

Report of tests carried out on Viton O-ring Seals to assess suitability for operation over the temperature range -40°C to +220°C when used in Package Design 2863B

1. Introduction

To satisfy the requirements of US Regulatory bodies the O-ring seals in the containment vessels of Package Design 2863B have to be shown to operate satisfactorily (ie remain leaktight) at the extremes of temperature that they are expected to experience during both normal and hypothetical accident conditions of transport. For Package Design 2863B this effectively means that the seals must remain leaktight over the temperature range -40°C to + 220°C, but to ensure that an adequate safety margin exists the seals should preferably remain leaktight over the range -50°C to +250°C.

This test report describes the procedures and results of tests carried out on Viton seals over the temperature range -50°C to +250°C.

2. Administrative Details

2.1 The tests were carried out by M Lam and M B Johnson with the assistance, where appropriate, of the Inspection and Testing Services Division of AEA Technology, Harwell.

2.2 The work was carried out under Croft project reference Z93/11/10 during the period August 1994 - October 1994.

3. Test Procedures and Objective

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The general procedure followed during the tests was to measure the leaktightness of the seals whilst assembled into a mechanical assembly ('Test Head Assembly') which exactly represented the vessel closure section of the 2870 vessel. The test head assembly however had a shortened body, which enabled the assembly to be placed into the controllable temperature region of a temperature adjustable environmental chamber, thereby allowing leakage tests to be carried out over the whole temperature range from -50°C to +250°C. Assessment of seal temperature was made by the temperature measurement system contained in the environmental chamber, and cross-checked by thermocouples located close to the seals in the test head assembly.

The objective of the tests was to show that the seals remained leaktight as defined in ANSI N14.5 (Ref 1) throughout the temperature -50 to +250. Leakage tests were performed using helium mass spectrometry leakage testing. However, prior to carrying out these tests it was decided to first carry out a series of 'scoping' tests using pressure drop testing. The detailed procedures followed for these tests are

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contained in Croft procedures CP 157 Issue A and CP 158 Issue A.

4. Selection of Seal Material

Commercially available seals made from compounds based on Viton Fluorocarbon material are widely used in the UK in radioactive packagings.

Drop tests have been previously carried out on a prototype of the 2863B package, the seals in which were procured to a Dowty Seals Limited Viton Specification (Dowty Material Type 9775).

Subsequently it was recognised that not all aspects of performance of the Dowty Specification were needed to obtain satisfactory seal performance when used in the 2870 containment vessel.

After consideration of what parameters were essential to be included in the procurement specification for such seals, specification CM 055 Issue B was produced to include these. The seals used in the tests described in this report were therefore procured from Ceetak Limited (Ref 2) to Material Specification CM 055 Issue B, and dimensional requirements as defined for containment vessel Design Number 2870, in drawing number 1C-2415 Issue E.

5. Results

5.1 Test Head Assembly

The test head assembly was manufactured by Oxford Engineering Limited (Ref 3) to Drawing List DL-OC-4027 Issue A under Croft project reference Y93/9/18.

Prior to use, however, 2 additional features were added to facilitate the testing; firstly an additional connection was made through the lid to enable the test head cavity to be evacuated through one hole and back filled with helium through the other; secondly 2 additional holes were added to allow use of 4 (rather than 2) thermocouples for monitoring the seal temperature.

Detailed metrology carried out on the test head assembly showed that with the exception of the above two modifications the test head complied in all respects with the design requirements detailed under drawing list DL-OC-4027 Issue A. In particular the O-ring groove profiles and positions were all within specification, with the groove depths being measured at an actual dimension of 2.23 mm which is within specification requirements of 2.17/2.32 mm.

5.2 Environmental Chamber and Thermocouples

The environmental chamber equipment used during the tests was supplied by Climatic Systems Limited (Ref 4).

The equipment was purpose-built for this test work but the design was based on a standard Climatic Systems product (Model BT 125 L), with a modification to enable it to operate at a higher temperature (250°C compared to 180°C for the standard equipment). The chamber temperature is measured by a calibrated measurement system contained within the equipment. The system uses platinum resistance thermometry and the temperature is displayed on an integral display panel. Temperature stability of the chamber is stated to be within $\pm 0.5^\circ\text{C}$, with thermal gradient within the chamber to within $\pm 1^\circ\text{C}$.

The voltages developed by the thermocouples installed in the test head were converted to temperatures by an interface which fed directly into a data logging system. The accuracy of the logged temperatures was checked by comparison with independent thermocouple measurements made with a calibrated instrument (Digitron Model 3202K, Serial No 051/9). Measurements agreed to within 2-3°C. Comparison of the temperatures measured by the environmental chamber measurement system with the data logged temperatures measured on the thermocouples showed agreement generally to within $\pm 1^\circ\text{C}$.

Because the thermocouple measurements were not directly calibrated measurements they were only used to verify temperature stability of the test head during leakage testing. Measured temperatures quoted later in this report therefore refer to the figures taken from the environmental chamber display.

5.3 Seals

7 sets of seals were used during the tests; 4 sets for the initial pressure drop testing trials, and 3 further sets for the helium leakage tests.

No tests were performed on the seals to verify that the seal material was indeed a Viton formulation, but certificates of conformity supplied with the O-rings certified that they met specification, and as the supplier, Ceetak Ltd (Ref 1), is a recognised O-ring supplier approved by Lloyds Register as an approved stockist to ISO 9002, it was decided that Certificates of Conformity provided adequate guarantee of material conformance to specification.

The cross section diameter and hardness were checked prior to use and found to be within specification on all O-rings. Before each test the O-rings were visually inspected to confirm that they were free from mechanical defects

(cuts, scratches, etc).

The low temperature pressure drop tests were performed with the O-rings lightly lubricated by wiping with silicone grease. The high temperature pressure drop tests however were performed with un-lubricated rings.

It was initially intended to perform comparative measurements at both high and low temperatures with both lubricated and un-lubricated rings. However, due to time pressure it was not possible to complete these measurements before proceeding to the helium leakage tests, which were carried out with lubricated O-rings only.

5.4 Seal Compression/Torque Setting

The operating procedure for the 2863B package design specifies that the 2870 containment can should be closed using a torque of between 160 and 180 Nm applied to the screw retaining ring. Pre-test trials showed that although the package will, at room temperature, be leaktight to the required level when closed at this torque setting the lid and vessel body will not quite be in metal to metal contact. Further trials showed a torque of 195 Nm was needed to provide a metal to metal condition, and therefore all tests were carried out after closing the test head assembly using a torque of 200 Nm. The relative positions of the screw retaining ring and test head were marked in the metal to metal condition to provide a further check that the same condition was achieved on subsequent assembly of the components.

As stated in 5.1 the depths of the O-ring grooves were measured to be 2.23 mm, therefore in the metal to metal condition the seal compression was nominally 25.7%, based on the nominal O-ring cross section diameter of 3mm.

5.5 Pressure Drop Leakage Tests

The general set up and test procedure used for the pressure drop tests was as detailed in procedure CP 158 Issue A. A CALT 5 Leakage Tester was used to perform the leakage rate measurements. The pass criterion was set arbitrarily as a leakage rate of 5×10^{-4} bar cc/s SLR.

The full set of results from all the pressure drop tests are listed in Appendix 1. These results are summarised in Table 1. The tests can be broadly classified into 4 categories; initial set-up trials, low temperature tests, high temperature tests, and finally confirmatory low temperature tests prior to helium leakage testing.

The initial set up trials concentrated on low temperature performance since it is at low temperatures that Viton's ability to remain leaktight is most in question.

More than one set of seals were used during the set up trials. The seals were then replaced at the start of each of the subsequent phases of testing and the seals were not changed during these test phases. The test head assembly was cleaned each time it was dismantled for replacement of the seals.

The results of the leakage tests during the set-up trials indicated that although there was no gross leakage, the leakage rate exceeded the pass criterion in 3 of the 7 tests (all at $< -40^{\circ}\text{C}$).

The results of the low temperature and high temperature tests showed that the seals achieved the pass criterion of leakage rate $< 5 \times 10^{-4}$ bar cc/s SLR throughout, including after returning the seals to ambient temperature.

The results of the leakage tests during the confirmatory low temperature tests indicated that the seals leaked (at a leakage rate greater than 5×10^{-4} bar cc/s SLR) when the temperature was at, or below, -30°C .

No obvious reason was found for why the confirmatory tests in particular did not follow the pattern of the earlier low temperature testing, and as the prime objective of the test program was to assess the ability of these Viton seals to remain leaktight to helium at an even lower leakage rate pass criterion it was decided to discontinue further pressure drop testing and proceed with the helium tests.

Visual examination of each set of seals after testing showed no obvious signs of physical degradation of the seals either at high or low temperatures.

5.6 Helium Leakage Tests

The general set up and test procedure used for the helium leakage tests was as detailed in procedure CP 157 Issue A.

The tests were carried out by the Inspection and Testing Services section of AEA Technology, Harwell under the supervision of Croft Associates staff.

Before carrying out the leakage tests the rate at which helium permeated through the Viton seals was assessed in accordance with the procedure described in Appendix A of CP 157. It was found that it took approximately 60 minutes for the apparent leakage rate due to permeation to increase from a background rate of 1×10^{-9} bar cc/s to 1×10^{-7} bar cc/s. On the basis of this result it was therefore decided that during leakage tests the monitoring

time should be limited to a maximum of 10 minutes.

The full set of results of the helium leakage tests is summarised in Table 2.

3 sets of seals were used during these tests; set 1 for tests VH1 and VH2; set 2 for tests VH3 and VH4; and set 3 for all subsequent tests. Set 1 was not the same set that was used for the confirmatory pressure drop tests.

From the results (VH1 and VH2) it can be seen that the seals (Set 1) which were leaktight at ambient were leaking when retested after the test assembly had been cooled down to -40°C . A similar result was then subsequently obtained on testing seal set 2 which was found to be leaking on testing at -30°C .

The intention in testing the third set of seals was to determine the lowest temperature at which the seals remained leaktight, but, as can be seen from the results, the seals remained leaktight down to -45°C during these tests, and were confirmed to still be leaktight on warming back up to room temperature.

A single test was performed at high temperature but a high helium background level was found at the start of this test. It was concluded that this was due to outgassing of helium which had been absorbed into the seals during the low temperature tests. Further testing was suspended pending a review of the results obtained to date.

6. Conclusions

The variability of the results at low temperature, by both pressure drop and helium leakage testing, would indicate that the particular formulation of Viton tested cannot be used to provide a reliable leaktight seal at -40°C .

Although the results of the pressure drop tests at high temperature were satisfactory, insufficient testing has been carried out using helium leakage testing to draw a firm conclusion about the high temperature performance of the material tested.

References

1. American National Standard for radioactive materials - leakage tests on packages for shipment: ANSI N14.5. 1987.

2. Ceetak Limited
1 Napier Road
BEDFORD
England
MK41 0QR

3. Oxford Engineering Limited
6 Colwell Drive
Abingdon Business Park
Oxfordshire
OX14 1AU

4. Climatic Systems Limited
Elm Place
Station Road
RUSTINGTON
West Sussex
England BN16 3BJ

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Checked and Approved

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Date

13/10/95

Table 1 - Results of Pressure Drop Leakage Tests

Test Phase	Test Date	Test Reference # (On CALT printout)	Temperature (°C)	Leakage Rate (bar cc/s SLR)	Pass/Fail	Comment	
Set up trials	5/8/94	1	-40	2.8×10^{-6}	Pass		
	5/8/94	2	-45	6.7×10^{-6}	Pass		
	5/8/94	3	-50	1.4×10^{-6}	Pass		
	5/8/94	4	-50	1.9×10^{-5}	Pass	Repeat of test 3 after 1 hour soak. Test head dismantled after test. Seals changed	
	10/8/94	1	-45	3×10^{-3}	Fail		
	11/8/94	1	-43	5.1×10^{-4}	Fail		
	12/8/94	1	-45	6.3×10^{-4}	Fail	Test head dismantled after test. Seals changed	
						
	Low temp Tests	8/9/94	1	18	8.6×10^{-6}	Pass	
8/9/94		2	10	5.6×10^{-6}	Pass		
8/9/94		3	0	1.5×10^{-5}	Pass		
8/9/94		4	-10	6.3×10^{-6}	Pass		
8/9/94		5	-20	9.2×10^{-6}	Pass		
8/9/94		6	-30	1.6×10^{-6}	Pass	Warmed up to RT after test to avoid overnight	
9/9/94		7	-30	1.0×10^{-6}	Pass	Re-test of previous result after re-cooling.	
9/9/94		8	-35	5.9×10^{-6}	Pass		
9/9/94		9	-40	1.4×10^{-5}	Pass		
9/9/94		10	-45	3.9×10^{-5}	Pass		
9/9/94		11	-50	1.8×10^{-5}	Pass		
10/9/95		12	-50	1.2×10^{-5}	Pass	Repeat of test 11 after 24 hour soak at -50°C	
12/9/95		13	17	5.1×10^{-7}	Pass		
.....							

Table 1 continued - Results of Pressure Drop Leakage Tests

Test Phase	Test Date	Test Reference # (On CALT printout)	Temperature (°C)	Leakage Rate (bar cc/s SLR)	Pass/Fail	Comment	
High temp Tests	12/9/94	V14	18	1.1×10^{-5}	Pass		
	12/9/94	V15	50	1.4×10^{-5}	Pass		
	12/9/94	V16	100	2.6×10^{-5}	Pass	Temp reduced after test to avoid overnight soak	
	13/9/94	V17	32	3.6×10^{-5}	Pass		
	13/9/94	V18	150	1.1×10^{-5}	Pass		
	13/9/94	V19	175	5.6×10^{-5}	Pass		
	13/9/94	V20	200	4.3×10^{-4}	Pass		
	13/9/94	V21	225	1.0×10^{-4}	Pass		
	13/9/94	V22	250	1.1×10^{-4}	Pass		
	14/9/94	V23	250	1.1×10^{-4}	Pass	Repeat of test V22 after 24 hours soak at 250°	
	15/9/94	V24	21	2.0×10^{-5}	Pass	Test head dismantled after test, and seals changed	
						
	Confirmatory	4/10/94	VA1	15	1.3×10^{-5}	Pass	
	Low Temp	4/10/94	VA2	10	8.6×10^{-6}	Pass	
Tests	4/10/94	VA3	0	1.1×10^{-5}	Pass		
	4/10/94	VA4	-10	1.2×10^{-5}	Pass		
	4/10/94	VA5	-20	1.0×10^{-5}	Pass		
	5/10/94	VA6	-30	8.1×10^{-6}	Pass		
	5/10/94	VA7	-35	Gross Leak	Fail	Test head failed to hold pressure. System warmed	
	5/10/94	VA8	21	1.8×10^{-6}	Pass		
	5/10/94	VA9	-30	1.7×10^{-3}	Fail	Test head dismantled after test and seals changed	

Table 2 - Results of Helium Leakage Tests

Test Date	Test Ref #	Temperature (°C)	Background Leakage Rate Before Helium Admitted to Chamber (bar cc/s (He))	Measured Leakage Rate After Evacuation and Backfilling with He (bar cc/s (He))	Comment
25/9/94	VH1	19	1.6×10^{-9}	1.6×10^{-9}	No detectable leak
25/9/94	VH2	-40	6×10^{-9}	Off Scale	Gross Leak. Head dismantled, seals changed after test.
25/9/94	VH3	21	$< 1 \times 10^{-9}$	1×10^{-9}	No detectable leak
25/9/94	VH4	-30	Failed to hold vacuum - Gross leak		Head dismantled, seals changed, after test.
13/10/94	VH5	21	$< 1 \times 10^{-9}$	1×10^{-9}	No detectable leak
13/10/94	VH6	-25	$< 1 \times 10^{-8}$	$< 1 \times 10^{-8}$	No detectable leak
13/10/94	VH7	-30	$< 1 \times 10^{-8}$	$< 1 \times 10^{-8}$	No detectable leak
13/10/94	VH8	-35	$< 1 \times 10^{-8}$	$< 1 \times 10^{-8}$	No detectable leak
13/10/94	VH9	-40	$< 2 \times 10^{-8}$	$< 1 \times 10^{-8}$	No detectable leak
13/10/95	VH10	-45	$< 1.8 \times 10^{-8}$	$< 1 \times 10^{-8}$	No detectable leak
14/10/94	VH11	20	$< 4.4 \times 10^{-7}$	3.9×10^{-7}	Pass - Result affected by helium absorbed into seals.
14/10/94	VH12	20	$< 1 \times 10^{-8}$	$< 1 \times 10^{-8}$	After pumping on seals to remove absorbed helium.
14/10/94	VH13	216	2×10^{-5}	2.2×10^{-4}	Unreliable result due to high outgassing of absorbed H

Appendix 1

CALT printouts of pressure drop tests



System Date FRI 05 AUG 1994 13:52:50
CALT No: 0006 Sensor No: 402890
Days since last calibration: 331

CROFT ASSOCIATES
CALTS - U1.35

*****LEAK TEST*****


Test Reference No:- 1
Design/Serial Nos:- 2870/
Comment:- -40
Interspace Volume:- 8.23 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -40°C
Temperature ratio:- 1.279
 μ ratio:- 0.859

TIME h:m:s	SLR	PRESSURE mbar
14:0:45	1.1E-05	2047
14:1:38	2.8E-05	2047
14:2:38	1.4E-05	2046
14:3:38	7.5E-06	2046
14:4:39	2.8E-06	2047
14:5:39	4.5E-06	2046
14:6:39	5.6E-06	2046
14:7:38	6.4E-06	2046
14:8:39	4.2E-06	2046
14:9:39	1.2E-06	2047
14:10:39	2.8E-06	2046

Leak Rate(SLR):- 2.8E-06 bar cc/sec
Atmos Pressure:- 1002 mbar
Starting Pressure:- 2047 mbar
Final Pressure:- 2046 mbar

Standard conditions:

Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 5/8/94

System Date FRI 05 AUG 1994 14:11:27
CALT No: 0006 Sensor No: 402890
Days since last calibration: 331

CROFT ASSOCIATES
CALTS - U1.35

*****LEAK TEST*****

Test Reference No:- 2
Design/Serial Nos:- 2870/
Comment:- -45
Interspace Volume:- 10.15 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -45°C
Temperature ratio:- 1.307
 μ ratio:- 0.848

TIME h:m:s	SLR	PRESSURE mbar
14:40:28	1.8E-05	2074
14:41:23	0.0E+00	2074
14:42:23	3.4E-06	2074
14:43:22	4.5E-06	2074
14:44:22	3.4E-06	2074
14:45:22	0.0E+00	2074
14:46:22	3.4E-06	2074
14:47:22	5.8E-06	2073
14:48:22	6.7E-06	2073
14:49:23	6.7E-06	2073
14:50:23	6.7E-06	2073

Leak Rate(SLR):- 6.7E-06 bar cc/sec
Atmos Pressure:- 1003 mbar
Starting Pressure:- 2074 mbar
Final Pressure:- 2073 mbar

Standard conditions:

Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 5/8/94

System Date THU 11 AUG 1994 13:38:38
CALT No: 0031 Sensor No: 089473
Days since last calibration: 1

System Date WED 10 AUG 1994 15:38:07
CALT No: 0031 Sensor No: 089473
Days since last calibration: 0

***CROFT ASSOCIATES**
CALTS - U1.35

***CROFT ASSOCIATES**
CALTS - U1.35

*****LEAK TEST*****

*****LEAK TEST*****

Test Reference No:- 1
Design/Serial Nos:- 2870/
Comment:- -43
Interspace Volume:- 8.81 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -43°C
Temperature ratio:- 1.296
p ratio:- 0.852

Test Reference No:- 1
Design/Serial Nos:- 2870/
Comment:- -45
Interspace Volume:- 8 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -45°C
Temperature ratio:- 1.307
p ratio:- 0.848

TIME h:m:s	SLR	PRESSURE mbar
13:46:17	1.2E-03	1854
13:47:12	1.0E-03	1839
13:48:11	8.1E-04	1830
13:49:12	7.1E-04	1822
13:50:12	6.7E-04	1814
13:51:11	6.3E-04	1807
13:52:11	5.9E-04	1801
13:53:11	5.7E-04	1794
13:54:12	5.5E-04	1788
13:55:11	5.3E-04	1783
13:56:11	5.1E-04	1778

TIME h:m:s	SLR	PRESSURE mbar
15:45:31	4.3E-03	1531
15:46:25	4.8E-03	1487
15:47:25	4.5E-03	1448
15:48:25	4.3E-03	1413
15:49:25	4.0E-03	1383
15:50:25	3.8E-03	1356
15:51:26	3.6E-03	1332
15:52:26	3.4E-03	1309
15:53:26	3.3E-03	1290
15:54:25	3.1E-03	1272
15:55:25	3.0E-03	1255

Leak Rate(SLR):- 5.1E-04 bar cc/sec
Atmos Pressure:- 996 mbar
Starting Pressure:- 1854 mbar
Final Pressure:- 1778 mbar

Leak Rate(SLR):- 3.0E-03 bar cc/sec
Atmos Pressure:- 992 mbar
Starting Pressure:- 1531 mbar
Final Pressure:- 1255 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 10/8/94

Sig:  Date: 10/8/94

System Date FRI 05 AUG 1994 15:29:31
CALT No: 0006 Sensor No: 402890
Days since last calibration: 331

CROFT ASSOCIATES
CALTS - V1.35

*****LEAK TEST*****

Test Reference No:- 3
Design/Serial Nos:- 2870/
Comment:- -50
Interspace Volume:- 10.15 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -50°C
Temperature ratio:- 1.336
p ratio:- 0.837

TIME h:m:s	SLR	PRESSURE mbar
15:37:7	5.7E-05	2043
15:38:1	1.4E-05	2043
15:39:1	7.1E-06	2043
15:40:2	4.7E-06	2043
15:41:1	5.3E-06	2043
15:42:1	1.4E-06	2043
15:43:1	1.2E-06	2043
15:44:1	2.0E-06	2043
15:45:1	1.8E-06	2043
15:46:1	1.6E-06	2043
15:47:1	1.4E-06	2043

Leak Rate(SLR):- 1.4E-06 bar cc/sec
Atmos Pressure:- 1002 mbar
Starting Pressure:- 2043 mbar
Final Pressure:- 2043 mbar

Standard conditions:

Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig: 

Date: 5/8/94

System Date FRI 05 AUG 1994 16:03:06
CALT No: 0006 Sensor No: 402890
Days since last calibration: 331

CROFT ASSOCIATES
CALTS - V1.35

*****LEAK TEST*****

Test Reference No:- 4
Design/Serial Nos:- 2870/
Comment:- -50
Interspace Volume:- 10.15 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -50°C
Temperature ratio:- 1.336
p ratio:- 0.837

TIME h:m:s	SLR	PRESSURE mbar
16:9:57	2.8E-06	2054
16:10:51	0.0E+00	2054
16:11:51	2.4E-05	2053
16:12:51	2.1E-05	2053
16:13:52	1.7E-05	2053
16:14:52	1.8E-05	2053
16:15:51	1.5E-05	2053
16:16:52	1.7E-05	2052
16:17:52	1.8E-05	2052
16:18:51	1.8E-05	2051
16:19:51	1.9E-05	2051

Leak Rate(SLR):- 1.9E-05 bar cc/sec
Atmos Pressure:- 1001 mbar
Starting Pressure:- 2054 mbar
Final Pressure:- 2051 mbar

Standard conditions:

Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig: 

Date: 5/8/94

System Date FRI 12 AUG 1994 09:11:25
CALT No: 0031 Sensor No: C89473
Days since last calibration: 2

CROFT ASSOCIATES
CALTS - U1.35

*****MEASURE VOLUME*****

Reference Volume:- 10 cc
Reference Volume No:-
Test Reference No:- 1
Design/Serial Nos:- 2870/

PRESSURE mbar		Volume
Atmos	Start Final	(cc)
996	1984 1438	8.14
997	2043 1465	8.14

Average Measured Volume:- 8.14 cc

Sig: 

Date: 12/8/94

System Date FRI 12 AUG 1994 14:00:09
CALT No: 0031 Sensor No: C89473
Days since last calibration: 2

CROFT ASSOCIATES
CALTS - U1.35

*****LEAK TEST*****

Test Reference No:- 1
Design/Serial Nos:- 2870/
Comment:- -45
Interspace Volume:- 8.14 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -45.1°C
Temperature ratio:- 1.308
p ratio:- 0.848

TIME h:m:s	SLR	PRESSURE mbar
14:6:55	1.3E-04	2066
14:7:49	6.2E-04	2053
14:8:49	6.6E-04	2037
14:9:50	6.9E-04	2021
14:10:50	7.0E-04	2005
14:11:50	7.0E-04	1990
14:12:49	6.9E-04	1977
14:13:50	6.7E-04	1964
14:14:49	6.6E-04	1951
14:15:49	6.5E-04	1939
14:16:49	6.3E-04	1929

Leak Rate(SLR):- 6.3E-04 bar cc/sec
Atmos Pressure:- 1003 mbar
Starting Pressure:- 2066 mbar
Final Pressure:- 1929 mbar

Standard conditions:

Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig: 

Date: 12/8/94



System Date THU 08 SEP 1994 09:52:34
CALT No: 0045 Sensor No: 653972
Days since last calibration: 21

CROFT ASSOCIATES
CALTS - U1.35

*****MEASURE VOLUME*****

Reference Volume:- 10 cc
Reference Volume No:-
Test Reference No:- 1
Design/Serial Nos:- 2870/
Comment:- test head

Atmos	Start	Final	Volume (cc)
983	2035	1477	8.88
982	2044	1482	8.93
982	2014	1469	8.96

Average Measured Volume:- 8.93 cc

Sig: 

Date: 8/9/94

System Date THU 08 SEP 1994 10:06:53
CALT No: 0045 Sensor No: 653972
Days since last calibration: 21

CROFT ASSOCIATES
CALTS - U1.35

*****LEAK TEST*****

Test Reference No:- 1
Design/Serial Nos:- 2870/
Comment:- test head-viton
Interspace Volume:- 8.93 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 18.4°C
Temperature ratio:- 1.023
μ ratio:- 0.986

TIME h:m:s	SLR	PRESSURE mbar
10:13:11	3.0E-05	2035
10:14:4	2.0E-05	2035
10:15:4	1.3E-05	2035
10:16:5	1.0E-05	2034
10:17:4	1.4E-05	2034
10:18:4	9.1E-06	2034
10:19:5	1.0E-05	2034
10:20:5	9.4E-06	2034
10:21:5	7.6E-06	2034
10:22:4	9.5E-06	2033
10:23:4	8.6E-06	2033

Leak Rate(SLR):- 8.6E-06 bar cc/sec
Atmos Pressure:- 983 mbar
Starting Pressure:- 2035 mbar
Final Pressure:- 2033 mbar

Standard conditions:

Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig: 

Date: 8/9/94



System Date THU 08 SEP 1994 11:32:54
CALT No: 0045 Sensor No: 653972
Days since last calibration: 21

System Date THU 08 SEP 1994 13:11:13
CALT No: 0045 Sensor No: 653972
Days since last calibration: 21

***CROFT ASSOCIATES**
CALTS - U1.35

***CROFT ASSOCIATES**
CALTS - U1.35

*****LEAK TEST*****

*****LEAK TEST*****

Test Reference No:- 2
Design/Serial Nos:- 2870/
Comment:- test head viton +10
Interspace Volume:- 8.93 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 10°C
Temperature ratio:- 1.053
p ratio:- 0.967

Test Reference No:- 3
Design/Serial Nos:- 2870/
Comment:- test head viton 0
Interspace Volume:- 8.93 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 0°C
Temperature ratio:- 1.092
p ratio:- 0.946

TIME h:m:s	SLR	PRESSURE mbar
11:39:29	2.3E-05	2036
11:40:24	1.8E-05	2036
11:41:23	7.7E-06	2036
11:42:23	6.8E-06	2036
11:43:23	7.7E-06	2035
11:44:23	6.1E-06	2035
11:45:23	6.0E-06	2035
11:46:24	5.8E-06	2035
11:47:24	6.4E-06	2035
11:48:24	6.0E-06	2035
11:49:24	5.6E-06	2035


TIME h:m:s	SLR	PRESSURE mbar
13:17:37	3.9E-05	2027
13:18:31	0.0E+00	2027
13:19:31	7.8E-06	2027
13:20:30	1.0E-05	2027
13:21:30	1.0E-05	2027
13:22:30	1.4E-05	2026
13:23:30	1.4E-05	2026
13:24:31	1.6E-05	2025
13:25:31	1.5E-05	2025
13:26:30	1.6E-05	2025
13:27:30	1.5E-05	2024

Leak Rate(SLR):- 5.6E-06 bar cc/sec
Atmos Pressure:- 983 mbar
Starting Pressure:- 2036 mbar
Final Pressure:- 2035 mbar

Leak Rate(SLR):- 1.5E-05 bar cc/sec
Atmos Pressure:- 983 mbar
Starting Pressure:- 2027 mbar
Final Pressure:- 2024 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 8/9/94

Sig:  Date: 8/9/94



System Date THU 08 SEP 1994 14:22:48
CALT No: 0045 Sensor No: 653972
Days since last calibration: 21

CROFT ASSOCIATES
CALT5 - U1.35

*****LEAK TEST*****

Test Reference No:- 4
Design/Serial Nos:- 2870/
Comment:- test head viton -10
Interspace Volume:- 8.93 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -10°C
Temperature ratio:- 1.133
p ratio:- 0.924

TIME h:m:s	SLR	PRESSURE mbar
14:29:21	3.9E-05	2030
14:30:14	1.6E-05	2029
14:31:14	1.6E-05	2029
14:32:15	1.2E-05	2029
14:33:14	1.1E-05	2029
14:34:15	1.1E-05	2029
14:35:14	8.8E-06	2029
14:36:14	7.6E-06	2029
14:37:15	7.3E-06	2029
14:38:15	7.6E-06	2029
14:39:14	6.3E-06	2029

Leak Rate(SLR):- 6.3E-06 bar cc/sec
Atmos Pressure:- 984 mbar
Starting Pressure:- 2030 mbar
Final Pressure:- 2029 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 8/9/94

System Date THU 08 SEP 1994 15:26:02
CALT No: 0045 Sensor No: 653972
Days since last calibration: 21

CROFT ASSOCIATES
CALT5 - U1.35


*****LEAK TEST*****

Test Reference No:- 5
Design/Serial Nos:- 2870/
Comment:- test head viton -20
Interspace Volume:- 8.93 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -20°C
Temperature ratio:- 1.178
p ratio:- 0.902

TIME h:m:s	SLR	PRESSURE mbar
15:34:8	2.2E-05	2022
15:35:1	1.6E-05	2022
15:36:1	5.4E-06	2022
15:37:1	9.0E-06	2021
15:38:1	1.2E-05	2021
15:39:1	1.3E-05	2021
15:40:1	1.1E-05	2021
15:41:1	9.3E-06	2021
15:42:1	1.0E-05	2020
15:43:1	9.6E-06	2020
15:44:1	9.2E-06	2020

Leak Rate(SLR):- 9.2E-06 bar cc/sec
Atmos Pressure:- 981 mbar
Starting Pressure:- 2022 mbar
Final Pressure:- 2020 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 8/9/94

System Date THU 08 SEP 1994 16:49:28
DALTS No: 0045 Sensor No: 653972
Days since last calibration: 21

CROFT ASSOCIATES
DALTS - U1.35


*****LEAK TEST*****

Test Reference No:- 6
Design/Serial Nos:- 2870/
Comment:- test head viton -30
Interspace Volume:- 8.93 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -30°C
Temperature ratio:- 1.226
μ ratio:- 0.880

TIME h:m:s	SLR	PRESSURE mbar
16:55:55	2.9E-05	2038
16:56:49	5.4E-06	2038
16:57:49	5.4E-06	2038
16:58:49	5.4E-06	2038
16:59:49	4.1E-06	2038
17:0:49	2.2E-06	2038
17:1:49	1.8E-06	2038
17:2:49	2.3E-06	2038
17:3:49	4.1E-06	2037
17:4:49	3.8E-06	2037
17:5:49	1.6E-06	2038

Leak Rate(SLR):- 1.6E-06 bar cc/sec
Atmos Pressure:- 985 mbar
Starting Pressure:- 2038 mbar
Final Pressure:- 2038 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 8/9/94

System Date FRI 09 SEP 1994 08:53:19
DALTS No: 0045 Sensor No: 653972
Days since last calibration: 22

CROFT ASSOCIATES
DALTS - U1.35


*****LEAK TEST*****

Test Reference No:- 7
Design/Serial Nos:- 2870/
Comment:- test head viton -30
Interspace Volume:- 8.93 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -30°C
Temperature ratio:- 1.226
μ ratio:- 0.880

TIME h:m:s	SLR	PRESSURE mbar
9:0:37	8.3E-06	2069
9:1:30	1.0E-05	2069
9:2:31	5.2E-06	2069
9:3:31	3.5E-06	2069
9:4:31	2.6E-06	2069
9:5:31	1.0E-06	2069
9:6:30	8.7E-07	2069
9:7:30	1.5E-06	2069
9:8:31	6.5E-07	2069
9:9:30	0.0E+00	2069
9:10:31	1.9E-06	2069

Leak Rate(SLR):- 1.0E-06 bar cc/sec
Atmos Pressure:- 990 mbar
Starting Pressure:- 2069 mbar
Final Pressure:- 2069 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 9/9/94

System Date FRI 09 SEP 1994 09:52:38
CALT No: 0045 Sensor No: 653972
Days since last calibration: 22

***CROFT ASSOCIATES**
CALTS - U1.35

*****LEAK TEST*****

Test Reference No:- 8
Design/Serial Nos:- 2870/
Comment:- test head viton -35
Interspace Volume:- 8.93 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -35°C
Temperature ratio:- 1.252
p ratio:- 0.870

System Date FRI 09 SEP 1994 10:50:35
CALT No: 0045 Sensor No: 653972
Days since last calibration: 22

***CROFT ASSOCIATES**
CALTS - U1.35

*****LEAK TEST*****

Test Reference No:- 9
Design/Serial Nos:- 2870/
Comment:- test head viton -40
Interspace Volume:- 8.93 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -40°C
Temperature ratio:- 1.279
p ratio:- 0.859

TIME h:m:s	SLR	PRESSURE mbar
9:59:17	2.5E-05	2049
10:0:11	1.6E-05	2049
10:1:11	1.3E-05	2049
10:2:12	1.3E-05	2048
10:3:11	1.1E-05	2048
10:4:11	8.6E-06	2048
10:5:11	8.1E-06	2048
10:6:12	6.9E-06	2048
10:7:12	7.4E-06	2048
10:8:12	7.2E-06	2048
10:9:11	5.9E-06	2048

Leak Rate(SLR):- 5.9E-06 bar cc/sec
Atmos Pressure:- 990 mbar
Starting Pressure:- 2049 mbar
Final Pressure:- 2048 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 9/9/94

TIME h:m:s	SLR	PRESSURE mbar
10:57:17	2.8E-05	2049
10:58:11	1.1E-05	2049
10:59:11	1.6E-05	2048
11:0:11	2.0E-05	2048
11:1:11	1.6E-05	2048
11:2:11	1.6E-05	2047
11:3:11	1.5E-05	2047
11:4:11	1.6E-05	2047
11:5:11	1.2E-05	2047
11:6:11	1.3E-05	2047
11:7:11	1.4E-05	2046

Leak Rate(SLR):- 1.4E-05 bar cc/sec
Atmos Pressure:- 990 mbar
Starting Pressure:- 2049 mbar
Final Pressure:- 2046 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 9/9/94



System Date FRI 09 SEP 1994 13:23:43
CALT No: 0045 Sensor No: 653972
Days since last calibration: 22

System Date FRI 09 SEP 1994 11:58:18
CALT No: 0045 Sensor No: 653972
Days since last calibration: 22

CROFT ASSOCIATES
CALTS - U1.35

CROFT ASSOCIATES
CALTS - U1.35

*****LEAK TEST*****

*****LEAK TEST*****

Test Reference No:- 11
Design/Serial Nos:- 2870/
 Comment:- test head viton -50
Interspace Volume:- 8.93 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -50°C
Temperature ratio:- 1.336
 p ratio:- 0.837

Test Reference No:- 10
Design/Serial Nos:- 2870/
 Comment:- test head viton -45
Interspace Volume:- 8.93 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -45°C
Temperature ratio:- 1.307
 p ratio:- 0.848

TIME h:m:s	SLR	PRESSURE mbar
13:31:0	3.4E-05	2051
13:31:54	1.1E-05	2051
13:32:54	1.1E-05	2051
13:33:54	1.5E-05	2050
13:34:55	1.8E-05	2050
13:35:54	1.5E-05	2049
13:36:54	1.9E-05	2049
13:37:55	1.8E-05	2049
13:38:54	1.8E-05	2048
13:39:54	1.8E-05	2048
13:40:54	1.8E-05	2048

TIME h:m:s	SLR	PRESSURE mbar
12:5:34	4.8E-05	2058
12:6:28	3.3E-05	2057
12:7:29	3.0E-05	2057
12:8:28	3.1E-05	2056
12:9:28	3.1E-05	2055
12:10:29	3.4E-05	2054
12:11:28	3.2E-05	2054
12:12:29	3.8E-05	2052
12:13:29	3.9E-05	2052
12:14:28	3.9E-05	2051
12:15:28	3.9E-05	2050

Leak Rate(SLR):- 1.8E-05 bar cc/sec
Atmos Pressure:- 990 mbar
Starting Pressure:- 2051 mbar
Final Pressure:- 2048 mbar

Leak Rate(SLR):- 3.9E-05 bar cc/sec
Atmos Pressure:- 993 mbar
Starting Pressure:- 2058 mbar
Final Pressure:- 2050 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 9/9/94

Sig:  Date: 9/9/94

System Date SAT 10 SEP 1994 19:37:42
CALT No: 0045 Sensor No: 653972
Days since last calibration: 23

System Date MON 12 SEP 1994 09:10:11
CALT No: 0045 Sensor No: 653972
Days since last calibration: 25

CROFT ASSOCIATES
CALTS - U1.35

CROFT ASSOCIATES
CALTS - U1.35

*****LEAK TEST*****

*****LEAK TEST*****

Test Reference No:- 13
Design/Serial Nos:- 2870/
Comment:- test head viton
Interspace Volume:- 8.93 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 17°C
Temperature ratio:- 1.028
μ ratio:- 0.983

Test Reference No:- 12
Design/Serial Nos:- 2870/
Comment:- test head viton -50
Interspace Volume:- 8.93 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -50°C
Temperature ratio:- 1.336
μ ratio:- 0.837

TIME h:m:s	SLR	PRESSURE mbar
9:17:3	1.1E-05	2037
9:17:57	2.0E-05	2037
9:18:57	1.0E-05	2037
9:19:57	3.4E-06	2037
9:20:58	3.8E-06	2037
9:21:58	3.8E-06	2037
9:22:57	4.2E-06	2037
9:23:57	2.2E-06	2037
9:24:57	1.3E-06	2037
9:25:58	1.1E-06	2037
9:26:58	5.1E-07	2037

TIME h:m:s	SLR	PRESSURE mbar
19:44:57	3.1E-05	2051
19:45:52	2.8E-05	2050
19:46:51	1.9E-05	2050
19:47:51	2.2E-05	2050
19:48:52	1.8E-05	2050
19:49:51	1.8E-05	2049
19:50:51	1.7E-05	2049
19:51:51	1.6E-05	2049
19:52:52	1.4E-05	2049
19:53:52	1.4E-05	2049
19:54:51	1.2E-05	2049


Leak Rate(SLR):- 5.1E-07 bar cc/sec
Atmos Pressure:- 994 mbar
Starting Pressure:- 2037 mbar
Final Pressure:- 2037 mbar

Leak Rate(SLR):- 1.2E-05 bar cc/sec
Atmos Pressure:- 996 mbar
Starting Pressure:- 2051 mbar
Final Pressure:- 2049 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 12/9/94

Sig:  Date: 10/9/94

System Date MON 12 SEP 1994 10:53:47
CALT No: 0045 Sensor No: 653972
Days since last calibration: 25

CROFT ASSOCIATES
CALTS - 01.35

*****LEAK TEST*****

Test Reference No:- 014
Design/Serial Nos:- 2870/
Comment:- test head viton amb
Interspace vol (cc):- 7.65 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 17.6°C
Temperature ratio:- 1.025
Pressure ratio:- 0.984

System Date MON 12 SEP 1994 10:43:33
CALT No: 0045 Sensor No: 653972
Days since last calibration: 25

CROFT ASSOCIATES
CALTS - 01.35

*****MEASURE VOLUME*****

Reference Volume:- 10 cc
Reference Volume No:-
Test Reference No:- 2
Design/Serial Nos:- 2870/
Comment:- test head viton

	Atmos	Start	Final	Volume (cc)
985	2024	1433		7.63
985	2064	1451		7.64
985	2065	1452		7.67

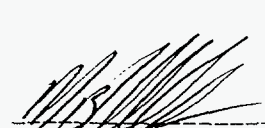
Average Measured Volume:- 7.65 cc

TIME h:m:s	SLR	PRESSURE mbar
10:59:48	4.5E-05	2057
11:0:42	1.7E-05	2057
11:1:42	1.7E-05	2056
11:2:43	1.5E-05	2056
11:3:42	1.4E-05	2056
11:4:43	1.3E-05	2056
11:5:42	1.3E-05	2055
11:6:42	1.1E-05	2055
11:7:43	1.1E-05	2055
11:8:42	1.1E-05	2055
11:9:42	1.1E-05	2054

Leak Rate (SLR):- 1.1E-05 bar cc/sec
Atmos Pressure:- 986 mbar
Starting Pressure:- 2057 mbar
Final Pressure:- 2054 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 12/9/94

Sig:  Date: 12/9/94



System Date MON 12 SEP 1994 15:37:31
CALT No: 0045 Sensor No: 653972
Days since last calibration: 25

***CROFT ASSOCIATES**
CALTS - U1.35

*****LEAK TEST*****

Test Reference No:- U15
Design/Serial Nos:- 2870//
Comment:- test head viton 50
Interspace Volume:- 8.93 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 50° C
Temperature ratio:- 0.923
p ratio:- 1.054

TIME h:m:s	SLR	PRESSURE mbar
15:48:41	2.4E-05	2095
15:49:35	9.1E-06	2095
15:50:34	9.1E-06	2094
15:51:35	1.8E-05	2093
15:52:34	1.9E-05	2093
15:53:35	1.6E-05	2093
15:54:34	1.6E-05	2092
15:55:35	1.7E-05	2092
15:56:34	1.5E-05	2092
15:57:34	1.4E-05	2092
15:58:34	1.4E-05	2091

Leak Rate(SLR):- 1.4E-05 bar cc/sec
Atmos Pressure:- 989 mbar
Starting Pressure:- 2095 mbar
Final Pressure:- 2091 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig: 9002 Date: 12/9/94

INCORRECT INTERSPACE VOL USED
CORRECT VOL 7.65 cc

∴ CORRECTION OF LEAKAGE RATE AS FOLLOWS:-

$$1.4 \times 10^{-5} \times \frac{7.65}{8.93} = 1.2 \times 10^{-5} \text{ bar cc/sec}$$

System Date MON 12 SEP 1994 18:04:06
CALT No: 0045 Sensor No: 653972
Days since last calibration: 25

***CROFT ASSOCIATES**
CALTS - U1.35

*****LEAK TEST*****

Test Reference No:- U16
Design/Serial Nos:- 2870//
Comment:- test head viton 100
Interspace Volume:- 7.65 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 100° C
Temperature ratio:- 0.799
p ratio:- 1.163

TIME h:m:s	SLR	PRESSURE mbar
18:10:20	1.4E-04	2065
18:11:13	4.6E-05	2064
18:12:13	4.1E-05	2063
18:13:13	3.6E-05	2062
18:14:13	3.5E-05	2062
18:15:14	3.2E-05	2061
18:16:13	3.0E-05	2060
18:17:13	2.8E-05	2060
18:18:13	2.6E-05	2060
18:19:14	2.7E-05	2059
18:20:14	2.6E-05	2058

Leak Rate(SLR):- 2.6E-05 bar cc/sec
Atmos Pressure:- 991 mbar
Starting Pressure:- 2065 mbar
Final Pressure:- 2058 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig: [Signature] Date: 13/9/94



System Date TUE 13 SEP 1994 07:43:21
CALT No: 0045 Sensor No: 653972
Days since last calibration: 26

System Date TUE 13 SEP 1994 11:13:27
CALT No: 0045 Sensor No: 653972
Days since last calibration: 26

***CROFT ASSOCIATES**
CALTS - U1.35

***CROFT ASSOCIATES**
CALTS - U1.35

*****LEAK TEST*****

*****LEAK TEST*****

Test Reference No:- U17
Design/Serial Nos:- 2876/
Comment:- t ho viton-100-amb>
Interspace Volume:- 7.65 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 32.4°C
Temperature ratio:- 0.976
p ratio:- 1.016

Test Reference No:- U18
Design/Serial Nos:- 2870/
Comment:- test head viton 150
Interspace Volume:- 7.65 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 150°C
Temperature ratio:- 0.704
p ratio:- 1.272

TIME h:m:s	SLR	PRESSURE mbar
8:8:39	7.1E-05	2298
8:9:34	8.7E-05	2297
8:10:34	6.0E-05	2297
8:11:33	5.1E-05	2296
8:12:33	4.1E-05	2296
8:13:33	4.4E-05	2296
8:14:33	4.0E-05	2296
8:15:34	4.2E-05	2295
8:16:34	3.7E-05	2295
8:17:33	3.8E-05	2295
8:18:34	3.6E-05	2294

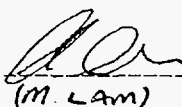
TIME h:m:s	SLR	PRESSURE mbar
11:19:46	3.7E-06	2068
11:20:40	7.4E-06	2068
11:21:41	0.0E+00	2068
11:22:41	3.7E-06	2068
11:23:40	3.7E-06	2068
11:24:41	4.5E-06	2068
11:25:40	5.0E-06	2067
11:26:41	6.4E-06	2067
11:27:40	9.3E-06	2066
11:28:40	9.9E-06	2066
11:29:40	1.1E-05	2065


Leak Rate(SLR):- 3.6E-05 bar cc/sec
Atmos Pressure:- 2010 mbar
Starting Pressure:- 2298 mbar
Final Pressure:- 2294 mbar

Leak Rate(SLR):- 1.1E-05 bar cc/sec
Atmos Pressure:- 996 mbar
Starting Pressure:- 2068 mbar
Final Pressure:- 2065 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 13/9/94

Sig:  Date: 13/9/94

System Date TUE 13 SEP 1994 13:37:23
CALT No: 0045 Sensor No: 653972
Days since last calibration: 26

***CROFT ASSOCIATES**
CALTS - U1.35

*****LEAK TEST*****

Test Reference No:- U19
Design/Serial Nos:- 2870/
Comment:- test head viton 175
Interspace Volume:- 7.65 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 175°C
Temperature ratio:- 0.665
p ratio:- 1.326

TIME h:m:s	SLR	PRESSURE mbar
13:43:26	1.0E-04	2030
13:44:20	8.1E-05	2028
13:45:21	6.3E-05	2027
13:46:20	7.0E-05	2024
13:47:21	6.5E-05	2023
13:48:20	5.8E-05	2022
13:49:21	5.8E-05	2021
13:50:20	5.7E-05	2019
13:51:21	5.9E-05	2017
13:52:20	5.6E-05	2016
13:53:21	5.6E-05	2014

Leak Rate(SLR):- 5.6E-05 bar cc/sec
Atmos Pressure:- 995 mbar
Starting Pressure:- 2030 mbar
Final Pressure:- 2014 mbar

Standard conditions:

Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 13/9/94

System Date TUE 13 SEP 1994 15:01:16
CALT No: 0045 Sensor No: 653972
Days since last calibration: 26

***CROFT ASSOCIATES**
CALTS - U1.35

*****LEAK TEST*****


Test Reference No:- U20
Design/Serial Nos:- 2870/
Comment:- test hd-viton 200
Interspace Volume:- 7.65 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 200°C
Temperature ratio:- 0.630
p ratio:- 1.380

TIME h:m:s	SLR	PRESSURE mbar
15:14:41	4.1E-04	2072
15:15:35	5.0E-04	2069
15:16:35	5.0E-04	2066
15:17:35	4.5E-04	2064
15:18:35	4.4E-04	2061
15:19:35	4.6E-04	2058
15:20:36	4.5E-04	2056
15:21:36	4.4E-04	2054
15:22:35	4.4E-04	2051
15:23:35	4.3E-04	2049
15:24:35	4.3E-04	2047

Leak Rate(SLR):- 4.3E-04 bar cc/sec
Atmos Pressure:- 1911 mbar
Starting Pressure:- 2072 mbar
Final Pressure:- 2047 mbar

Standard conditions:

Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 13/9/94



System Date TUE 13 SEP 1994 16:35:28
CALT No: 0045 Sensor No: 653972
Days since last calibration: 26

System Date TUE 13 SEP 1994 21:03:28
CALT No: 0045 Sensor No: 653972
Days since last calibration: 26

CROFT ASSOCIATES
CALTS - V1.35

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CALTS - V1.35

*****LEAK TEST*****

*****LEAK TEST*****

Test Reference No:- U21
Design/Serial Nos:- 2870/
 Comment:- test hd viton 225
Interspace Volume:- 7.65 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 225°C
Temperature ratio:- 0.598
 μ ratio:- 1.435

Test Reference No:- U22
Design/Serial Nos:- 2870/
 Comment:- test head viton 250
Interspace Volume:- 7.65 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 250°C
Temperature ratio:- 0.570
 μ ratio:- 1.489

TIME h:m:s	SLR	PRESSURE mbar
16:42:46	3.2E-04	1983
16:43:41	1.4E-04	1979
16:44:41	1.3E-04	1975
16:45:41	1.2E-04	1973
16:46:41	1.2E-04	1970
16:47:40	1.1E-04	1967
16:48:40	1.1E-04	1966
16:49:40	1.1E-04	1962
16:50:40	1.0E-04	1960
16:51:40	1.0E-04	1958
16:52:40	1.0E-04	1956

TIME h:m:s	SLR	PRESSURE mbar
21:9:53	2.0E-04	2041
21:10:47	1.9E-04	2036
21:11:47	1.6E-04	2032
21:12:47	1.4E-04	2029
21:13:48	1.4E-04	2025
21:14:48	1.3E-04	2023
21:15:48	1.2E-04	2020
21:16:48	1.2E-04	2017
21:17:47	1.1E-04	2015
21:18:47	1.1E-04	2012
21:19:47	1.1E-04	2010

Leak Rate(SLR):- 1.0E-04 bar cc/sec
Atmos Pressure:- 994 mbar
Starting Pressure:- 1983 mbar
Final Pressure:- 1956 mbar

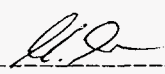
Leak Rate(SLR):- 1.1E-04 bar cc/sec
Atmos Pressure:- 996 mbar
Starting Pressure:- 2041 mbar
Final Pressure:- 2010 mbar

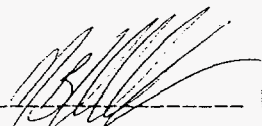
Standard conditions:

Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Standard conditions:

Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 13/9/94

Sig:  Date: 13/9/94

System Date WED 14 SEP 1994 21:10:25
CALT No: 0045 Sensor No: 653972
Days since last calibration: 27

System Date THU 15 SEP 1994 08:49:27
CALT No: 0045 Sensor No: 653972
Days since last calibration: 28

***CROFT ASSOCIATES**
CALTS - U1.35

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*****LEAK TEST*****

*****LEAK TEST*****

Test Reference No:- U23
Design/Serial Nos:- 2870/
Comment:- test head viton 250
Interspace Volume:- 7.65 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 250°C
Temperature ratio:- 0.578
p ratio:- 1.489

Test Reference No:- U24
Design/Serial Nos:- 2870/
Comment:- test head viton amp
Interspace Volume:- 7.65 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 21°C
Temperature ratio:- 1.914
p ratio:- 0.991

TIME h:m:s	SLR	PRESSURE mbar
21:16:33	2.5E-04	2013
21:17:26	1.5E-04	2008
21:18:26	1.4E-04	2004
21:19:26	1.3E-04	2002
21:20:26	1.2E-04	1998
21:21:27	1.2E-04	1995
21:22:27	1.2E-04	1993
21:23:27	1.2E-04	1989
21:24:27	1.1E-04	1987
21:25:27	1.1E-04	1983
21:26:26	1.1E-04	1981

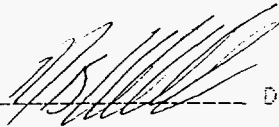
TIME h:m:s	SLR	PRESSURE mbar
8:46:37	4.7E-05	2041
8:47:31	6.0E-05	2040
8:48:31	5.2E-05	2039
8:49:32	4.2E-05	2038
8:50:31	3.2E-05	2038
8:51:31	3.0E-05	2037
8:52:31	2.8E-05	2037
8:53:31	2.6E-05	2037
8:54:31	2.2E-05	2037
8:55:32	2.1E-05	2037
8:56:31	2.0E-05	2036


Leak Rate(SLR):- 1.1E-04 bar cc/sec
Atmos Pressure:- 983 mbar
Starting Pressure:- 2013 mbar
Final Pressure:- 1981 mbar

Leak Rate(SLR):- 2.0E-05 bar cc/sec
Atmos Pressure:- 987 mbar
Starting Pressure:- 2041 mbar
Final Pressure:- 2036 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 14/9/94

Sig:  Date: 15/9/94

System Date TUE 04 OCT 1994 09:34:04
CALT No: 0045 Sensor No: 653972
Days since last calibration: 47

System Date TUE 04 OCT 1994 10:44:50
CALT No: 0045 Sensor No: 653972
Days since last calibration: 47

***CROFT ASSOCIATES**
CALTS - U1.35

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MEASURE VOLUME

LEAK TEST

Reference Volume:- 10 cc
Reference Volume No:-
Test Reference No:- 1
Design/Serial Nos:- 2870V
Comment:- test head union

Test Reference No:- UR1
Design/Serial Nos:- 2870V
Comment:- test head union amb
Interspace Volume:- 7.89 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 14.6°C
Temperature ratio:- 1.036
P ratio:- 0.977

PRESSURE mbar		Volume
Atmos	Start	Final (cc)
1010	1080	1479 7.87
1010	1086	1483 7.89
1010	1073	1479 7.86

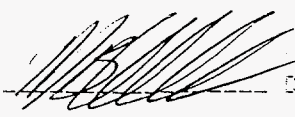
TIME h:m:s	SLR	PRESSURE mbar
10:51:31	3.5E-05	2065
10:52:26	1.3E-05	2065
10:53:26	1.1E-05	2064
10:54:26	1.6E-05	2064
10:55:26	1.4E-05	2064
10:56:26	1.4E-05	2063
10:57:26	1.5E-05	2063
10:58:26	1.4E-05	2063
10:59:25	1.4E-05	2062
11:00:25	1.3E-05	2062
11:11:26	1.3E-05	2062

Average Measured Volume:- 7.89 cc

Leak Rate(SLR):- 1.3E-05 bar cc/sec
Atmos Pressure:- 1009 mbar
Starting Pressure:- 2065 mbar
Final Pressure:- 2062 mbar

Sig:  Date: 1/10/94

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 1/10/94

System Date TUE 04 OCT 1994 11:51:53
CALT No: 0045 Sensor No: 653972
Days since last calibration: 47

CROFT ASSOCIATES
CALTS - V1.35

*****LEAK TEST*****

Test Reference No:- VA2
Design/Serial Nos:- 2870/
Comment:- test head viton Ø
Interspace Volume:- 7.89 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 10°C
Temperature ratio:- 1.053
µ ratio:- 0.967

TIME h:m:s	SLR	PRESSURE mbar
11:58:34	2.0E-05	2050
11:59:28	1.4E-05	2050
12:0:29	6.8E-06	2050
12:1:28	6.0E-06	2049
12:2:28	9.0E-06	2049
12:3:29	1.1E-05	2049
12:4:28	7.5E-06	2049
12:5:29	8.4E-06	2049
12:6:28	7.3E-06	2048
12:7:28	7.0E-06	2048
12:8:28	8.6E-06	2048

Leak Rate(SLR):- 8.6E-06 bar cc/sec
Atmos Pressure:- 1011 mbar
Starting Pressure:- 2050 mbar
Final Pressure:- 2048 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 4/10/94

System Date TUE 04 OCT 1994 13:28:58
CALT No: 0045 Sensor No: 653972
Days since last calibration: 47

CROFT ASSOCIATES
CALTS - V1.35

*****LEAK TEST*****

Test Reference No:- VA3
Design/Serial Nos:- 2870/
Comment:- test head viton Ø
Interspace Volume:- 7.89 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 0°C
Temperature ratio:- 1.092
µ ratio:- 0.946

TIME h:m:s	SLR	PRESSURE mbar
13:36:7	2.3E-05	2065
13:37:1	2.7E-05	2064
13:38:1	2.5E-05	2063
13:39:1	9.0E-06	2064
13:40:1	7.9E-06	2064
13:41:1	9.0E-06	2063
13:42:1	9.7E-06	2063
13:43:1	9.6E-06	2063
13:44:1	1.0E-05	2063
13:45:1	1.0E-05	2062
13:46:1	1.1E-05	2062

Leak Rate(SLR):- 1.1E-05 bar cc/sec
Atmos Pressure:- 1013 mbar
Starting Pressure:- 2065 mbar
Final Pressure:- 2062 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 4/10/94

System Date TUE 04 OCT 1994 14:43:57
CALT No: 0045 Sensor No: 653972
Days since last calibration: 47

System Date TUE 04 OCT 1994 16:29:23
CALT No: 0045 Sensor No: 653972
Days since last calibration: 47

CROFT ASSOCIATES
CALTS - U1.35

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CALTS - U1.35

*****LEAK TEST*****

*****LEAK TEST*****

Test Reference No:- UA4
Design/Serial Nos:- 2870/
Comment:- test head viton -10
Interspace Volume:- 7.89 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -10°C
Temperature ratio:- 1.133
μ ratio:- 0.924

Test Reference No:- UA5
Design/Serial Nos:- 2870/
Comment:- test head viton -20
Interspace Volume:- 7.89 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -20°C
Temperature ratio:- 1.178
μ ratio:- 0.902

TIME h:m:s	SLR	PRESSURE mbar
14:50:54	1.6E-05	2062
14:51:48	1.8E-05	2062
14:52:48	1.8E-05	2062
14:53:48	1.1E-05	2062
14:54:48	1.1E-05	2061
14:55:48	1.3E-05	2061
14:56:48	1.1E-05	2061
14:57:48	1.2E-05	2060
14:58:48	1.8E-05	2060
14:59:48	1.5E-05	2059
15:0:48	1.2E-05	2059

TIME h:m:s	SLR	PRESSURE mbar
16:37:18	1.4E-05	2070
16:38:13	9.2E-06	2070
16:39:13	9.2E-06	2070
16:40:12	9.2E-06	2070
16:41:12	8.1E-06	2069
16:42:13	8.3E-06	2069
16:43:13	9.2E-06	2069
16:44:12	1.1E-05	2069
16:45:12	9.8E-06	2068
16:46:12	8.7E-06	2068
16:47:13	1.0E-05	2068

Leak Rate(SLR):- 1.2E-05 bar cc/sec
Atmos Pressure:- 1015 mbar
Starting Pressure:- 2062 mbar
Final Pressure:- 2059 mbar

Leak Rate(SLR):- 1.0E-05 bar cc/sec
Atmos Pressure:- 1024 mbar
Starting Pressure:- 2070 mbar
Final Pressure:- 2068 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 4/10/94

Sig:  Date: 4/10/94



System Date WED 05 OCT 1994 08:40:48
CALT No: 0045 Sensor No: 653972
Days since last calibration: 48

System Date WED 05 OCT 1994 09:32:24
CALT No: 0045 Sensor No: 653972
Days since last calibration: 48

***CROFT ASSOCIATES**
CALTS - U1.35

***CROFT ASSOCIATES**
CALTS - U1.35

*****LEAK TEST*****

*****LEAK TEST*****

Test Reference No:- U96
Design/Serial Nos:- 2870/
Comment:- test head viton -30
Interspace Volume:- 7.89 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -30°C
Temperature ratio:- 1.226
p ratio:- 0.980

Test Reference No:- UA7
Design/Serial Nos:- 2870/
Comment:- test head viton -35
Interspace Volume:- 7.89 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -35°C
Temperature ratio:- 1.252
p ratio:- 0.870

TIME h:m:s	SLR	PRESSURE mbar
8:46:59	1.7E-05	2098
8:47:53	4.5E-06	2097
8:48:53	1.4E-05	2097
8:49:53	1.2E-05	2097
8:50:53	1.0E-05	2097
8:51:53	9.1E-06	2096
8:52:53	9.1E-06	2096
8:53:54	8.4E-06	2096
8:54:53	8.5E-06	2096
8:55:53	9.6E-06	2095
8:56:53	8.1E-06	2096

TIME h:m:s	SLR	PRESSURE mbar
9:39:0	6.3E-03	1334
9:39:53	1.2E-02	1276
PRESSURE GAUGE		
9:41:51		1938 mbar
Any key to exit		
PRESSURE GAUGE		
9:41:57		1912 mbar
Any key to exit		
PRESSURE GAUGE		

Leak Rate(SLR):- 8.1E-06 bar cc/sec
Atmos Pressure:- 1022 mbar
Starting Pressure:- 2098 mbar
Final Pressure:- 2096 mbar

9:42:6 1876 mbar
Any key to exit

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 5/10/94

System Date WED 05 OCT 1994 10:57:20
CALT No: 0011 Sensor No: C89100
Days since last calibration: 0

***CROFT ASSOCIATES**
CALTS - U1.35

*****LEAK TEST*****

Test Reference No:- UA8
Design/Serial Nos:- 2870/
Comment:- test head viton amb
Interspace Volume:- 7.89 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- 21° C
Temperature ratio:- 1.014
μ ratio:- 0.991

TIME h:m:s	SLR	PRESSURE mbar
11:4:29	3.8E-05	2097
11:5:23	1.1E-05	2097
11:6:23	1.1E-05	2097
11:7:23	8.5E-06	2097
11:8:22	5.4E-06	2097
11:9:22	5.8E-06	2097
11:10:22	3.6E-06	2097
11:11:22	3.1E-06	2097
11:12:22	1.8E-06	2097
11:13:22	2.4E-06	2097
11:14:23	1.8E-06	2097

Leak Rate(SLR):- 1.8E-06 bar cc/sec
Atmos Pressure:- 1023 mbar
Starting Pressure:- 2097 mbar
Final Pressure:- 2097 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 5/10/94

System Date WED 05 OCT 1994 13:36:02
CALT No: 0011 Sensor No: C89100
Days since last calibration: 0

***CROFT ASSOCIATES**
CALTS - U1.35


*****LEAK TEST*****

Test Reference No:- UA9
Design/Serial Nos:- 2870/
Comment:- test head viton -30
Interspace Volume:- 7.89 cc
Settling Time:- 5 mins
Test Duration:- 10 mins
Temperature:- -30° C
Temperature ratio:- 1.226
μ ratio:- 0.880

TIME h:m:s	SLR	PRESSURE mbar
13:43:17	1.8E-03	1830
13:44:10	2.1E-03	1796
13:45:10	2.1E-03	1763
13:46:10	2.0E-03	1732
13:47:10	2.0E-03	1703
13:48:10	1.9E-03	1675
13:49:11	1.9E-03	1649
13:50:10	1.8E-03	1624
13:51:10	1.8E-03	1601
13:52:10	1.7E-03	1578
13:53:11	1.7E-03	1556

Leak Rate(SLR):- 1.7E-03 bar cc/sec
Atmos Pressure:- 1037 mbar
Starting Pressure:- 1830 mbar
Final Pressure:- 1556 mbar

Standard conditions:
Temperature:- 25° C
Up stream pressure:- 1000 mbar
Down stream pressure:- 0 mbar

Sig:  Date: 5/10/94