API Ballot id# 6418 SC5 TG TGC

Work Item Number	3089
Title of Work Item	Transition Load Steps
Ballot Revision Level	00
Type of Ballot (Initial, Comment, Comment resolution (reference API ballot#), 1st Re-ballot, 2nd Re-ballot, etc.)	Initial
Submitter Name(s)	Pierre Martin / Mark Turnbaugh
API Document Modified	API RP 5C5 4th ed.
Impacted Documents	
Revision Key	Current API document in black, Deletions in red strikethrough ~~remove~~, 1st Ballot Additions in blue underlined add, Comment Resolution Additions in green underlined add, Comment Resolution Deletions in purple strikethrough ~~remove~~

Work Item Charge: Evaluate standardized transition load path steps and include as normative.

Ballot Rationale: In the API 5C5:2017 the transition load path is informative where on API 5C5:2003 it was normative.

Ballot Text:

3.2 Abbreviations

4

A connection A, mill end

AMYS actual minimum yield strength

B connection B, field end

BO breakout

CAL connection assessment level

CCW counter-clockwise direction around the test load envelope

CEE connection evaluation envelope

CEPL capped end pressure load (tension) generated either by the external or the internal pressure at the designated pressure

5.8.1.6 Leak Detection and Measurement by Water Level

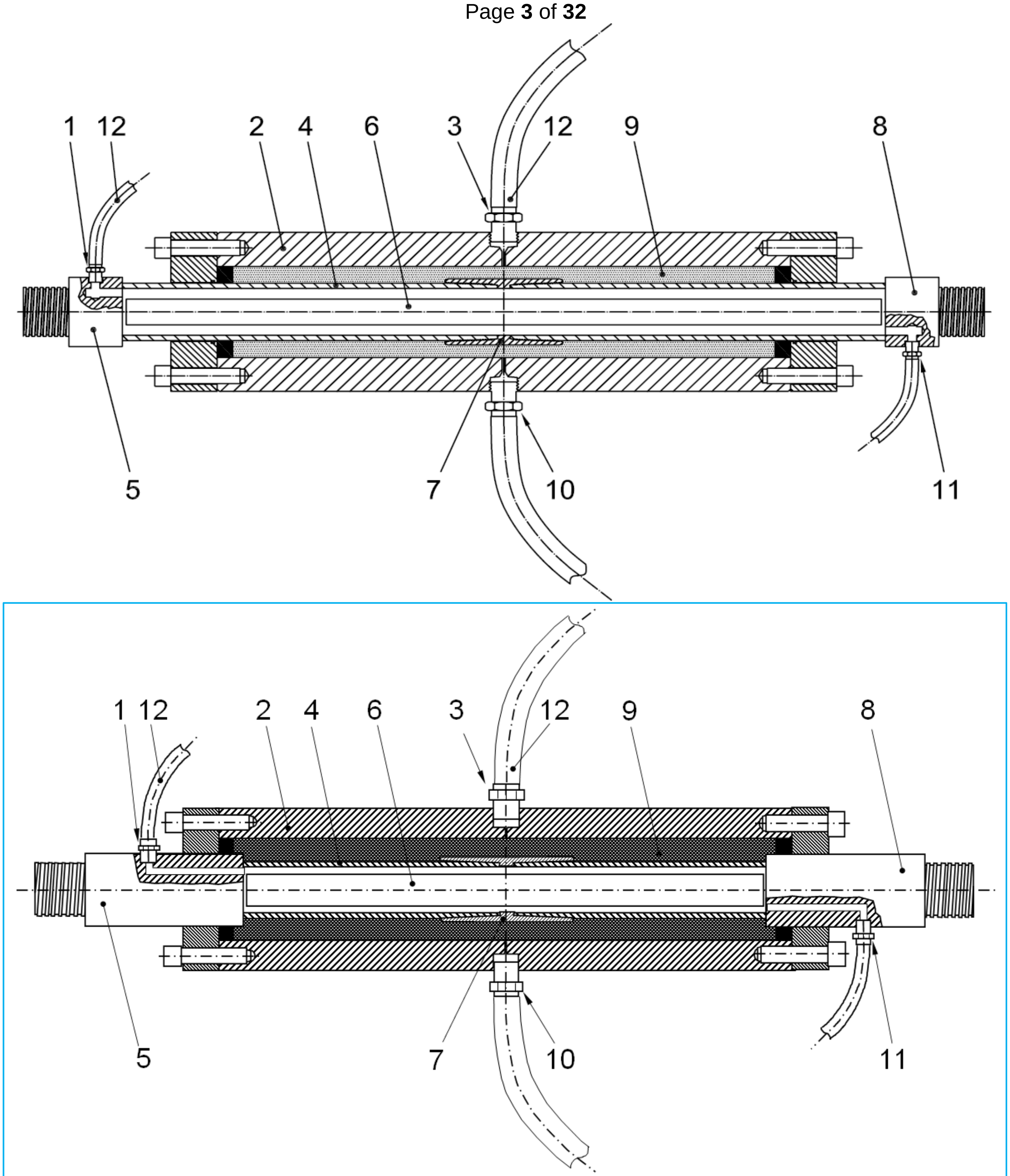
For internal pressure tests at ambient temperature, the chamber and leak detection lines shall be filled with water as described in 5.8.1.4. As described in 5.8.1.5, the flexible hose shall be connected to the leak detection system as shown in key items 3 and 12 in Figure 14 and item 8 in Figure 15.

For external pressure tests at ambient temperature, the specimen and leak detection lines shall be filled with water as described in 5.8.1.4. As described in 5.8.1.5, the flexible hose shall be connected to the leak detection system as shown in key items 8 and 12 in Figure 14 and item 8 in Figure 15.

During TS-A pressure testing, a chamber encloses the test connection and some portion of the pipe on both sides of the connection. During the pressure testing, it has been observed that immediately after reaching full pressure and axial load, there may be significant (greater than 0.9 cm3/15 minute) water displacement. This displacement usually exhibits a decreasing trend that requires a stabilization period that shall be performed before starting the required hold period. In view of this test behavior, the following criteria should be used for TS-A pressure tests.

a) Apply the full required internal or external test pressure and close the pressure line valves from the pressurizing pump.
b) Small pressure increases may be necessary immediately after closing the valves in order to maintain the required pressure.
c) Begin recording the frame loads, pressures, and graduated cylinder water level readings shortly after closing the valves (after target loads are applied and the leak detection system is stabilized).

d) Record the frame loads, pressures, and graduated cylinder water level readings as described in 8.3.
e) Document the leak rate and note the trend of leakage in the bubble tube—pressure sealing acceptance criteria are stated in 8.3.



Key

1 port for pressure transducer for internal gas test, leak detection for external pressure test, shop air inlet to drain water after external pressure test

2 external pressure chamber

3 hole, equipped with flexible hose to leak detection for internal pressure test or pressure transducer for external pressure test

4 test pipe

5 end cap, containing top internal port, see key item 1

6 internal filler bar, for safety

7 test connection

8 end cap containing bottom internal port, see key item 11

9 chamber, fully filled with water

10 hole, for water pressure inlet to chamber

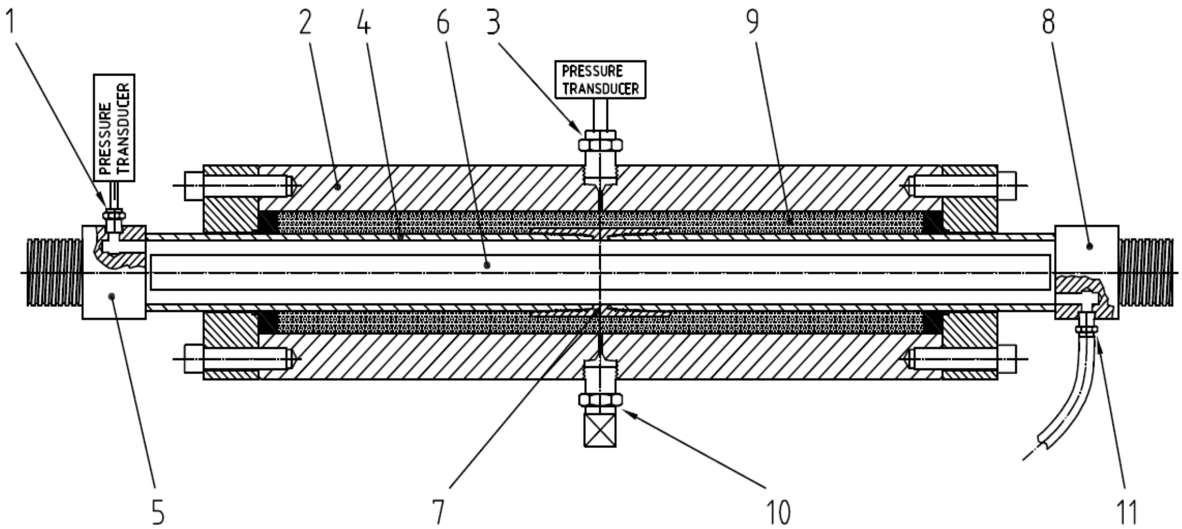
11 port for gas pressure inlet, water fill for external pressure test, water drain after external pressure test

12 flexible hose that attaches to leak detection system (see key item 8 in Figure 15)

Figure 14—Examples Setup for TS-A

5.9.1 General

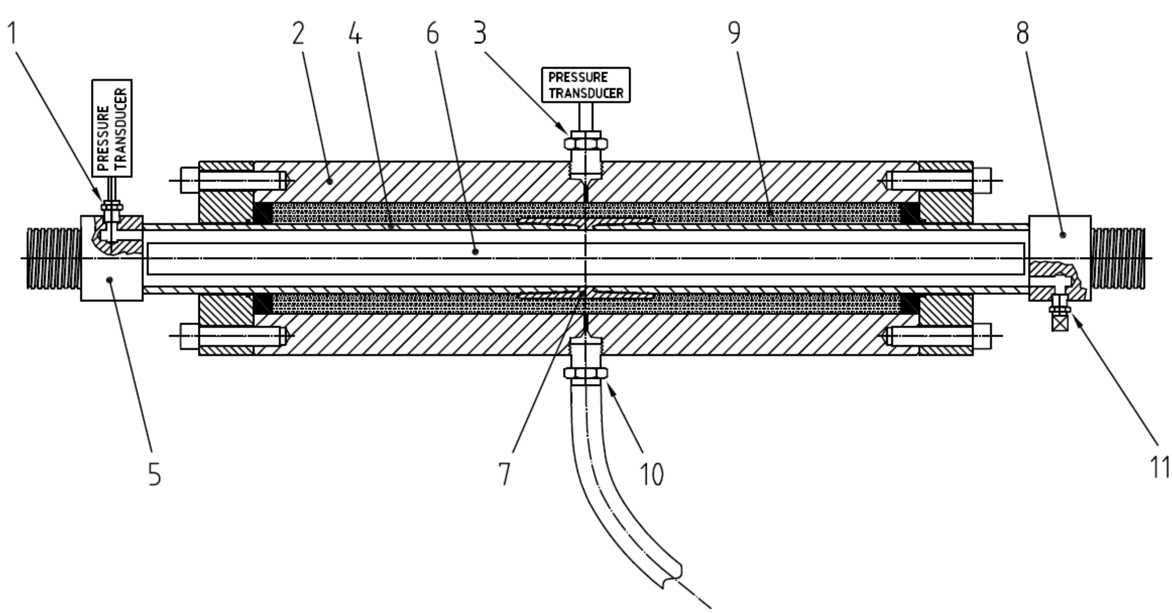
Correct and adequate recording of data is fundamental to the testing program. Without adequate records, it is not possible to provide the objective evidence of the performance verification of a connection.



Key

1 port for pressure transducer for internal gas pressure test
2 external pressure chamber
3 hole equipped with pressure transducer for internal gas pressure test
4 test pipe
5 end cap, containing top internal port, see key item 1
6 internal filler bar, for safety
7 test connection
8 end cap containing bottom internal port, see key item 11
9 chamber, fully filled with fluid
10 hole, for fluid inlet to chamber, closed off for internal gas pressure test
11 port for gas pressure inlet

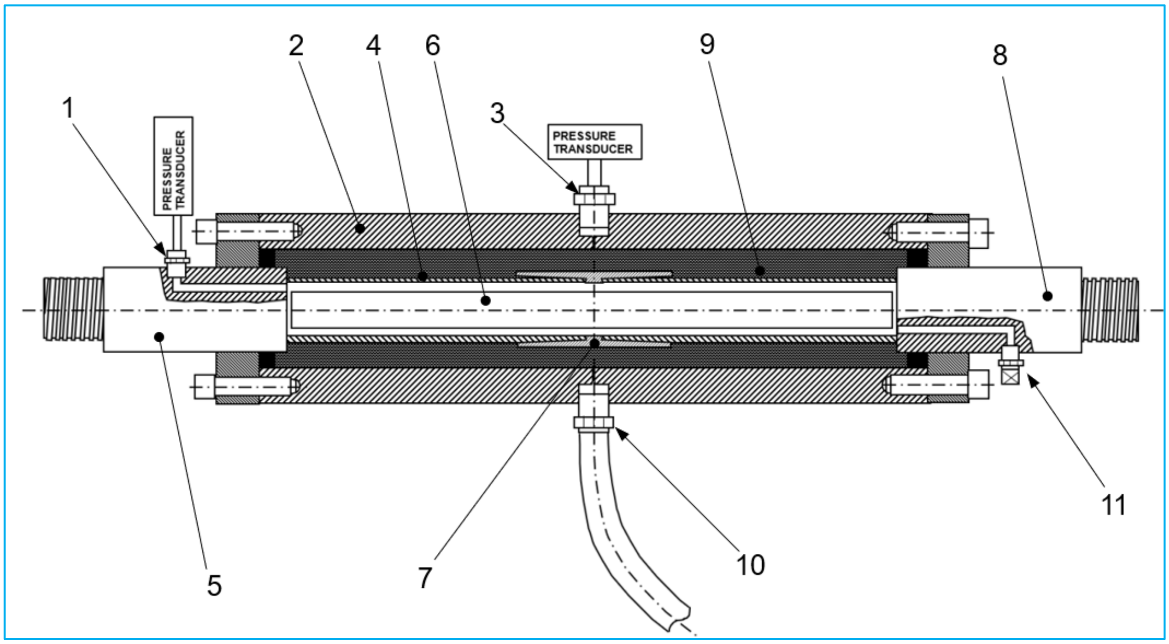
Figure 16—Example Setup for Elevated TS-A (Internal Pressure)



Key

1 port for pressure transducer for external pressure test, shop air inlet to drain fluid after external pressure test
2 external pressure chamber
3 hole, equipped with pressure transducer for external pressure test
4 test pipe
5 end cap, containing top internal port, see key item 1
6 internal filler bar, for safety
7 test connection
8 end cap containing bottom internal port, see key item 11
9 chamber, fully filled with fluid
10 hole, for fluid pressure inlet to chamber
11 port for fluid fill for external pressure test, fluid drain after external pressure test

Figure 17—Example Setup for Elevated TS-A (External Pressure)



Key

1 port for pressure transducer for external pressure test, shop air inlet to drain fluid after external pressure test
2 external pressure chamber
3 hole, equipped with pressure transducer for external pressure test
4 test pipe
5 end cap, containing top internal port, see key item 1
6 internal filler bar, for safety
7 test connection
8 end cap containing bottom internal port, see key item 11
9 chamber, fully filled with fluid
10 hole, for fluid pressure inlet to chamber
11 port for fluid fill for external pressure test, fluid drain after external pressure test

Figure 18—Additional Example Setup for Elevated TS-A (External Pressure)

7.3.3.4 Calculation and guidance for transition load steps TS-A

In the case of the transition load steps are not outside the TLE (e.g. capped end effect), the number of load points shall be minimized to go from one load point to another:

- Increase or decrease the tension or the compression and then increase or decrease the pressure.
- Increase or decrease the pressure then increase or decrease tension or compression.

For load points LP 12, LP 13, and LP 14 (at 90% and/or 95% levels at ambient temperature), an additional load step may be added to transition to the intended load point with axial frame load, but the last transition axial frame load shall not exceed 5% of LP 10a90 TLEa.

If due to the capped end effect, the load step to go from one load point to another is outside the TLE, it is allowed to introduce the minimum number of transition load steps to remain inside the TLE.

7.3.4.4 Calculation and guidance for transition load steps TS-B

In the case of the transition load steps are not outside the TLE (e.g., capped end effect), the number of load points shall be minimized to go from one load point to another:

- Increase or decrease the tension or the compression and then increase or decrease the pressure.
- Increase or decrease the pressure then increase or decrease tension or compression.

If due to the capped end effect, the load step to go from one load point to another is outside the TLE, it is allowed to introduce the minimum number of transition load steps to remain inside the TLE.

D.5.1 General

As stated in 4.2, it is the intent of this RP to test each specimen to as high a load or combination of loads as safely practical. Some connection performance properties may not be impacted by actual pipe body dimensions or material yield strength. The methodology used to define the connection performance for a specific test specimen is assumed to be proprietary in nature. The manufacturer is responsible for defining the CEE based on the connection design, test specimen pipe body and connection actual dimensions, and test specimen pipe body and connection actual material yield strengths at both ambient and elevated temperature. Once the CEE has been established by the manufacturer, the CEE points can be determined using Table 8. From the CEE points, TLE load points are determined for each test specimen based on bi- axial scaling at 80 %, 90 %, 95 %, or 100 % (whichever applies) of the CEE as defined in Table 8. There are 32 CEE points that define the TLE load points at ambient temperature, whereas only 15 CEE points define the TLE load points at elevated temperature. The individual TLE load points establish the TLE.

As required by 7.3.5.3 and Table 14, TLE load points 28_a90, 29_a90, 30_a90, and 31_a90 have been established to specify the load path for the ambient temperature mechanical cycles in TS-C (see Figure 34). There is no CEE point used as the basis for these TLE load points; they depend on TLE load point 14_a90.

The CEE may be limited by the pipe body or connection performance properties. If the CEE is less than the pipe body reference envelope, the bi-axial scaling factors depend on whether the CEE limitation is based on material yield strength or some other factor. If the CEE limitation is based on material yield strength, the TLE shall be scaled to 80 %, 90 %, or 95 % (whichever applies) of the CEE. If the CEE limitation is due to a factor other than material yield strength, then the TLE shall be 100 % of the CEE. Some examples of connection CEE limitations that would require 100 % scaling factors include connections limited to API MYIP (minimum internal yield pressure as defined by API 5C3) and connections limited to the nominal API collapse pressure. The 80 % scaling factor applies both to CEE's limited by material yield strength and to CEE's limited by some other factor.

The ambient and elevated temperature pipe body reference curves developed in D.3 and D.4, respectively, are used to evaluate and interpret the test results.

As shown in Figure 2, the manufacturer shall determine the CEE at ambient and elevated temperature for each test specimen. The TLEs at ambient and elevated temperature are developed based on the corresponding

CEE as shown in Figure 3. Table D.12 summarizes the specified and measured dimensions, specified and actual material yield strengths, proprietary high collapse rating, and $K_{383°}$ used to calculate the CEE and TLE for this example.

Table D.12—Parameters Used to Calculate Reference Curves

Specified OD	Specified Wall	SMYS	D_{avg}	t_{min}	t_{avg}	AMYS[a]	HC Rating	$K_{383°}$	Max Temp
9.625 in.	0.545 in.	110,000 psi	9.697 in.	0.507 in.	0.540 in.	125,000 psi	9140 psi	0.8864	383 °F

Table D.13— Additional Parameters Used to Calculate load point transition with external capped-end effect

Capped-end OD	Capped-end Effect
12.401 in.	46.930 in²

In case of external pressure chamber (fig.18) holds around end cap, tension load is induced during external pressure loading. This tension load is defined as the external capped-end effect.

D.6.4.3 TS-A 90 % Level at Elevated Temperature (QIII, QIV) and (QIV, QIII)

As shown in Figure D.27 and Table D.34, CAL IV TS-A continues with external pressure testing at elevated temperature. A series of QIII/QIV load points is executed first in the CCW and then in the CW direction (to evaluate load path dependency) at a 90 % level. The majority of the hold points require sealability evaluation. Sealability evaluation shall be by the pressure-drop method (see 5.8.2 and Figure 17). The system should remain closed to prevent hot fluid from escaping the external pressure chamber.

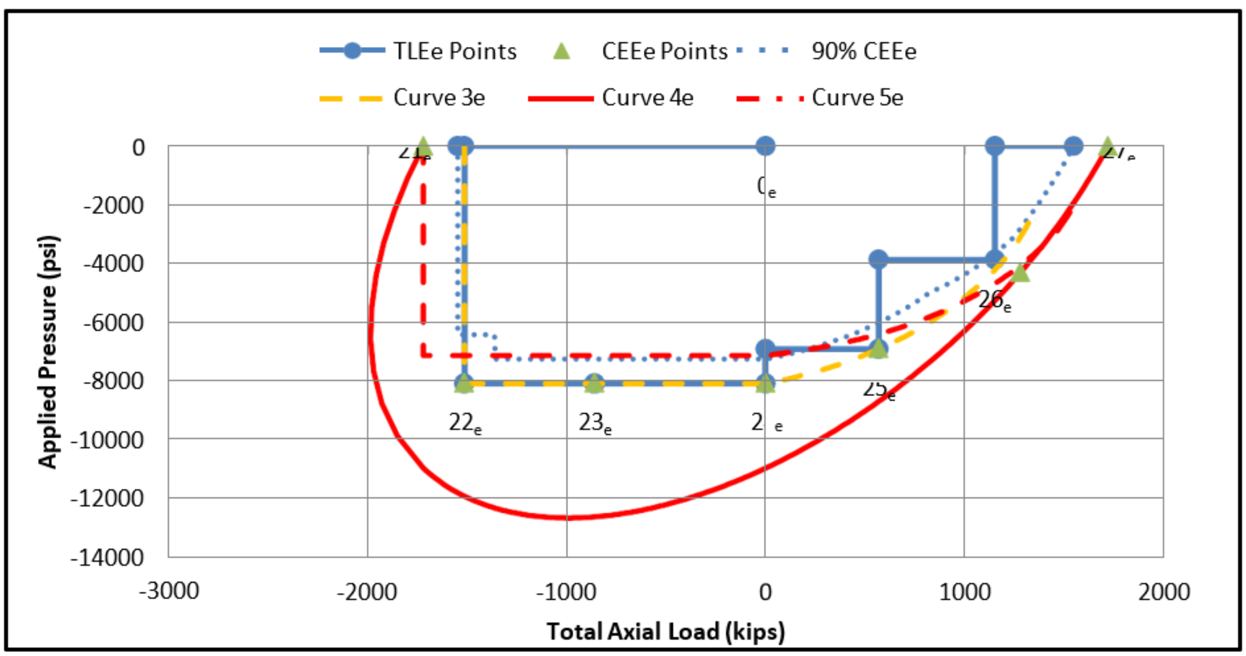


Figure D.27—Ae 90 % (QIII, QIV) and Ae 90 % (QIV, QIII), TS-A Load Steps 25 to 51

Table D.34—TS-A 90 % Level at Elevated Temperature (QIII, QIV) and (QIV, QIII)

Load Step	LP	Total Load (kips)	CEPL (kips)	Frame Load (kips)	Pressure (psi)	Temperature (°F)	Hold Time (min)	Direction
Continue CAL IV TS-A with A^e 90 % (QIII, QIV) and A^e 90 % (QIV, QIII) Leak Detection for TS-A at Elevated Temperature								
25	0	0	0	0	0	356		CCW (90 % Level) See Table 9, Table D.23, and Figure D.27
26	21_e	−1549	0	−1549	0	356	2	
27	Transition	−1516	0	−1516	0	356		
28	22_e	−1516	0	−1516	−8102	356	60	
29	Transition	−861	0	−861	−8102	356		
30	23_e	−861	0	−861	−8102	356	10	
31	Transition	−861	0	−861	−8102	356		
32	24_e	0	0	0	−8102	356	10	
33	Transition	0	0	0	−6924	356		
34	25_e	568	0	568	−6924	356	10	
35	Transition	568	0	568	−3876	356		
36	26_e	1153	0	1153	−3876	356	10	
37	Transition	1153	0	1153	0	356		
38	27_e	1549	0	1549	0	356	2	
39	Transition	1153	0	1153	0	356		CW (90 % Level) See Table 9, Table D.23, and Figure D.27
40	26_e	1153	0	1153	−3876	356	10	
41	Transition	568	0	568	−3876	356		
42	25_e	568	0	568	−6924	356	10	
43	Transition	0	0	0	−6924	356		
44	24_e	0	0	0	−8102	356	60	
45	Transition	−861	0	−861	−8102	356		
46	23_e	−861	0	−861	−8102	356	10	
47	Transition	−861	0	−861	−8102	356		
48	22_e	−1516	0	−1516	−8102	356	10	
49	Transition	−1516	0	−1516	0	356		
50	21_e	−1549	0	−1549	0	356	2	
51	0	0	0	0	0	356		
End of A^e 90 % (QIII, QIV) and A^e 90 % (QIV, QIII) Switch from External Pressure to Internal Pressure Testing								

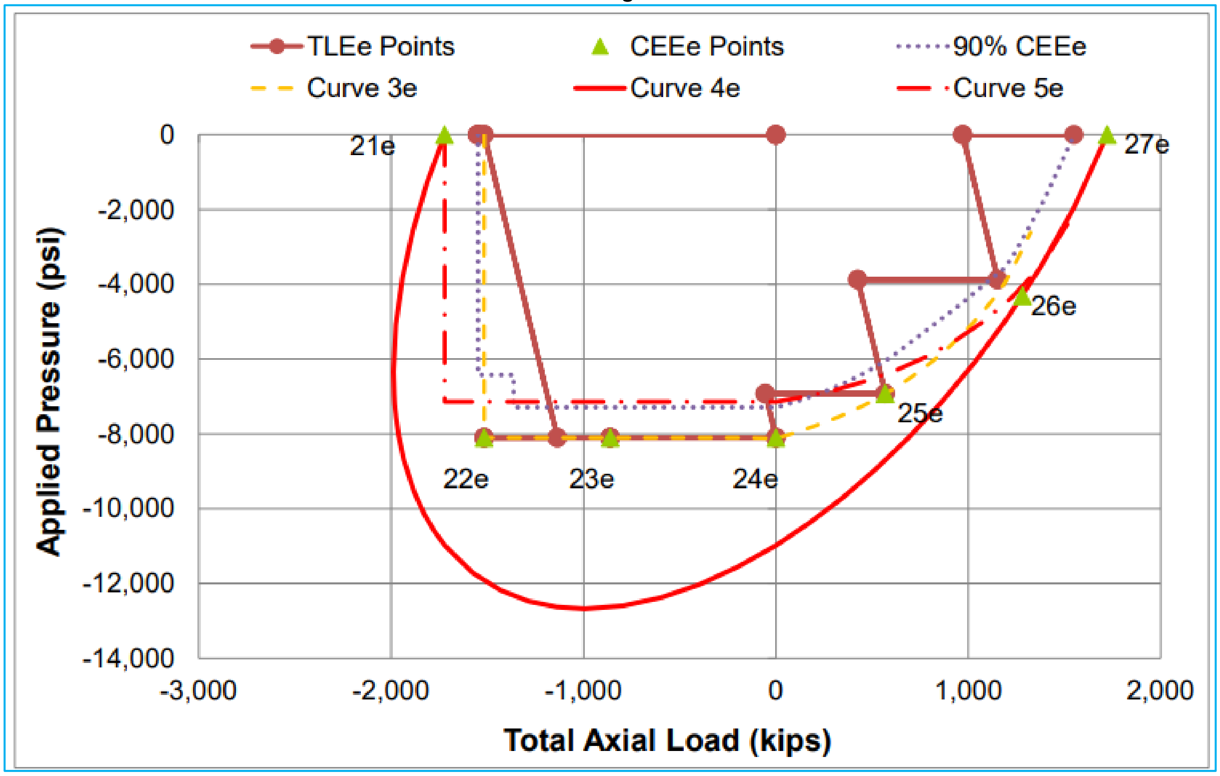


Figure D.2X—A^e 90 % (QIII, QIV) and A^e 90 % (QIV, QIII), TS-A Load Steps 25 to 51 with external capped-end effect

Table D.3X—TS-A 90 % Level at Elevated Temperature (QIII, QIV) and (QIV, QIII) with external CEPL

Continue CAL IV TS-A with A^e 90 % (QIII, QIV) and A^e 90 % (QIV, QIII) Leak Detection for TS-A at Elevated Temperature								
Load Step	**LP**	**Total Load (kips)**	**CEPL (kips)**	**Frame Load (kips)**	**Pressure (psi)**	**Temperature (°F)**	**Hold Time (min)**	**Direction**
25	0	0	0	0	0	356		CCW (90 % Level)
26	21_e	-1,549	0	-1549	0	356	2	
27-1	Transition	-1,516	0	-1516	0	356		
27-2	Transition	-1,136	380	-1516	-8,102	356		
28	22_e	-1,516	380	-1896	-8,102	356	60	
29	Transition	-861	380	-1241	-8,102	356		
30	23_e	-861	380	-1241	-8,102	356	10	
31	Transition	0	380	-380	-8,102	356		
32	24_e	0	380	-380	-8,102	356	10	
33	Transition	-55	325	-380	-6,924	356		
34	25_e	568	325	243	-6,924	356	10	
35	Transition	425	182	243	-3,876	356		
36	26_e	1,153	182	971	-3,876	356	10	
37	Transition	971	0	971	0	356		
38	27_e	1,549	0	1549	0	356	2	

39	Transition	971	0	971	0	356		
40	26_e	1,153	182	971	-3,876	356	10	
41	Transition	425	182	243	-3,876	356		
42	25_e	568	325	243	-6,924	356	10	
43	Transition	-55	325	-380	-6,924	356		
44	24_e	0	380	-380	-8,102	356	60	CW (90 % Level)
45	Transition	-861	380	-1241	-8,102	356		
46	23_e	-861	380	-1241	-8,102	356	10	
47	Transition	-1,516	380	-1896	-8,102	356		
48	22_e	-1,516	380	-1896	-8,102	356	10	
49-1	Transition	-1,136	380	-1516	-8,102	356		
49-2	Transition	-1,516	0	-1516	0	356		
50	21_e	-1,549	0	-1549	0	356	2	
51	0	0	0	0	0	356		
End of A^e 90 % (QIII, QIV) and A^e 90 % (QIV, QIII) Switch from External Pressure to Internal Pressure Testing								

D.6.4.5 TS-A 90 % Level 5 QI to QIII Cycles

As shown in Figure D.29 and Table D.36, CAL IV TS-A continues with load and temperature cycling (five cycles) between QI at ambient temperature [≤150 ° F (65 ° C)] and QIII at elevated temperature. The hold points in QI and QIII require sealability evaluation. This testing can be performed with the external pressure vessel installed, and sealability evaluation is by the pressure drop method (see 5.8.2 and Figure 16). However, the external pressure vessel may be removed so that one of the leak-detection methods described in 5.7 may be used. For external pressure testing, sealability evaluation shall be by the pressure-drop method (see 5.8.2 and Figure 17). The system should remain closed to prevent hot fluid from escaping the external pressure chamber.

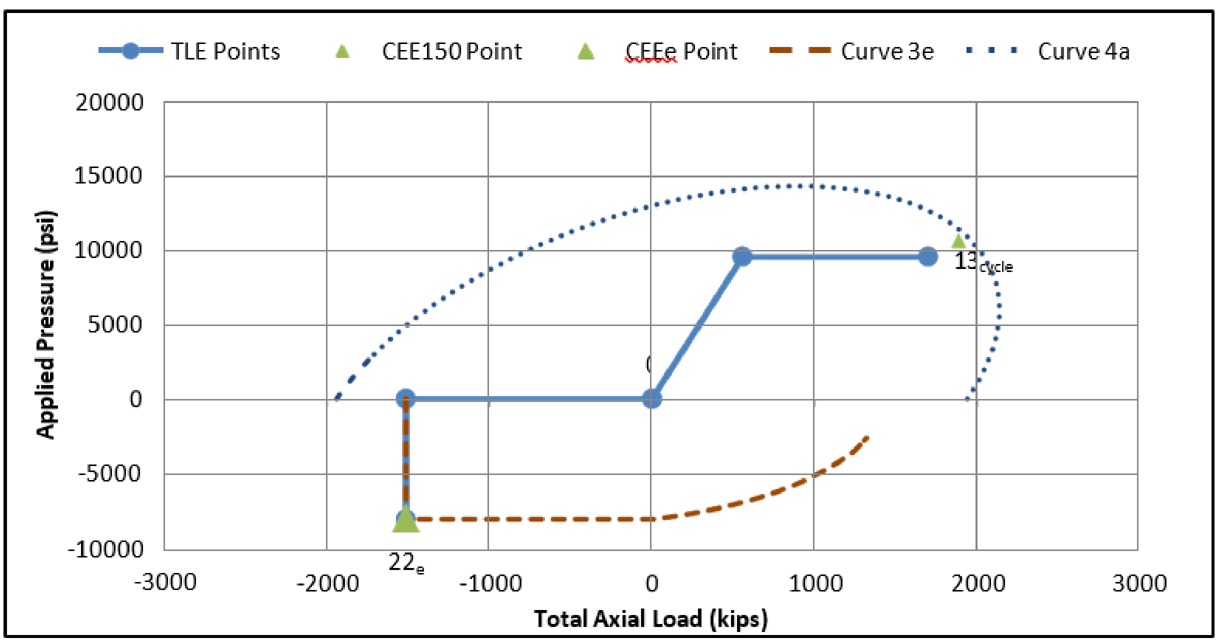


Figure D.29—A^e 90 % 5 QI-QIII Cycles, TS-A Load Steps 75 to 125

Table D.36—TS-A 90 % Level 5 QI-QIII Cycles

Continue CAL IV TS-A with 90 % 5 QI-QIII Cycles Leak Detection for TS-A at Elevated Temperature								
Load Step	**LP**	**Total Load (kips)**	**CEPL (kips)**	**Frame Load (kips)**	**Pressure (psi)**	**Temperature (°F)**	**Hold Time (min)**	**Direction**
75	0	0	0	0	0	Cooldown		Cycle 1 (90 % Level) See Table 9, Table D.20, Table D.23, and Figure D.29
76	Transition	557	557	0	9544	150		
77	13_{cycle}	1699	557	1143	9544	150	15	
78	Transition	557	557	0	9544	150		
79	0	0	0	0	0	150		
80	0	0	0	0	0	Heat-up		
81	Transition	–1516	0	–1516	0	356		
82	22_e	–1516	0	–1516	8102	356	15	
83	Transition	–1516	0	–1516	0	356		
84	0	0	0	0	0	356		
85	0	0	0	0	0	Cooldown		Cycle 2 (90 % Level) See Table 9, Table D.20, Table D.23, and Figure D.29
86	Transition	557	557	0	9544	150		
87	13_{cycle}	1699	557	1143	9544	150	15	
88	Transition	557	557	0	9544	150		
89	0	0	0	0	0	150		
90	0	0	0	0	0	Heat-up		
91	Transition	–1516	0	–1516	0	356		
92	22_e	–1516	0	–1516	–8102	356	15	
93	Transition	–1516	0	–1516	0	356		
94	0	0	0	0	0	356		
95	0	0	0	0	0	Cooldown		Cycle 3 (90 % Level) See Table 9, Table D.20, Table D.23, and Figure D.29
96	Transition	557	557	0	9544	150		
97	13_{cycle}	1699	557	1143	9544	150	15	
98	Transition	557	557	0	9544	150		
99	0	0	0	0	0	150		
100	0	0	0	0	0	Heat-up		
101	Transition	–1516	0	–1516	0	356		
102	22_e	–1516	0	–1516	–8102	356	15	
103	Transition	–1516	0	–1516	0	356		
104	0	0	0	0	0	356		

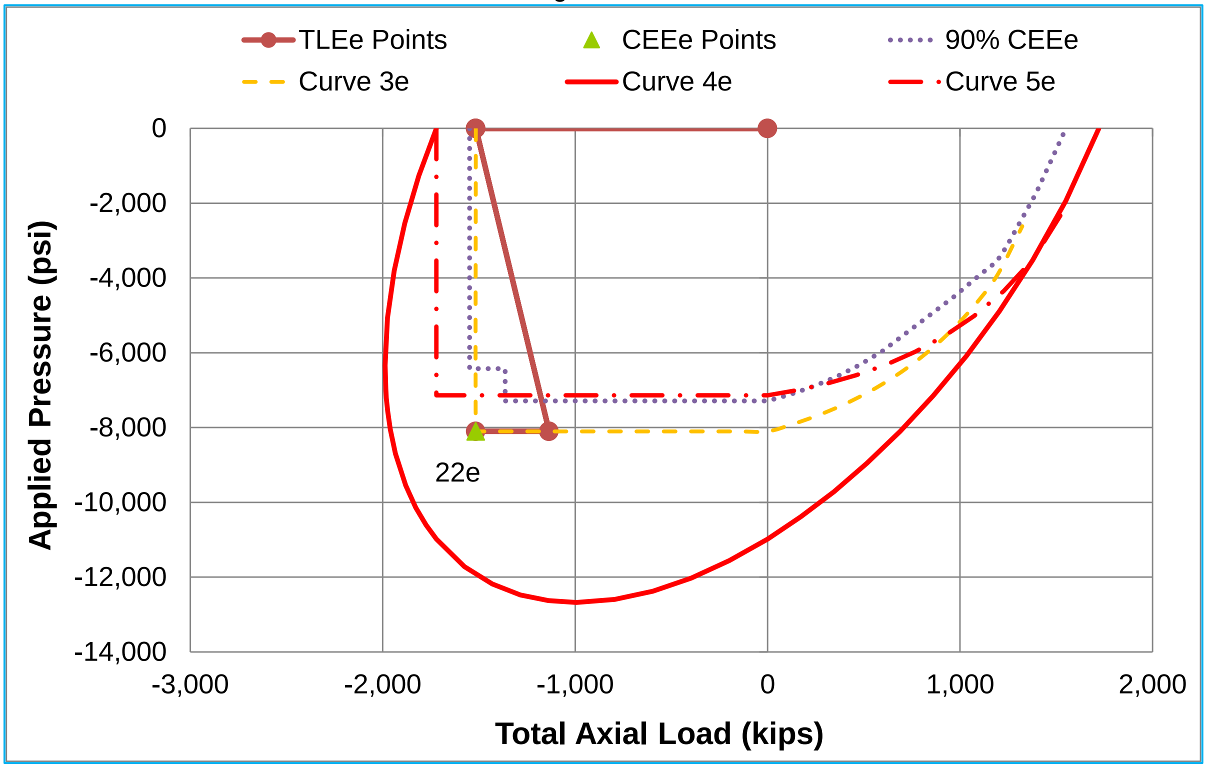


Figure xx. – Ae 90% 5 QI-QIII Cycles, TS-A Load Steps 80 to 84 with external capped-end effect

Table X. – TS-A 90% Level – 1 cycle of QIII in 5 QI-QIII Cycles with external CEPL

Continue CAL IV TS-A with 90% 5 QI-QIII cycles Leak Detection for TS-A at Elevated Temperature								
Load Step	LP	Total Load (kips)	CEPL (kips)	Frame Load (kips)	Pressure (psi)	Temperature (°F)	Hold Time (min)	Direction
80	0	0	0	0	0	Heat-up		QIII of Cycle 1 (90% Level)
81-1	Transition	-1,516	0	-1516	0	356		
81-2	Transition	-1,136	380	-1516	-8,102	356		
82	22_e	-1,516	380	-1896	-8,102	356	15	
83-1	Transition	-1,136	380	-1516	-8,102	356		
83-2	Transition	-1,516	0	-1516	0	356		
84	0	0	0	0	0	356		

D.6.4.6 TS-A 90 % Level at Ambient Temperature (QI, QII)

As shown in Figure D.30 and Table D.37, CAL IV TS-A continues with internal pressure testing at ambient temperature. A series of QI/QII load points is executed in the CCW direction at a 90 % level. The majority of the hold points require sealability evaluation. This testing can be performed with the external pressure vessel installed, and sealability evaluation is by the water column method (see 5.8.1 and Figure 14). However, the external pressure vessel may be removed so that one of the leak-detection methods described in 5.7 may be used.

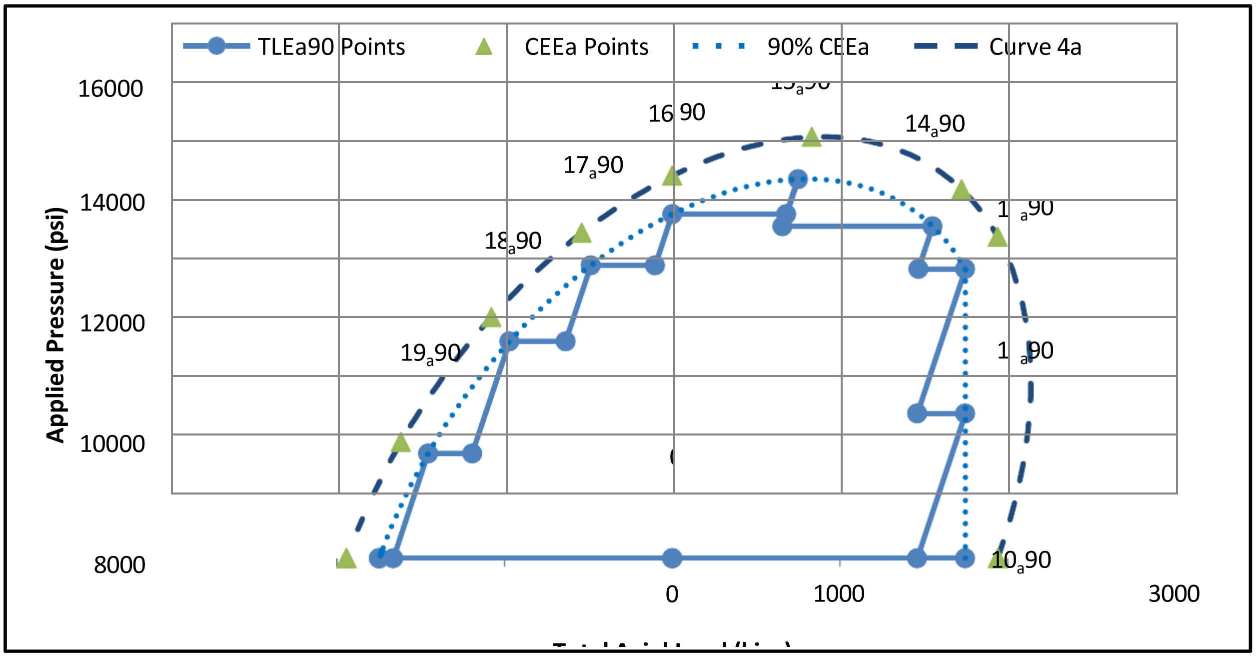


Figure D.30—A^a 90 % (QI, QII), TS-A Load Steps 126 to 148

Table D.37—TS-A 90 % Level at Ambient Temperature (QI, QII)

Continue CAL IV TS-A with A^a 90 % (QI, QII) Leak Detection for TS-A at Ambient Temperature								
Load Step	**LP**	**Total Load (kips)**	**CEPL (kips)**	**Frame Load (kips)**	**Pressure (psi)**	**Temperature (°F)**	**Hold Time (min)**	**Direction**
126	0	0	0	0	0	Ambient		CCW (90 % Level) See Table 9, Table D.19, and Figure D.30
127	10_a90	1748	0	1748	0	Ambient	2	
128	Transition	1461	0	1461	0	Ambient		
129	12_a90	1748	286	1461	4908	Ambient	10	
130	Transition	1461	286	1175	4908	Ambient		
131	13_a90	1748	572	1175	9815	Ambient	10	
132	Transition	1469	572	896	9815	Ambient		
133	14_a90	1553	657	896	11,267	Ambient	10	
134	Transition	657	657	0	11,267	Ambient		
135	15_a90	750	750	0	12,866	Ambient	10	
136	Transition	681	681	0	11,683	Ambient		
137	16_a90	0	681	–681	11,683	Ambient	60	
138	Transition	−102	580	–681	9942	Ambient		
139	17_a90	−485	580	–1065	9942	Ambient	10	
140	Transition	−636	429	–1065	7363	Ambient		
141	18_a90	−971	429	–1400	7363	Ambient	10	
142	Transition	−1193	207	–1400	3554	Ambient		

Table D.37—TS-A 90 % Level at Ambient Temperature (QI, QII) (Continued)

Continue CAL IV TS-A with A^a 90 % (QI, QII) Leak Detection for TS-A at Ambient Temperature								
Load Step	**LP**	**Total Load (kips)**	**CEPL (kips)**	**Frame Load (kips)**	**Pressure (psi)**	**Temperature (°F)**	**Hold Time (min)**	**Direction**
143	19_a90	−1456	207	−1664	3554	Ambient	10	
144	Transition	−1664	0	–1664	0	Ambient		
145	20_a90	−1748	0	–1748	0	Ambient	2 [b]	
146	Transition	−1748	0	–1748	0	Ambient		
147	21_a90	−1748	0	–1748	0	Ambient	2	
148	0	0	0	0	0	Ambient		
End of A^a 90 % (QI, QII) Switch from Internal Pressure to External Pressure Testing								

[b] Since there is no pressure at this load point, the hold time was reduced from 10 minutes to 2 minutes.

As described in 7.3.3.4, calculation for additional transition path between LP10, LP12, LP13 and 14 with up to 5% axial load approach to required Load Point for Test Series A 90% at ambient temperature.

Maximum Axial Load (LP 12 & 13)= 1748 kips

Maximum allowable axial approach (5% Maximum Axial Load)= 87.4kips

Maximum Axial Load (LP 14)= 1553 kips

Maximum allowable axial approach (5% Maximum Axial Load)= 77.7kips

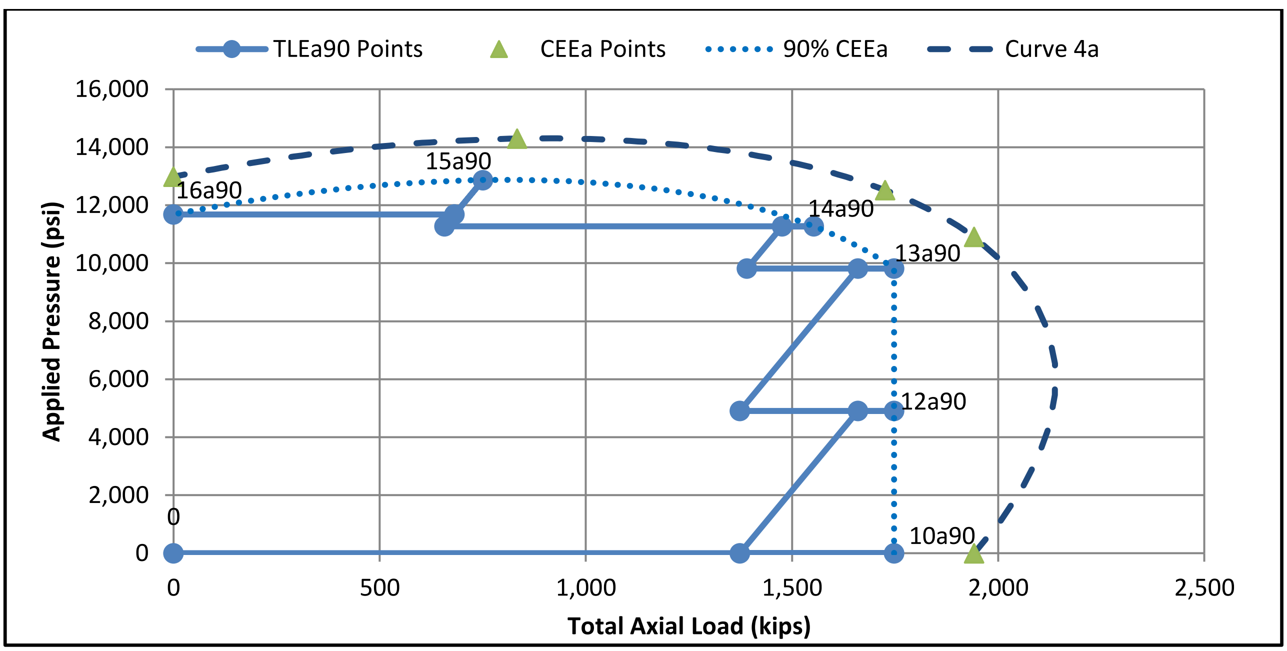


Figure D.X—A^a 90 % (QI), TS-A Load Steps 126 to 138 with optional transition load points

Table D.X—TS-A 90 % Level at Ambient Temperature (QI, QII) with additional and optional transition load points between LP10, LP12, LP13 and LP14

Optional transition load path between LP 10, LP 12, LP13 and LP14 CAL IV TS-A with A^a 90 % (QI) Leak Detection for TS-A at Ambient Temperature								
Load Step	**LP**	**Total Load (kips)**	**CEPL (kips)**	**Frame Load (kips)**	**Pressure (psi)**	**Temperature (°F)**	**Hold Time (min)**	**Direction**
126	0	0	0	0	0	Ambient		CCW (90 % Level) See Table 9, Table D.19, and Figure D.X
127	10_a90	1748	0	1748	0	Ambient	2	
128	Transition 1st step	1374	0	1374	0	Ambient		
129	Transition 2nd step	1660	286	1375	4908	Ambient		
130	12_a90	1748	286	1461	4908	Ambient	10	
131	Transition 1st step	1374	286	1088	4908	Ambient		
132	Transition 2nd step	1660	572	1088	9815	Ambient		
133	13_a90	1748	572	1175	9815	Ambient	10	
134	Transition 1st step	1391	572	819	9815	Ambient		
135	Transition 2nd step	1476	657	819	11267	Ambient		
136	14_a90	1553	657	896	11,267	Ambient	10	
137	Transition	657	657	0	11,267	Ambient		
138	15_a90	750	750	0	12,866	Ambient	10	

D.6.4.7 TS-A 90 % Level at Ambient Temperature (QIII, QIV) & (QIV, QIII)

As shown in Figure D.31 and Table D.38, CAL IV TS-A continues with external pressure testing. A series of QIII/QIV load points is executed first in the CCW and then in the CW direction (to evaluate load path dependency) at a 90 % level. The majority of the hold points require sealability evaluation. Sealability evaluation shall be by the water-column method (see 5.8.1 and Figure 14).

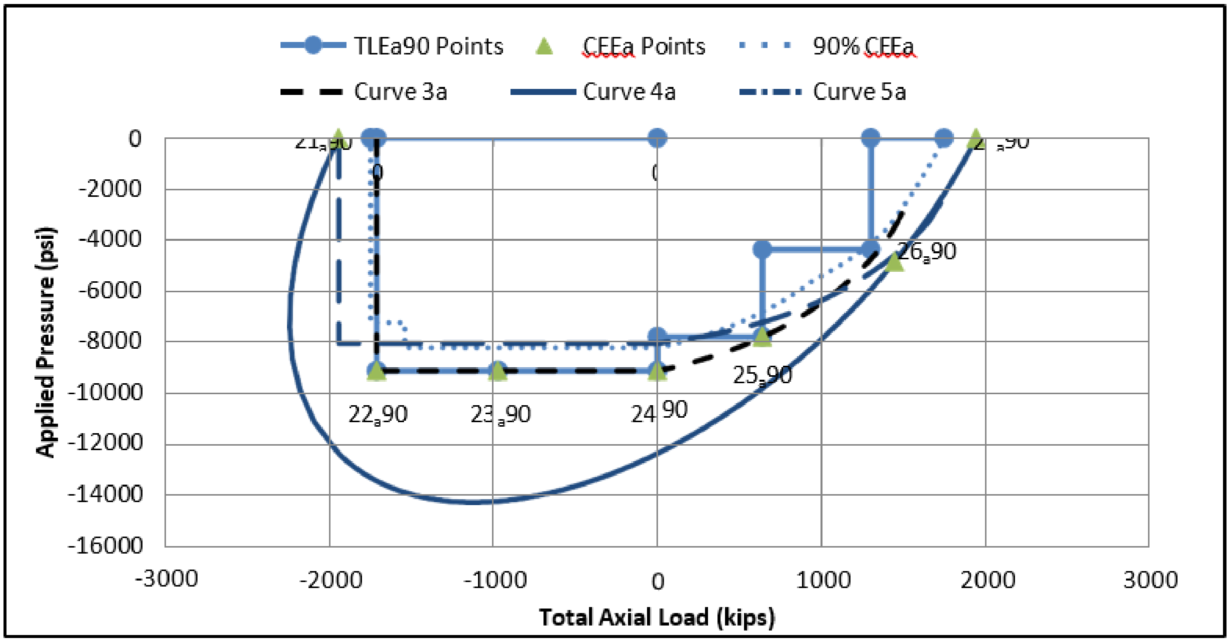


Figure D.31—A^{a} 90 % (QIII, QIV) and A^{a} 90 % (QIV, QIII), TS-A Load Steps 149 to 175

Table D.38—TS-A 90 % Level at Ambient Temperature (QIII, QIV) and (QIV, QIII)

Continue CAL IV TS-A with A^{a} 90 % (QIII, QIV) and A^{a} 90 % (QIV, QIII) Leak Detection for TS-A at Ambient Temperature								
Load Step	**LP**	**Total Load (kips)**	**CEPL (kips)**	**Frame Load (kips)**	**Pressure (psi)**	**Temperature (°F)**	**Hold Time (min)**	**Direction**
149	0	0	0	0	0	Ambient		CCW (90 % Level) See Table 9, Table D.19, and Figure D.31
150	$21_{a}90$	−1748	0	−1748	0	Ambient	2	
151	Transition	−1710	0	−1710	0	Ambient		
152	$22_{a}90$	−1710	0	−1710	−9140	Ambient	60	
153	Transition	−971	0	−971	−9140	Ambient		
154	$23_{a}90$	−971	0	−971	−9140	Ambient	10	
155	Transition	−971	0	−971	−9140	Ambient		
156	$24_{a}90$	0	0	0	−9140	Ambient	10	
157	Transition	0	0	0	−7811	Ambient		
158	$25_{a}90$	641	0	641	−7811	Ambient	10	
159	Transition	641	0	641	−4373	Ambient		
160	$26_{a}90$	1301	0	1301	−4373	Ambient	10	
161	Transition	1301	0	1301	0	Ambient		
162	$27_{a}90$	1748	0	1748	0	Ambient	2	
163	Transition	1301	0	1301	0	Ambient		CW (90 % Level)
164	$26_{a}90$	1301	0	1301	−4373	Ambient	10	
165	Transition	641	0	641	−4373	Ambient		
166	$25_{a}90$	641	0	641	−7811	Ambient	10	
167	Transition	0	0	0	−7811	Ambient		
168	$24_{a}90$	0	0	0	−9140	Ambient	60	
169	Transition	−971	0	−971	−9140	Ambient		

170	23$_{a}$90	−971	0	−971	−9140	Ambient	10	See Table 9, Table D.19, and Figure D.31
171	Transition	−971	0	−971	−9140	Ambient		
172	22$_{a}$90	−1710	0	−1710	−9140	Ambient	10	
173	Transition	−1710	0	−1710	0	Ambient		
174	21$_{a}$90	−1748	0	−1748	0	Ambient	2	
175	0	0	0	0	0	Ambient		
End of Begin A^{a} 90 % (QIII, QIV) and A^{a} 90 % (QIV, QIII) Switch from External Pressure to Internal Pressure Testing								

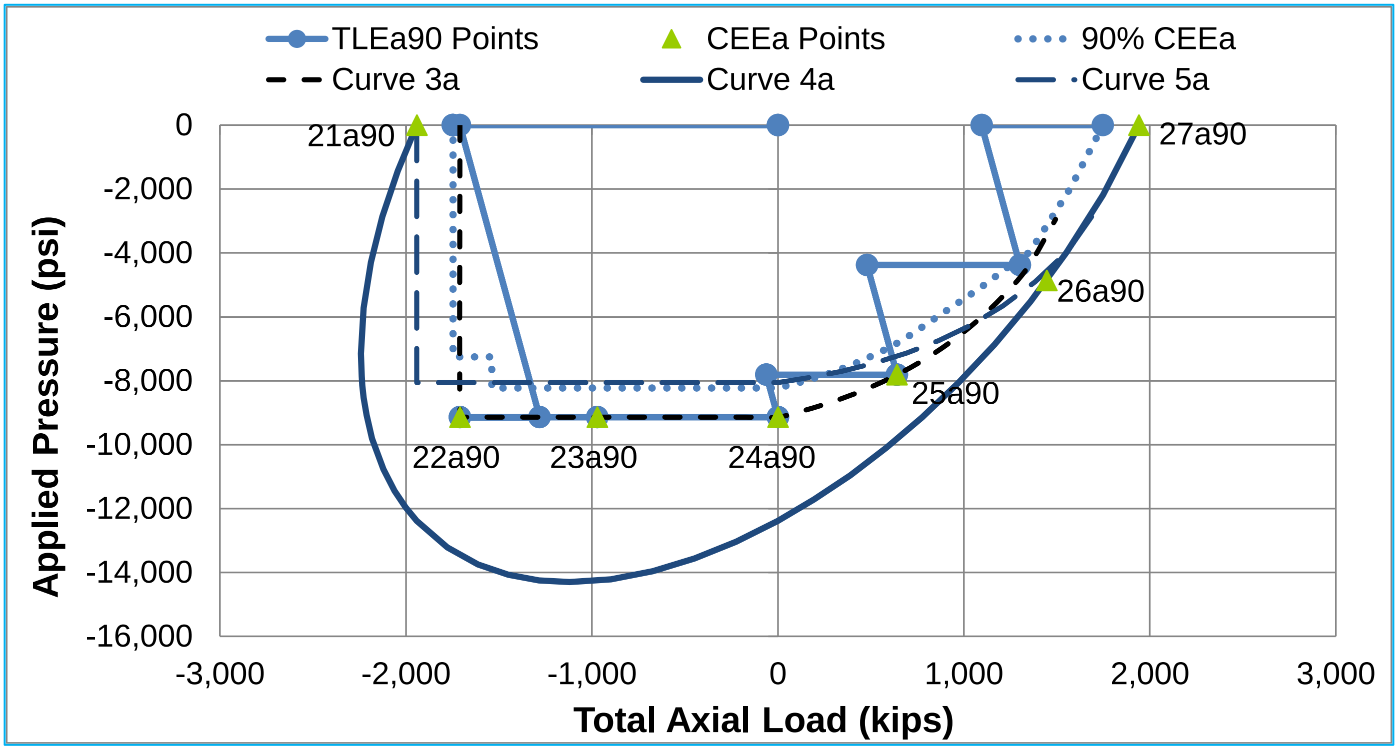


Figure XX. – Aa 90% (QIII, QIV) and Aa 90% (QIV, QIII), TS-A Load Steps 149 to 175 with external capped-end effect

Table XX. – TS-A 90% Level at Ambient Temperature (QIII, QIV) and (QIV, QIII) with external CEPL

Continue CAL IV TS-A with Aª 90% (QIII, QIV) and Aª 90% (QIV, QIII) Leak Detection for TS-A at Ambient Temperature								
Load Step	LP	Total Load (kips)	CEPL (kips)	Frame Load (kips)	Pressure (psi)	Temperature (°F)	Hold Time (min)	Direction
149	0	0	0	0	0	Ambient		
150	21a90	-1,748	0	-1748	0	Ambient	2	
151-1	Transition	-1,710	0	-1710	0	Ambient		
151-2	Transition	-1,281	429	-1710	-9,140	Ambient		
152	22a90	-1,710	429	-2139	-9,140	Ambient	60	CCW (90% Level)
153	Transition	-971	429	-1400	-9,140	Ambient		
154	23a90	-971	429	-1400	-9,140	Ambient	10	
155	Transition	0	429	-429	-9,140	Ambient		
156	24a90	0	429	-429	-9,140	Ambient	10	

157	Transition	-62	367	-429	-7,811	Ambient		
158	25a90	641	367	274	-7,811	Ambient	10	
159	Transition	479	205	274	-4,373	Ambient		
160	26a90	1,301	205	1096	-4,373	Ambient	10	
161	Transition	1,096	0	1096	0	Ambient		
162	27a90	1,748	0	1748	0	Ambient	2	
163	Transition	1,096	0	1096	0	Ambient		CW (90% Level)
164	26a90	1,301	205	1096	-4,373	Ambient	10	
165	Transition	479	205	274	-4,373	Ambient		
166	25a90	641	367	274	-7,811	Ambient	10	
167	Transition	-62	367	-429	-7,811	Ambient		
168	24a90	0	429	-429	-9,140	Ambient	60	
169	Transition	-971	429	-1400	-9,140	Ambient		
170	23a90	-971	429	-1400	-9,140	Ambient	10	
171	Transition	-1,710	429	-2139	-9,140	Ambient		
172	22a90	-1,710	429	-2139	-9,140	Ambient	10	
173-1	Transition	-1,281	429	-1710	-9,140	Ambient		
173-2	Transition	-1,710	0	-1710	0	Ambient		
174	21a90	-1,748	0	-1748	0	Ambient	2	
175	0	0	0	0	0	Ambient		
End of Aª 90% (QIII, QIV) and Aª 90% (QIV, QIII) Switch from External Pressure to Internal Pressure Testing								

D.6.4.8 TS-A 90 % Level at Ambient Temperature (QII, QI)

As shown in Figure D.32 and Table D.39, CAL IV TS-A continues with internal pressure testing. A series of QI/QII load points is executed in the CW direction to allow evaluation of load path dependency at a 90 % level. The majority of the hold points require sealability evaluation. This testing can be performed with the external pressure vessel installed, and sealability evaluation is by the water-column method (see 5.8.1 and Figure 14). However, the external pressure vessel may be removed so that one of the leak-detection methods described in 5.7 may be used. Successful completion of each test through the end of this test sequence demonstrates the test specimen's compliance for CAL IV at a 90 % level.

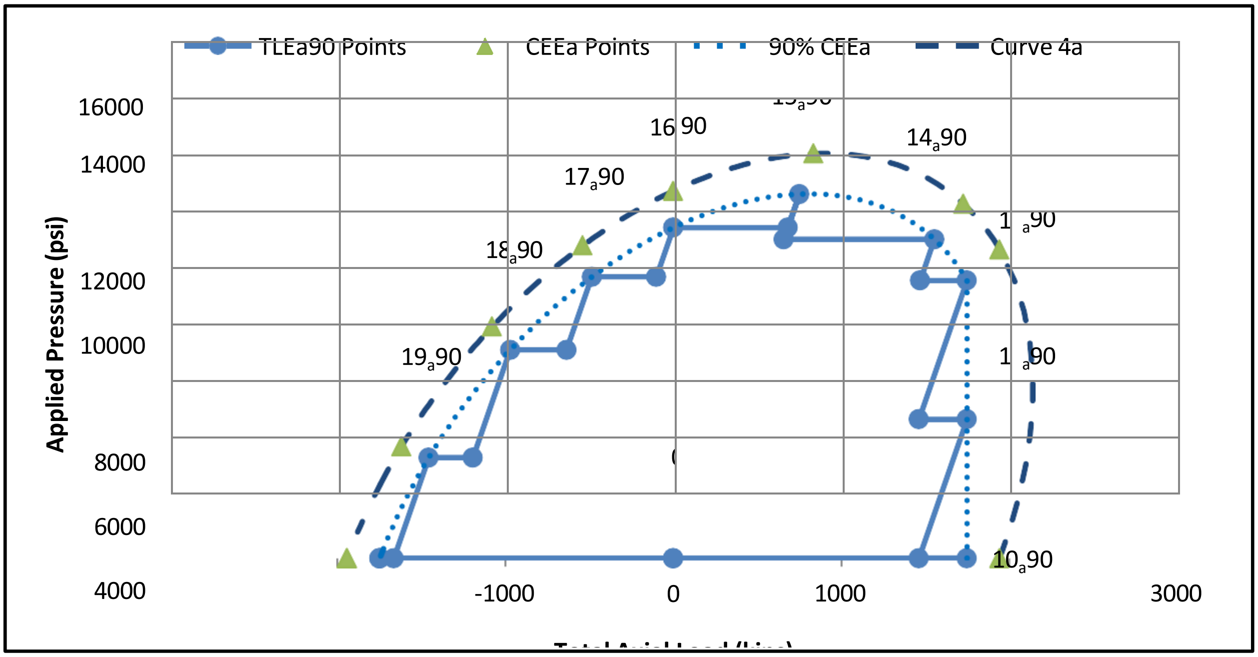


Figure D.32—A^a 90 % (QI, QII), TS-A Load Steps 176 to 198

Table D.39—TS-A 90 % Level at Ambient Temperature (QII, QI)

Continue CAL IV TS-A with A^a 90 % (QII, QI) Leak Detection for TS-A at Ambient Temperature								
Load Step	**LP**	**Total Load (kips)**	**CEPL (kips)**	**Frame Load (kips)**	**Pressure (psi)**	**Temperature (°F)**	**Hold Time (min)**	**Direction**
176	0	0	0	0	0	Ambient		CW (90 % Level) See Table 9, Table D.19, and Figure D.32
177	21_a90	−1748	0	−1748	0	Ambient	2	
178	Transition	−1748	0	−1748	0	Ambient		
179	20_a90	−1748	0	−1748	0	Ambient	2[b]	
180	Transition	−1664	0	−1664	0	Ambient		
181	19_a90	−1456	207	−1664	3554	Ambient	10	
182	Transition	−1193	207	−1400	3554	Ambient		
183	18_a90	−971	429	−1400	7363	Ambient	60	
184	Transition	−636	429	−1065	7363	Ambient		
185	17_a90	−485	580	−1065	9942	Ambient	10	
186	Transition	−102	580	−681	9942	Ambient		
187	16_a90	0	681	−681	11,683	Ambient	10	
188	Transition	681	681	0	11,683	Ambient		
189	15_a90	750	750	0	12,866	Ambient	10	
190	Transition	657	657	0	11,267	Ambient		
191	14_a90	1553	657	896	11,267	Ambient	60	
192	Transition	1469	572	896	9815	Ambient		
193	13_a90	1748	572	1175	9815	Ambient	10	

Table D.39—TS-A 90 % Level at Ambient Temperature (QII, QI) (Continued)

Continue CAL IV TS-A with A^{a} 90 % (QII, QI) Leak Detection for TS-A at Ambient Temperature								
Load Step	**LP**	**Total Load (kips)**	**CEPL (kips)**	**Frame Load (kips)**	**Pressure (psi)**	**Temperature (°F)**	**Hold Time (min)**	**Direction**
194	Transition	1461	286	1175	4908	Ambient		CW (90 % Level) See Table 9, Table D.19, and Figure D.32
195	$12_{a}90$	1748	286	1461	4908	Ambient	10	
196	Transition	1461	0	1461	0	Ambient		
197	$10_{a}90$	1748	0	1748	0	Ambient	2	
198	0	0	0	0	0	Ambient		
End of TS-A 90 % Level								

[b] Since there is no pressure at this load point, the hold time was reduced from 10 minutes to 2 minutes.

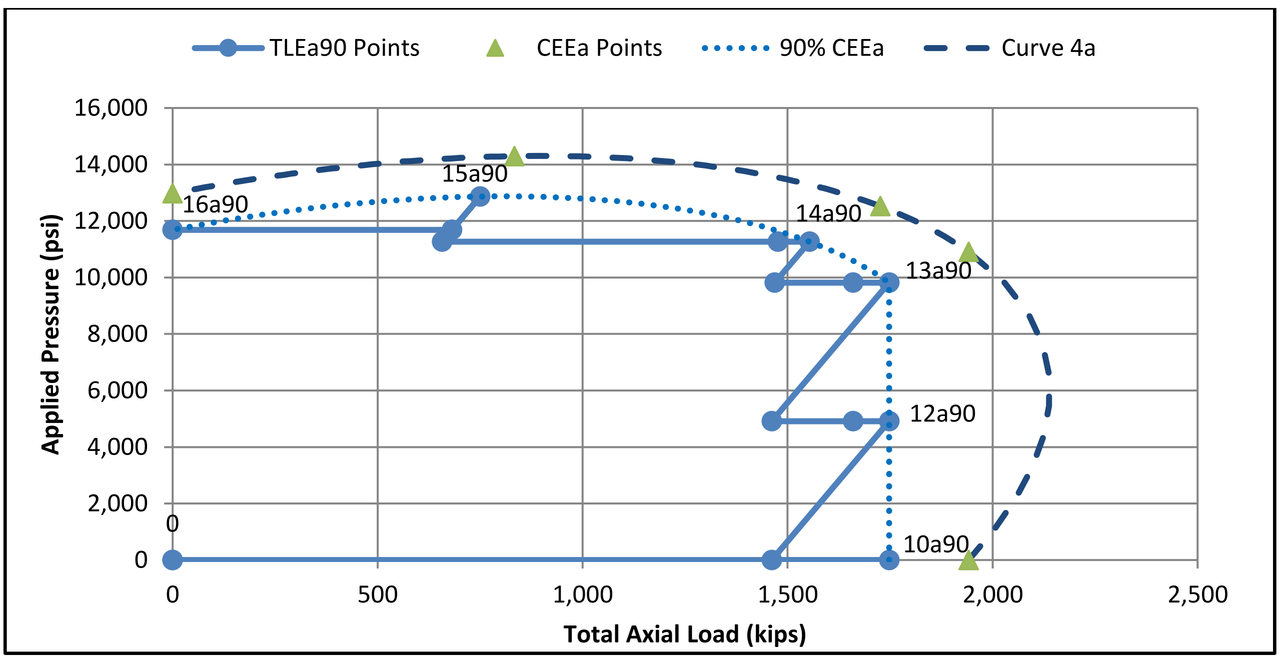


Figure D.X—A^{a} 90 % (QI), TS-A Load Steps 189 to 201 with optional transition load points

Table D.X—TS-A 90 % Level at Ambient Temperature (QI, QII) with additional and optional transition load points between LP10, LP12, LP13 and LP14

Optional transition load path between LP 10, LP 12, LP13 and LP14 CAL IV TS-A with *A*[a] 90 % (QI, QII) Leak Detection for TS-A at Ambient Temperature								
Load Step	**LP**	**Total Load (kips)**	**CEPL (kips)**	**Frame Load (kips)**	**Pressure (psi)**	**Temperature (°F)**	**Hold Time (min)**	**Direction**
189	15a90	750	750	0	12,866	Ambient	10	CW (90 % Level) See Table 9, Table D.19, and Figure D.X
190	Transition 1st step	657	657	0	11,267	Ambient		
191	Transition 2nd step	1476	657	819	11267	Ambient		
192	14a90	1553	657	896	11,267	Ambient	60	
193	Transition 1st step	1469	572	896	9815	Ambient		
194	Transition 2nd step	1660	572	1088	9815	Ambient		
195	13a90	1748	572	1175	9815	Ambient	10	
196	Transition 1st step	1461	286	1175	4908	Ambient		
197	Transition 2nd step	1660	286	1375	4908	Ambient		
198	12a90	1748	286	1461	4908	Ambient	10	
199	Transition	1461	0	1461	0	Ambient		
200	10a90	1748	0	1748	0	Ambient	2	
201	0	0	0	0	0	Ambient		

D.7.4.9 **TS-A 95 % Level at Ambient Temperature (QI, QII)**

To demonstrate connection performance at a 95 % level, CAL IV TS-A continues with internal pressure testing as shown in Figure D.33 and Table D.40. A series of QI/QII load points is executed in the CCW direction at a 95 % level. The majority of the hold points require sealability evaluation. This testing can be performed with the external pressure vessel installed, and sealability evaluation is by the water-column method (see 5.8.1 and Figure 14). However, the external pressure vessel may be removed so that one of the leak-detection methods described in 5.7 may be used.

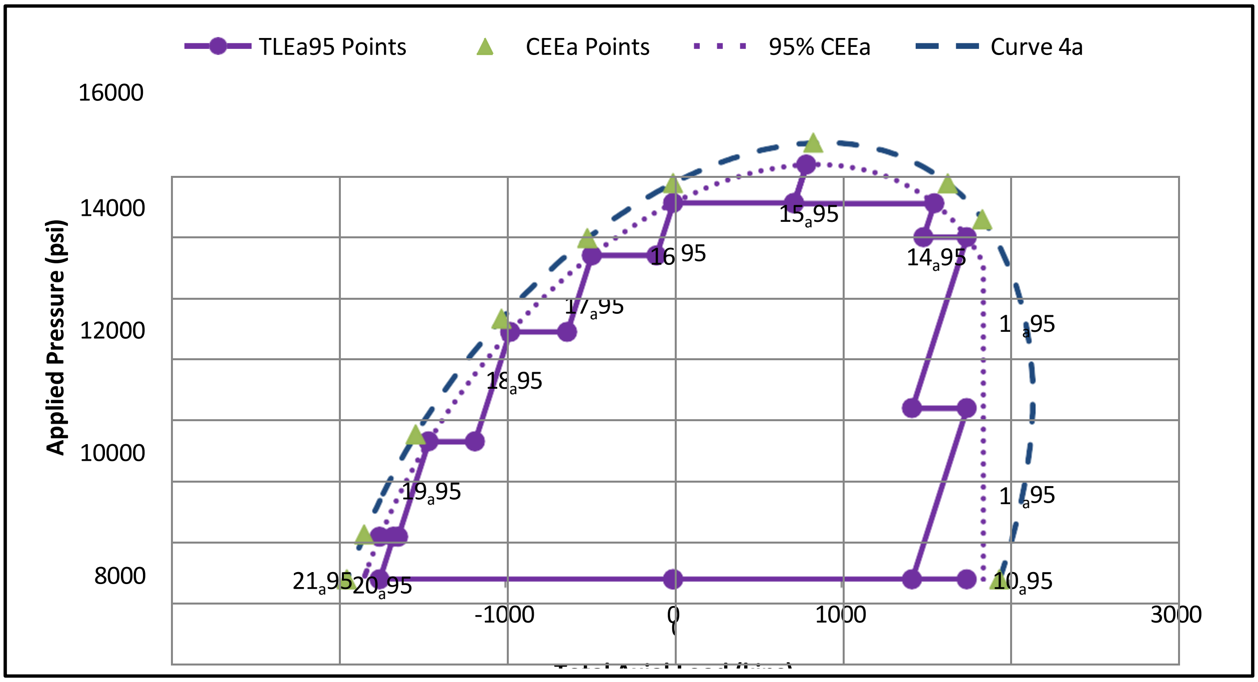


Figure D.33—A^{a} 95 % (QI, QII), TS-A Load Steps 199 to 221

Table D.40—TS-A 95 % Level at Ambient Temperature (QI, QII)

Continue TS-A with A^a 95 % (QI, QII) Leak Detection for TS-A at Ambient Temperature								
Load Step	**LP**	**Total Load (kips)**	**CEPL (kips)**	**Frame Load (kips)**	**Pressure (psi)**	**Temperature (°F)**	**Hold Time (min)**	**Direction**
199	0	0	0	0	0	Ambient		CCW (95 % Level) See Table 9, Table D.16, and Figure D.33
200	10$_a$95	1748	0	1748	0	Ambient	2	
201	Transition	1421	0	1421	0	Ambient		
202	12$_a$95	1748	327	1421	5603	Ambient	10	
203	Transition	1421	327	1094	5603	Ambient		
204	13$_a$95	1748	654	1094	11,206	Ambient	10	
205	Transition	1489	654	835	11,206	Ambient		
206	14$_a$95	1553	718	835	12,316	Ambient	10	
207	Transition	718	718	0	12,316	Ambient		
208	15$_a$95	792	792	0	13,581	Ambient	10	
209	Transition	719	719	0	12,332	Ambient		
210	16$_a$95	0	719	−719	12,332	Ambient	60	
211	Transition	−100	619	−719	10,612	Ambient		
212	17$_a$95	−485	619	−1104	10,612	Ambient	10	
213	Transition	−631	473	−1104	8108	Ambient		
214	18$_a$95	−971	473	−1444	8108	Ambient	10	
215	Transition	−1181	263	−1444	4513	Ambient		
216	19$_a$95	−1456	263	−1720	4513	Ambient	10	
217	Transition	−1638	81	−1720	1391	Ambient		
218	20$_a$95	−1748	81	−1829	1391	Ambient	10	
219	Transition	−1667	81	−1748	1391	Ambient		
220	21$_a$95	−1748	0	−1748	0	Ambient	2	
221	0	0	0	0	0	Ambient		
End of A^a 95 % (QI, QII) Switch from Internal Pressure to External Pressure Testing								

As described in 7.3.3.4, calculation for additional transition path between LP10, LP12, LP13 and 14 with up to 5% axial load approach to required Load Point for Test Series A 95% at ambient temperature.

Maximum Axial Load (LP 12 & 13)= 1748 kips

Maximum allowable axial approach (5% Maximum Axial Load)= 87.4kips

Maximum Axial Load (LP 14)= 1553 kips

Maximum allowable axial approach (5% Maximum Axial Load)= 77.7kips

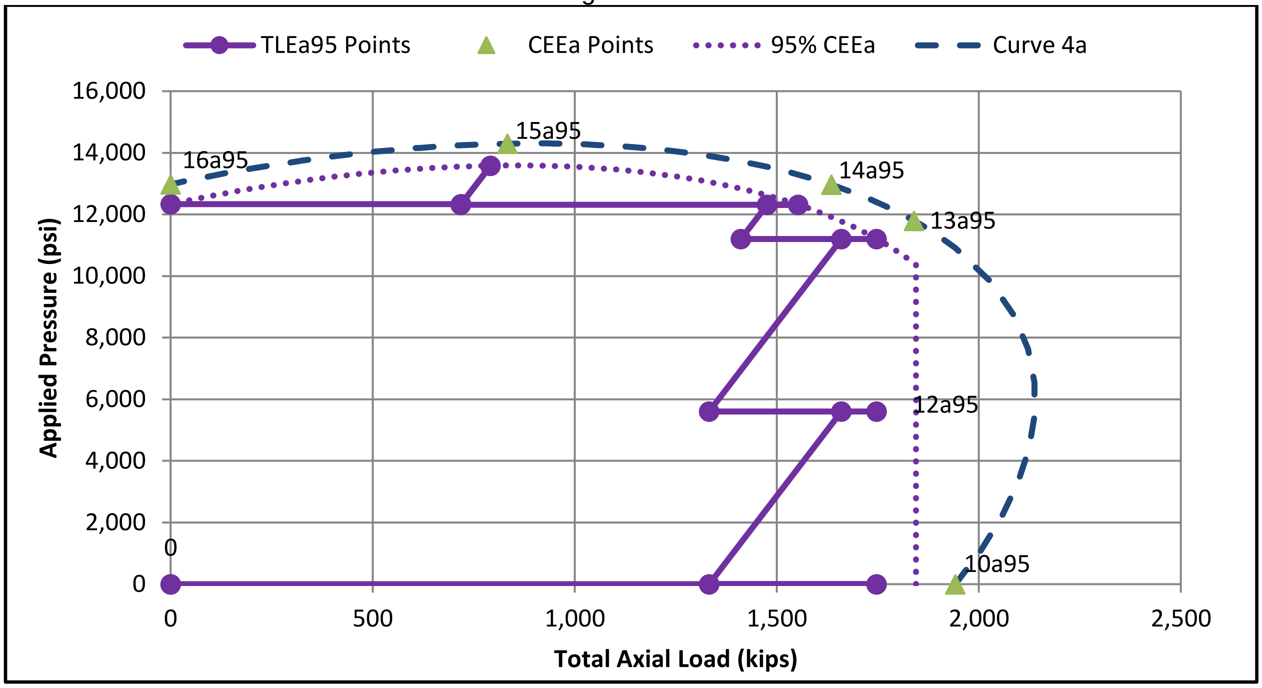


Figure D.X—A^a 95 % (QI), TS-A Load Steps 199 to 212 with optional transition load points

Optional transition load path between LP 10, LP 12, LP13 and LP14 CAL IV TS-A with A^a 95 % (QI, QII) Leak Detection for TS-A at Ambient Temperature								
Load Step	**LP**	**Total Load (kips)**	**CEPL (kips)**	**Frame Load (kips)**	**Pressure (psi)**	**Temperature (°F)**	**Hold Time (min)**	**Direction**
199	0	0	0	0	0	Ambient		CCW (95 % Level) See Table 9, Table D.16, and Figure D.X
200	10_{a}95	1748	0	1748	0	Ambient	2	
201	Transition 1st step	1333	0	1333	0	Ambient		
202	Transition 2nd step	1660	327	1333	5603	Ambient		
203	12_{a}95	1748	327	1421	5603	Ambient	10	
204	Transition 1st step	1333	327	1007	5603	Ambient		
205	Transition 2nd step	1660	654	1007	11206	Ambient		
206	13_{a}95	1748	654	1094	11,206	Ambient	10	
207	Transition 1st step	1411	654	758	11206	Ambient		
208	Transition 2nd step	1476	718	758	12316	Ambient		
209	14_{a}95	1553	718	835	12,316	Ambient	10	
210	Transition	718	718	0	12,316	Ambient		
212	15_{a}95	792	792	0	13,581	Ambient	10	

D.6.4.10 TS-A 95 % Level at Ambient Temperature (QIII, QIV) & (QIV, QIII)

As shown in Figure D.34 and Table D.41, CAL IV TS-A continues with external pressure testing. A series of QIII/QIV load points is executed first in the CCW and then in the CW direction (to evaluate load path dependency) at a 95 % level. The majority of the hold points require sealability evaluation. Sealability evaluation shall be by the water-column method (see 5.8.1 and Figure 14).

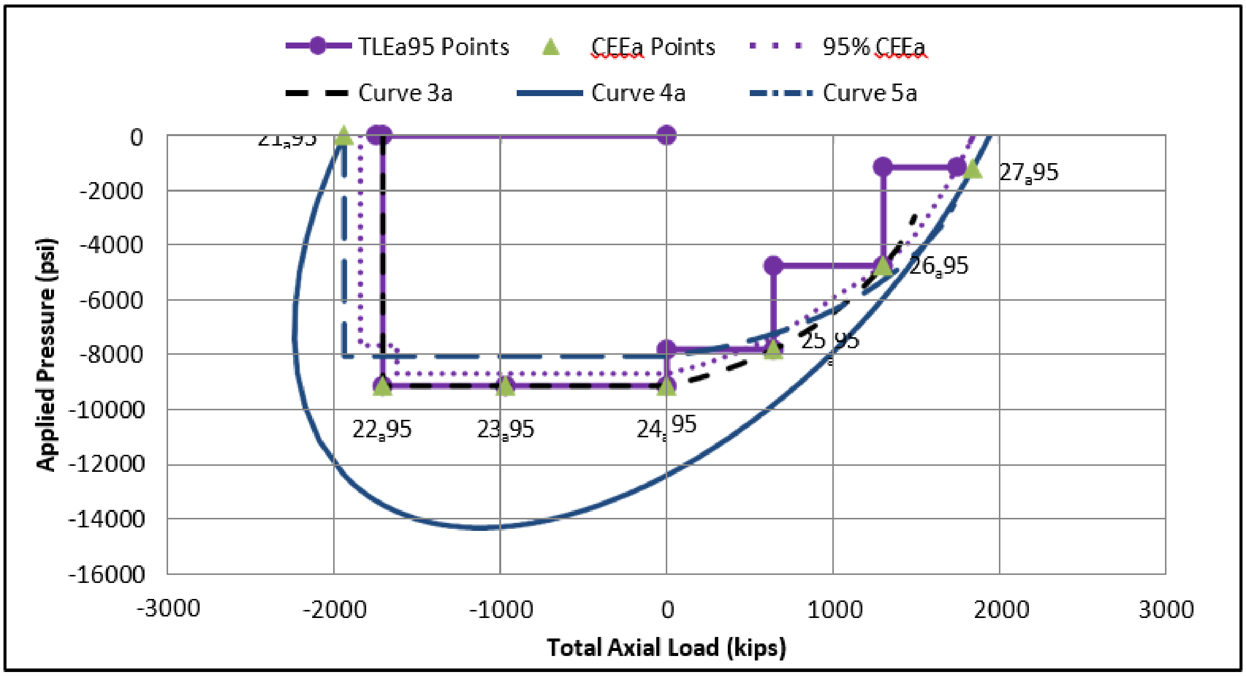


Figure D.34—A^a 95 % (QIII, QIV) and A^a 95 % (QIV, QIII), TS-A Load Steps 222 to 248

Table D.41—TS-A 95 % Level at Ambient Temperature (QIII, QIV) and (QIV, QIII)

Continue CAL IV TS-A with A^a 95 % (QIII, QIV) and A^a 95 % (QIV, QIII) Leak Detection for TS-A at Ambient Temperature								
Load Step	**LP**	**Total Load (kips)**	**CEPL (kips)**	**Frame Load (kips)**	**Pressure (psi)**	**Temperature (°F)**	**Hold Time (min)**	**Direction**
222	0	0	0	0	0	Ambient		CCW (95 % Level) See Table 9, Table D.16, and Figure D.34
223	21$_a$95	−1748	0	−1748	0	Ambient	2	
224	Transition	−1710	0	−1710	0	Ambient		
225	22$_a$95	−1710	0	−1710	−9140	Ambient	60	
226	Transition	−971	0	−971	−9140	Ambient		
227	23$_a$95	−971	0	−971	−9140	Ambient	10	
228	Transition	−971	0	−971	−9140	Ambient		
229	24$_a$95	0	0	0	−9140	Ambient	10	
230	Transition	0	0	0	−7811	Ambient		
231	25$_a$95	641	0	641	−7811	Ambient	10	
232	Transition	641	0	641	−4755	Ambient		
233	26$_a$95	1301	0	1301	−4755	Ambient	10	
234	Transition	1301	0	1301	−1154	Ambient		
235	27$_a$95	1748	0	1748	−1154	Ambient	2	

Table D.41—TS-A 95 % Level at Ambient Temperature (QIII, QIV) and (QIV, QIII) (Continued)

Continue CAL IV TS-A with A^a 95 % (QIII, QIV) and A^a 95 % (QIV, QIII) Leak Detection for TS-A at Ambient Temperature								
Load Step	**LP**	**Total Load (kips)**	**CEPL (kips)**	**Frame Load (kips)**	**Pressure (psi)**	**Temperature (°F)**	**Hold Time (min)**	**Direction**
236	Transition	1301	0	1301	−1154	Ambient		CW (95 % Level) See Table 9, Table D.16, and Figure D.34
237	26_a95	1301	0	1301	−4755	Ambient	10	
238	Transition	641	0	641	−4755	Ambient		
239	25_a95	641	0	641	−7811	Ambient	10	
240	Transition	0	0	0	−7811	Ambient		
241	24_a95	0	0	0	−9140	Ambient	60	
242	Transition	−971	0	−971	−9140	Ambient		
243	23_a95	−971	0	−971	−9140	Ambient	10	
244	Transition	−971	0	−971	−9140	Ambient		
245	22_a95	−1710	0	−1710	−9140	Ambient	10	
246	Transition	−1710	0	−1710	0	Ambient		
247	21_a95	−1748	0	−1748	0	Ambient	2	
248	0	0	0	0	0	Ambient		
End of A^a 95 % (QIII, QIV) and A^a 95 % (QIV, QIII) Switch from External Pressure to Internal Pressure Testing								

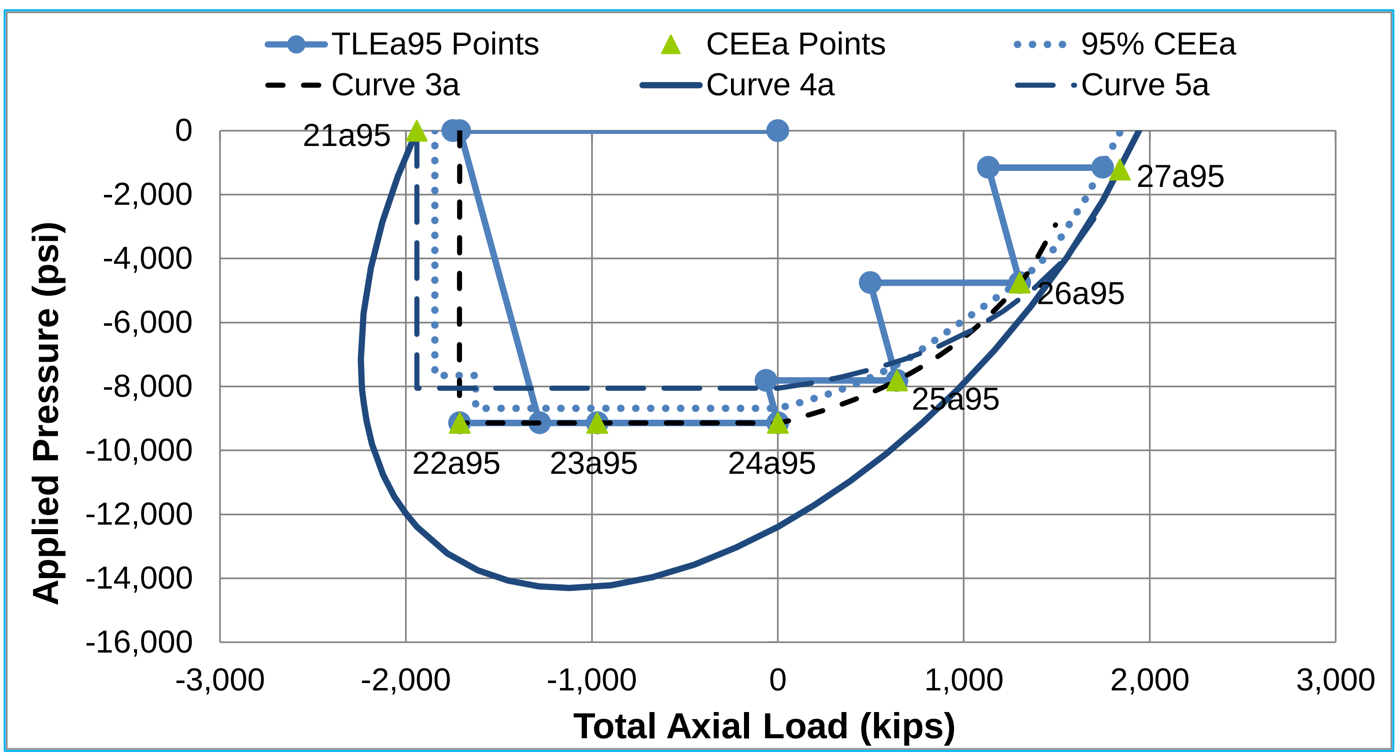


Figure XX. – Aa 95% (QIII, QIV) and Aa 95% (QIV, QIII), TS-A Load Steps 222 to 248 with external capped-end effect

Table D.X – TS-A 95% Level at Ambient Temperature (QIII, QIV) and (QIV, QIII) with external CEPL

Continue CAL IV TS-A with A^a 95% (QIII, QIV) and A^a 95% (QIV, QIII)
Leak Detection for TS-A at Ambient Temperature

Load Step	LP	Total Load (kips)	CEPL (kips)	Frame Load (kips)	Pressure (psi)	Temperature (°F)	Hold Time (min)	Direction
222	0	0	0	0	0	Ambient		
223	21a95	-1,748	0	-1,748	0	Ambient	2	
224-1	Transition	-1,710	0	-1,710	0	Ambient		
224-2	Transition	-1,281	429	-1,710	-9,140	Ambient		
225	22a95	-1,710	429	-2,139	-9,140	Ambient	60	
226	Transition	-971	429	-1,400	-9,140	Ambient		
227	23a95	-971	429	-1,400	-9,140	Ambient	10	
228	Transition	0	429	-429	-9,140	Ambient		CCW (95% Level)
229	24a95	0	429	-429	-9,140	Ambient	10	
230	Transition	-62	367	-429	-7,811	Ambient		
231	25a95	641	367	274	-7,811	Ambient	10	
232	Transition	497	223	274	-4,755	Ambient		
233	26a95	1,301	223	1,078	-4,755	Ambient	10	
234	Transition	1,132	54	1,078	-1,154	Ambient		
235	27a95	1,748	54	1,693	-1,154	Ambient	2	
236	Transition	1,132	54	1,078	-1,154	Ambient		
237	26a95	1,301	223	1,078	-4,755	Ambient	10	
238	Transition	497	223	274	-4,755	Ambient		
239	25a95	641	367	274	-7,811	Ambient	10	
240	Transition	-62	367	-429	-7,811	Ambient		
241	24a95	0	429	-429	-9,140	Ambient	60	
242	Transition	-971	429	-1,400	-9,140	Ambient		CW (95% Level)
243	23a95	-971	429	-1,400	-9,140	Ambient	10	
244	Transition	-1,710	429	-2,139	-9,140	Ambient		
245	22a95	-1,710	429	-2,139	-9,140	Ambient	10	
246-1	Transition	-1,281	429	-1,710	-9,140	Ambient		
246-2	Transition	-1,710	0	-1,710	0	Ambient		
247	21a95	-1,748	0	-1,748	0	Ambient	2	
248	0	0	0	0	0	Ambient		

End of A^a 95% (QIII, QIV) and A^a 95% (QIV, QIII)
Switch from External Pressure to Internal Pressure Testing

D.6.11 TS-A 95 % Level at Ambient Temperature (QII, QI)

As shown in Figure D.35 and Table D.42, CAL IV TS-A concludes with internal pressure testing. A series of QI/QII load points is executed in the CW direction, which allows evaluation of load path dependency at a 95 % level. The majority of the hold points require sealability evaluation. This testing can be performed with the external pressure vessel installed, and sealability evaluation is by the water-column method (see 5.8.1 and Figure 14). However, the external pressure vessel may be removed so that one of the leak-detection methods described in 5.7 may be used.

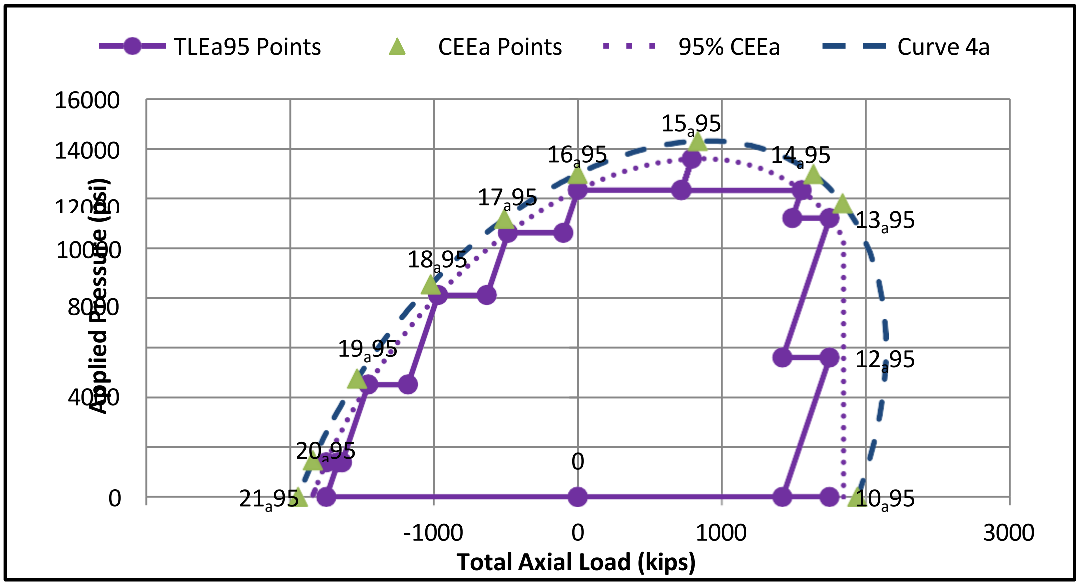


Figure D.35—A^{a} 95 % (QI, QII), TS-A Load Steps 249 to 271

Table D.42—TS-A 95 % Level at Ambient Temperature (QII, QI)

Continue CAL IV TS-A with A^{a} 95 % (QII, QI) Leak Detection for TS-A at Ambient Temperature								
Load Step	**LP**	**Total Load (kips)**	**CEPL (kips)**	**Frame Load (kips)**	**Pressure (psi)**	**Temperature (°F)**	**Hold Time (min)**	**Direction**
249	0	0	0	0	0	Ambient		CW (95 % Level) See Table 9, Table D.16, and Figure D.35
250	21a95	−1748	0	−1748	0	Ambient	2	
251	Transition	−1667	81	−1748	1391	Ambient		
252	20a95	−1748	81	−1829	1391	Ambient	10	
253	Transition	−1638	81	−1720	1391	Ambient		
254	19a95	−1456	263	−1720	4513	Ambient	10	
255	Transition	−1181	263	−1444	4513	Ambient		
256	18a95	−971	473	−1444	8108	Ambient	60	
257	Transition	−631	473	−1104	8108	Ambient		
258	17a95	−485	619	−1104	10,612	Ambient	10	
259	Transition	−100	619	−719	10,612	Ambient		
260	16a95	0	719	−719	12,332	Ambient	10	
261	Transition	719	719	0	12,332	Ambient		
262	15a95	792	792	0	13,581	Ambient	10	
263	Transition	718	718	0	12,316	Ambient		
264	14a95	1553	718	835	12,316	Ambient	60	
265	Transition	1489	654	835	11,206	Ambient		
266	13a95	1748	654	1094	11,206	Ambient	10	
267	Transition	1421	327	1094	5603	Ambient		
268	12a95	1748	327	1421	5603	Ambient	10	
269	Transition	1421	0	1421	0	Ambient		
270	10a95	1748	0	1748	0	Ambient	2	
271	0	0	0	0	0	Ambient		
End of CAL IV TS-A								

As described in 7.3.3.4, calculation for additional transition path between LP10, LP12, LP13 and 14 with up to 5% axial load approach to required Load Point for Test Series A 95% at ambient temperature.

Maximum Axial Load (LP 12 & 13)= 1748 kips

Maximum allowable axial approach (5% Maximum Axial Load)= 87.4kips

Maximum Axial Load (LP 14)= 1553 kips

Maximum allowable axial approach (5% Maximum Axial Load)= 77.7kips

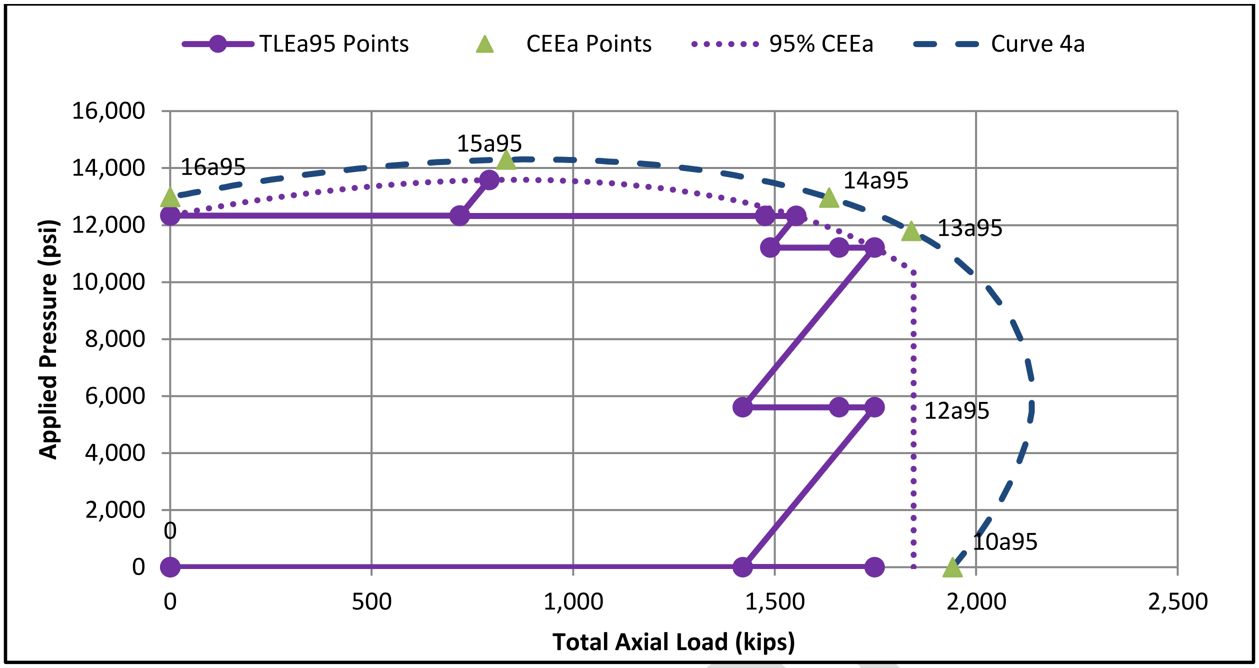


Figure D.X—A^a 95 % (QI), TS-A Load Steps 262 to 274 with optional transition load points

Optional transition load path between LP 10, LP 12, LP13 and LP14 CAL IV TS-A with A^a 95 % (QI, QII) Leak Detection for TS-A at Ambient Temperature								
Load Step	**LP**	**Total Load (kips)**	**CEPL (kips)**	**Frame Load (kips)**	**Pressure (psi)**	**Temperature (°F)**	**Hold Time (min)**	**Direction**
262	15a95	792	792	0	13581	Ambient	10	CW (95 % Level) See Table 9, Table D.16, and Figure D.X
263	Transition 1^{st} step	718	718	0	12316	Ambient		
264	Transition 2^{nd} step	1476	718	835	12316	Ambient		
265	14a95	1553	718	835	12316	Ambient	60	
266	Transition 1^{st} step	1489	654	835	11206	Ambient		
267	Transition 2^{nd} step	1660	654	1094	11206	Ambient		
268	13a95	1748	654	1094	11206	Ambient	10	
269	Transition 1^{st} step	1421	327	1094	5603	Ambient		
270	Transition 2^{nd} step	1660	327	1333	5603	Ambient		
271	12a95	1748	327	1421	5603	Ambient	10	
272	Transition	1421	0	1421	0	Ambient		
273	10a95	1748	0	1748	0	Ambient	2	
274	0	0	0	0	0	Ambient		
End of CAL-IV TS-A								