sq-in
Young's Modulus (E)	3.00E+07	psi

Section 4. Pressure History

Max Operating Pressure	1,359	psig
Hydrostatic Test Pressure	1,879	psig
Max. Press. in Original Spectrum	718	psig
Min. Press. in Original Spectrum	304	psig
Amplitude Filter	25	psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	1024	
# of Days Cycles Occurred	365	Days
Number of Cycles	1020	
Conversion Factor (Cycles/Year)	1,020.2	

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	50.00	Years
Based on a Safety Factor of	2.000	

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.1827	0.2850	102,020	100.0	90.4%	0.1835	0.2856	1,851	576
80.0%	0.1624	0.4400	102,020	100.0	80.6%	0.1637	0.4405	1,859	576
70.0%	0.1421	0.6050	102,020	100.0	70.7%	0.1436	0.6053	1,860	576
60.0%	0.1218	0.8050	102,020	100.0	60.7%	0.1233	0.8051	1,865	576
50.0%	0.1015	1.1000	102,020	100.0	50.6%	0.1028	1.1001	1,867	576
40.0%	0.0812	1.6500	102,020	100.0	40.4%	0.0820	1.6500	1,871	576
30.0%	0.0609	3.2550	102,020	100.0	30.2%	0.0614	3.2550	1,874	576
20.0%	0.0406	8.9400	102,020	100.0	20.1%	0.0408	8.9400	1,876	576
10.0%	0.0203	25.8750	102,020	100.0	10.0%	0.0204	25.8750	2,060	576

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Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 10 - Sta 7387+00
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.203

Section 3. Material

Material	X42	
Yield Stress	42,000	
Flow Stress	52,000	psi
Charpy V-Notch	25	ft-lbs
Charpy V-Notch Area	0.124	sq-in
Young's Modulus (E)	3.00E+07	psi

Section 4. Pressure History

Max Operating Pressure	1,359	psig
Hydrostatic Test Pressure	1,771	psig
Max. Press. in Original Spectrum	547	psig
Min. Press. in Original Spectrum	88	psig
Amplitude Filter	25	psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	912	
# of Days Cycles Occurred	365	Days
Number of Cycles	909	
Conversion Factor (Cycles/Year)	909.1	

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	50.00	Years
Based on a Safety Factor of	2.000	

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.1827	0.3250	90,913	100.0	90.7%	0.1840	0.3261	1,716	244
80.0%	0.1624	0.5050	90,913	100.0	81.1%	0.1647	0.5059	1,729	244
70.0%	0.1421	0.7000	90,913	100.0	71.4%	0.1449	0.7005	1,736	244
60.0%	0.1218	0.9550	90,913	100.0	61.4%	0.1246	0.9552	1,742	244
50.0%	0.1015	1.3650	90,913	100.0	51.2%	0.1038	1.3651	1,747	244
40.0%	0.0812	2.2800	90,913	100.0	40.7%	0.0827	2.2800	1,755	244
30.0%	0.0609	5.0850	90,913	100.0	30.3%	0.0616	5.0850	1,763	244
20.0%	0.0406	17.5650	90,913	100.0	20.1%	0.0409	17.5650	1,767	244
10.0%	0.0203	25.8750	90,913	100.0	10.0%	0.0204	25.8750	2,059	244

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Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 10 - Sta 7883+00
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.375

Section 3. Material

Material	Grade B
Yield Stress	35,000
Flow Stress	45,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,359 psig
Hydrostatic Test Pressure	2,026 psig
Max. Press. in Original Spectrum	678 psig
Min. Press. in Original Spectrum	132 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	816
# of Days Cycles Occurred	365 Days
Number of Cycles	812
Conversion Factor (Cycles/Year)	812.1

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	50.00 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.3375	0.7150	81,207	100.0	90.5%	0.3395	0.7162	1,963	407
80.0%	0.3000	1.2150	81,207	100.0	80.9%	0.3034	1.2159	1,966	407
70.0%	0.2625	1.9400	81,207	100.0	71.2%	0.2672	1.9405	1,966	407
60.0%	0.2250	3.5650	81,207	100.0	61.7%	0.2312	3.5652	1,958	407
50.0%	0.1875	8.2450	81,207	100.0	51.4%	0.1927	8.2450	1,975	407
40.0%	0.1500	18.6900	81,207	100.0	40.6%	0.1522	18.6900	2,002	407
30.0%	0.1125	25.8750	81,207	100.0	30.2%	0.1134	25.8750	2,341	407
20.0%	0.0750	25.8750	81,207	100.0	20.1%	0.0754	25.8750	2,810	407
10.0%	0.0375	25.8750	81,207	100.0	10.0%	0.0376	25.8750	3,318	407

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Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 11 - Sta 8118+16
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.375

Section 3. Material

Material	Grade B
Yield Stress	35,000
Flow Stress	45,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,359 psig
Hydrostatic Test Pressure	2,011 psig
Max. Press. in Original Spectrum	773 psig
Min. Press. in Original Spectrum	160 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	786
# of Days Cycles Occurred	365 Days
Number of Cycles	782
Conversion Factor (Cycles/Year)	782.0

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	50.00 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.3375	0.7250	78,205	100.0	90.7%	0.3402	0.7268	1,919	406
80.0%	0.3000	1.2300	78,205	100.0	81.3%	0.3048	1.2313	1,925	406
70.0%	0.2625	1.9700	78,205	100.0	71.8%	0.2693	1.9707	1,924	406
60.0%	0.2250	3.6700	78,205	100.0	62.6%	0.2346	3.6703	1,906	406
50.0%	0.1875	8.5150	78,205	100.0	52.1%	0.1954	8.5150	1,933	406
40.0%	0.1500	19.4950	78,205	100.0	40.9%	0.1532	19.4950	1,977	406
30.0%	0.1125	25.8750	78,205	100.0	30.3%	0.1137	25.8750	2,338	406
20.0%	0.0750	25.8750	78,205	100.0	20.1%	0.0755	25.8750	2,808	406
10.0%	0.0375	25.8750	78,205	100.0	10.0%	0.0377	25.8750	3,318	406

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Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 12 - Sta 8391+00
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.203

Section 3. Material

Material	X42
Yield Stress	42,000
Flow Stress	52,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,359 psig
Hydrostatic Test Pressure	1,960 psig
Max. Press. in Original Spectrum	744 psig
Min. Press. in Original Spectrum	1 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	791
# of Days Cycles Occurred	365 Days
Number of Cycles	784
Conversion Factor (Cycles/Year)	784.5

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	50.00 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.1827	0.2600	78,455	100.0	91.7%	0.1862	0.2656	1,840	334
80.0%	0.1624	0.3950	78,455	100.0	83.7%	0.1698	0.4001	1,844	334
70.0%	0.1421	0.5400	78,455	100.0	75.1%	0.1525	0.5433	1,840	334
60.0%	0.1218	0.7050	78,455	100.0	65.4%	0.1328	0.7067	1,861	334
50.0%	0.1015	0.9400	78,455	100.0	54.7%	0.1110	0.9406	1,881	334
40.0%	0.0812	1.3350	78,455	100.0	43.1%	0.0875	1.3352	1,907	334
30.0%	0.0609	2.3150	78,455	100.0	31.5%	0.0640	2.3150	1,932	334
20.0%	0.0406	5.9700	78,455	100.0	20.6%	0.0418	5.9700	1,947	334
10.0%	0.0203	25.8750	78,455	100.0	10.2%	0.0206	25.8750	2,055	334

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Program Run Date and Time 9/25/10 11:12

Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 12 - Sta 8510+91 Spike Test P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.375

Section 3. Material

Material	Grade B
Yield Stress	35,000
Flow Stress	45,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,359 psig
Hydrostatic Test Pressure	2,160 psig
Max. Press. in Original Spectrum	854 psig
Min. Press. in Original Spectrum	45 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	794
# of Days Cycles Occurred	365 Days
Number of Cycles	787
Conversion Factor (Cycles/Year)	787.5

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	50.00 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.3375	0.6600	78,755	100.0	91.0%	0.3412	0.6632	2,041	449
80.0%	0.3000	1.1000	78,755	100.0	81.9%	0.3072	1.1024	2,033	449
70.0%	0.2625	1.6900	78,755	100.0	72.7%	0.2726	1.6913	2,031	449
60.0%	0.2250	2.8350	78,755	100.0	63.5%	0.2381	2.8356	2,016	449
50.0%	0.1875	6.1150	78,755	100.0	53.4%	0.2001	6.1151	2,033	449
40.0%	0.1500	13.4900	78,755	100.0	41.5%	0.1555	13.4900	2,104	449
30.0%	0.1125	25.8750	78,755	100.0	30.5%	0.1144	25.8750	2,329	449
20.0%	0.0750	25.8750	78,755	100.0	20.2%	0.0757	25.8750	2,805	449
10.0%	0.0375	25.8750	78,755	100.0	10.1%	0.0377	25.8750	3,317	449

Analysis Performed by Kiefner & Associates, Inc.
Software by Kiefner & Associates, Inc.
PipeLife 3 - Excel 2007

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Program Run Date and Time 9/25/10 11:15

Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Description:	TS 12 - Sta 8527+11
	Spike Test
	P-41

Section 2. Geometry

Diameter	8.625
Wall Thickness	0.375

Section 3. Material

Material	X42
Yield Stress	42,000
Flow Stress	52,000 psi
Charpy V-Notch	25 ft-lbs
Charpy V-Notch Area	0.124 sq-in
Young's Modulus (E)	3.00E+07 psi

Section 4. Pressure History

Max Operating Pressure	1,359 psig
Hydrostatic Test Pressure	2,176 psig
Max. Press. in Original Spectrum	854 psig
Min. Press. in Original Spectrum	45 psig
Amplitude Filter	25 psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.61E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	794
# of Days Cycles Occurred	365 Days
Number of Cycles	787
Conversion Factor (Cycles/Year)	787.5

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	50.00 Years
Based on a Safety Factor of	2.000

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.3375	0.7850	78,755	100.0	91.3%	0.3423	0.7884	1,989	449
80.0%	0.3000	1.3600	78,755	100.0	82.5%	0.3095	1.3624	1,982	449
70.0%	0.2625	2.2800	78,755	100.0	74.1%	0.2780	2.2814	1,945	449
60.0%	0.2250	4.4150	78,755	100.0	66.5%	0.2494	4.4156	1,870	449
50.0%	0.1875	9.0350	78,755	100.0	54.4%	0.2038	9.0351	1,993	449
40.0%	0.1500	24.8300	78,755	100.0	41.6%	0.1560	24.8300	2,100	449
30.0%	0.1125	25.8750	78,755	100.0	30.5%	0.1144	25.8750	2,642	449
20.0%	0.0750	25.8750	78,755	100.0	20.2%	0.0757	25.8750	3,205	449
10.0%	0.0375	25.8750	78,755	100.0	10.1%	0.0377	25.8750	3,811	449

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APPENDIX C – DESCRIPTION OF PIPELIFE RESULTS PAGE

The following pages present details of Pipelife analysis cases based on nine initial flaws. The important features of this type of analysis are described below based on a generic marked-up case. Note that this generic case is based on using a hydrostatic test to establish a family of nine initial flaws.

(See generic marked-up case)

Section 1

The purpose of this section is to identify the analysis case. Here the pipeline name and location of analysis are given.

Section 2

This section presents the outside diameter and nominal wall thickness of the pipe being analyzed.

Section 3

This section presents the yield strength, full-size-equivalent Charpy V-notch upper-shelf energy and Young's Modulus for the pipe material. Other parameters are listed or calculated but are generally of secondary importance.

Section 4

Under this section, the hydrostatic test pressure is given. This level is an essential input as it greatly affects the starting flaw size. The maximum operating pressure is also given, but its effect on the output is relatively minor.

Section 5

This section shows adjustments, if any, to the "rainflow"-counted pressure-cycle spectrum. The default values (mean shift = 0, scale factor = 1) are sometimes changed to examine the effects of variations in the pressure-cycle spectrum. The scale factor is the more useful of the two as it allows one to quickly examine the effects of hypothetical pressure reductions or pressure increases.

Additionally in this section, one finds a "C" value and an "n" value. These are the crack-growth-rate constants used in the particular analysis case, and changing them can radically alter the results.

Results

At the bottom of the page, the starting crack sizes are given in terms of "a - Initial" and "c - Initial". The maximum depth of the flaw in the through-wall-thickness direction is "a". One half of the axial length of the flaw is "c". The ratio of "a" to wall thickness "t" is also given. The output in terms of time to failure for each of the nine initial flaws is given in the "Years to Leak" column.

GENERIC MARKED-UP CASE

Kiefner & Associates, Inc.

PipeLife Version 1.1

Revision May 2005

File Copy (Formulas and graphs are not linked)

Program Run Date and Time 7/24/06 11:02

Type 2 Analysis Performed on Input Cycles

Section 1. Analysis

Analysis Title:	Kiefner Pipeline
Description:	Worthington Dischare
Pipeline Number:	KAI #1 8-inch

Section 2. Geometry

Diameter	8.625	
Wall Thickness	0.203	

Section 3. Material

Material	Grade B	
Yield Stress	35,000	
Flow Stress	45,000	psi
Charpy V-Notch	25	ft-lbs
Charpy V-Notch Area	0.124	sq-in
Young's Modulus (E)	3.00E+07	psi

Section 4. Pressure History

Max Operating Pressure	1,075	psig
Hydrostatic Test Pressure	1,564	psig
Max. Press. in Original Spectrum	1,072	psig
Min. Press. in Original Spectrum	164	psig
Amplitude Filter	25	psig

Section 5. Factors

Mean Shift Factor (Add)	0.0
Scale Factor (Mult.)	1.000
Crack Growth Rate Const. (C)	8.60E-19
Crack Growth Rate Const. (n)	3
Eccentricity (e/t)	0.01

Section 6. Pressure History

Num. Pressure Histories	83	
# of Days Cycles Occurred	61	Days
Number of Cycles	78	
Conversion Factor (Cycles/Year)	464.0	

Section 7. Miscellaneous Input

Eccentricity	0.01
Bending Multiplication Factor is	1.00
Analysis Does Not Consider Threshold Effects	
Analysis Does Consider Bending Stress	

Section 8. Retest Interval and Safety Factor

Maximum Retest Interval	31.38	Years
Based on a Safety Factor of	2.000	

a/t Percent	a - Initial inch	c - Initial inch	Life to Leak (Cycles)	Years to Leak	a/t Final Percent	a - Final inch	c - Final inch	Pfail Defect Failure Press psig	Pmax in Failure Cycle psig
90.0%	0.1827	0.3100	33,699	72.6	95.7%	0.1943	0.3261	1,070	1,071
80.0%	0.1624	0.4850	29,359	63.3	91.2%	0.1852	0.4982	1,070	1,071
70.0%	0.1421	0.6700	29,127	62.8	86.2%	0.1750	0.6793	1,070	1,071
60.0%	0.1218	0.9050	30,522	65.8	80.3%	0.1631	0.9108	1,071	1,071
50.0%	0.1015	1.2700	33,402	72.0	73.3%	0.1488	1.2730	1,070	1,071
40.0%	0.0812	2.0400	42,624	91.9	64.8%	0.1315	2.0411	1,070	1,071
30.0%	0.0609	5.0150	76,414	164.7	55.0%	0.1117	5.0152	1,071	1,071
20.0%	0.0406	9.7400	219,092	472.1	47.2%	0.0959	9.7401	1,071	1,071
10.0%	0.0203	14.4050	232,025	500.0	13.0%	0.0263	14.4050	1,516	1,044

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