Duolok®
INSTRUMENTATION TUBE FITTINGS

TECHNICAL REPORT

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Table 1: Contents

Table 1.0, Contents

Introduction

Since its inception in 1926, SSP has exhibited an expertise in the precision machining of tight tolerance, high quality fitting components. In fact, SSP's historical reputation for product quality, service and performance is recognized across the country and around the world.

In 1986, SSP relocated to its 25-acre property in Twinsburg, Ohio Southeast of Cleveland in North America's manufacturing heartland. Within its modern 165,000 square foot manufacturing facility, SSP has developed the internal ability to control its manufacturing variables as much or more than any other fittings' manufacturer. SSP designs and produces its own specialty cutting tools to proprietary standards with a 5 axis CNC tool and cutter grinder, high speed 4 axis CNC machining centers and ultra precise EDM's to allow manufacturing to the most stringent dimensional tolerances and surface finishes. Additionally, SSP's tool making capability supports an internal hot, closed-die forging operation. SSP plans, controls and performs its own metal forging operations on all elbows, tees and crosses manufactured into SSP fittings, connectors and adapters. Indeed, SSP's production capacity is among the largest single-site facilities in the entire industry with the capability to allow one-of-a kind, "specials" machining on single spindle CNC's to high volume production on multi-spindle automatics.

Furthermore, SSP's ISO9001 Quality System Certification and Registration by DNV assures conformance to the highest levels of quality. The substantial investment of time and funds to obtain and maintain such status has paid dividends for SSP and its customers in efficiencies in process and supply.

In 1993 in response to continued customer requests for an alternative product offering in the Instrumentation marketplace; strategic plans were developed to launch a division of SSP to design, manufacture and distribute American manufactured, Instrumentation quality tube fittings as a direct alternative to the registered trademark brand of Swagelok®. The recruitment of recognized Instrumentation industry experts occurred, and a specialized design and business unit team, SSP Instrumentation, was formed. Following an ISO 9001 design process pattern, the critical elements of design planning, including the detailed documentation of design inputs and outputs occurred for the development of **Duolok®** tube fittings. Examples of such design inputs include:

Dimensional similarity
Material of construction similarity
Installation instruction similarity with gageability
Operation and performance similarity
Brand interchangeability and intermixability
Corrosion resistance similarity
Applicable ANSI / ASME B 31.3 requirements

To accomplish the required design plan tasks of verification and validation, a specialized Technical Center was built within SSP. In addition to the exhaustive engineering calculations for confirmation of design conformance to industry standards and other engineering developed criteria, customized NIST traceable testing equipment was procured to allow:

Hydrostatic Proof and Burst Pressure Testing
Air and/or Helium Pressure Testing
High Vacuum Testing
Cyclic Vibration Testing
Tensile Pull Testing
Hydraulic Impulse Testing
Thermal Cycle Testing
Low Temperature (Cryogenic) Testing
High Temperature Testing

Additional specific testing of Duolok with Swagelok, Parker CPI® and Gyrolok® was undertaken to confirm design compatibility and performance similarity, as well as competitive interchangeability and intermixability.

Examples of such additional testing includes:

Dimensional Measurement Comparison
Installation Make-Up Torque Comparison
Make-up Gageability Confirmation and Comparison

Conformance to the design engineering team's prescribed acceptance criteria allows the products' release for production and distribution to the marketplace.

Section 1: Document Introduction

This document's purpose is to report, in a published format for public review, a representative sampling of the **Duolok** tube fitting's actual performance results from the Design Plan's Validation Tests. The performance results are measured against the Design Team's Approved Acceptance Criteria, which are based on meeting or exceeding the published and / or test-based performance of equivalent products from Swagelok and Parker. A positive testing performance of the products in the Validation Tests was required to complete the final element of the design cycle and provide for the Design Release of the **Duolok** product family.

Section 2: Tests and General Conclusions of Results

The preceding table (Table 1.0) lists the major Validation Tests that were performed, and the sections which follow describe the tests and outline specific results. All products manufactured at SSP are to approved and controlled engineering documentation, to established process and quality procedures at every stage of manufacture, with fully calibrated quality and process instrumentation, using only certified and traceable materials. Tested products were selected randomly from documented normal production runs. Before and after test samples were retained for reference. All tubing used in testing meets applicable ASTM specifications, and has approved material and chemical certifications.

All SSP tests conducted on products are with laboratory equipment and instrumentation in current calibration. Trained personnel conducted tests by following approved, written test procedures. All test results were subjected to thorough engineering review and approval before internal publication.

In every case all **Duolok** test results met or exceeded the established Design Team's Acceptance Criteria for these products. As such, they also met or exceeded equivalent major competitive product performance, as measured in test data and / or reported in publications.

Section 3.0: Validation Tests and Results

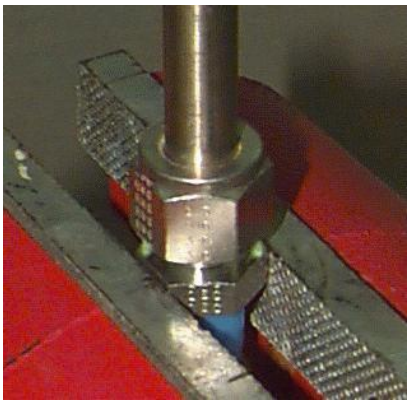
Section 3.1: Initial Makeup Test

Purpose: Test determines if the tube and fitting assembly has comparable levels of assembly torque to that of Swagelok and Parker, and achieves proper fitting makeup.

NOTE: Instrumentation Tube Fittings, due to the variances of tubing hardness and outside / inside diameters, require a certain geometric rotation of the tubing nut for proper makeup.

Assembly torque requirements vary per application and the level of torque is a general consideration, not a specification, for proper makeup.

Equipment & Configuration: Saw, tube deburring tool, vice and torque wrench. See Figures 3.1.1 - 2, Initial Makeup



Figures 3.1.1 - 2, Initial Makeup: Torque Measurement and Fitting Assembly

Test Procedure: The fitting and tube are assembled per published standard fitting makeup instructions. Torque, in inch-pounds (or foot-pounds), vs. nut tightening rotation is recorded in ¼ turn increments.

Acceptance Criteria: Fitting is to achieve proper makeup, with average assembly torque being equal to or less than Swagelok® / Parker® results. See Example Acceptance Criteria in Table 3.1.1 below.

Acceptance Criteria:

Tubing / Fitting			Acceptance Criteria				
			Torque, in-lb				
Size	Wall	W.P.	Revolutions				
#	in	psig	0.25	0.50	0.75	1.00	1.25
6	0.035	3,300	30	87	123	173	234
	0.065	6,550	48	105	163	205	259

Table 3.1.1, Example Initial Makeup Torque Acceptance Criteria

Test Results: Example results are shown in Table 3.1.2 below.

Results: Initial Makeup Torque Test

Sample No.	Initial Makeup Torque, in-lb												Test
	Size #	6	x	0.035"	Wall Tubing		Size #	6	x	0.065"	Wall Tubing		
	Revolutions					Pass Fail	Revolutions					Pass Fail	
	0.25	0.50	0.75	1.00	1.25	P / F	0.25	0.50	0.75	1.00	1.25	P / F	
1	10	40	60	80	120	P	10	40	65	105	150	P	Bite
2	10	40	55	80	140	P	10	50	70	110	160	P	
3	10	40	55	75	125	P	10	45	70	105	150	P	
4	10	35	55	80	125	P	15	60	90	130	170	P	
1	5	30	50	80	125	P	10	45	70	100	155	P	Tension
2	10	30	50	80	125	P	15	5	80	125	175	P	
3	10	35	55	80	135	P	15	50	70	100	150	P	
4	10	40	55	110	160	P	10	45	75	125	195	P	
5	5	40	65	90	140	P	10	50	70	110	165	P	
1	10	40	60	75	115	P	10	50	70	105	165	P	Gas Leak
2	10	35	60	85	135	P	10	50	75	115	165	P	
3	10	35	50	75	125	P	10	45	70	105	160	P	
4	10	40	55	85	135	P	10	50	80	110	175	P	
5	10	50	90	120	180	P	10	50	80	125	185	P	
6	10	40	60	80	130	P	10	50	75	100	160	P	
7	10	40	55	80	120	P	10	45	75	115	175	P	
8	10	40	60	85	145	P	10	50	80	115	170	P	
9	10	35	60	80	130	P	10	50	75	105	155	P	
10	10	40	70	90	145	P	10	45	65	95	145	P	
11	10	35	55	80	130	P	10	45	70	100	145	P	
12	10	40	60	90	150	P	10	40	65	100	155	P	
1	10	35	50	80	125	P	15	50	70	110	160	P	Thermal Cycle
2	10	40	60	90	135	P	20	55	80	115	165	P	
3	10	45	65	85	140	P	15	50	75	115	165	P	
4	10	40	60	85	145	P	15	60	90	130	180	P	
5	20	40	65	90	145	P	15	50	80	120	155	P	
1	5	35	55	95	130	P	10	50	75	105	155	P	Remake
2	5	40	55	85	130	P	10	40	70	110	155	P	
3	10	40	60	80	135	P	10	50	70	110	165	P	
4	10	35	55	90	145	P	10	40	70	105	155	P	
5	10	40	60	80	125	P	10	50	75	105	160	P	
6	10	40	65	90	140	P	10	50	75	110	170	P	

Table 3.1.2, Example Initial Makeup Torque Results

Conclusions: All Duolok assemblies met or exceeded the approved Acceptance Criteria.

Section 3.2: Hydrostatic Burst Pressure Test

Purpose: Test determines if the tube fitting assembly has adequate pressure-retaining capability, based on the ANSI / ASME B 31.3 maximum allowable working pressure of the tubing.

Equipment & Configuration: Two fittings are tested at a time – one on each end of a 4 ½" long test tube, per Initial Makeup Test (see Section 3). Both minimum and maximum recommended wall tubing (worst case conditions) are used for each tested product configuration. See Figures 3.2.1 – 3.

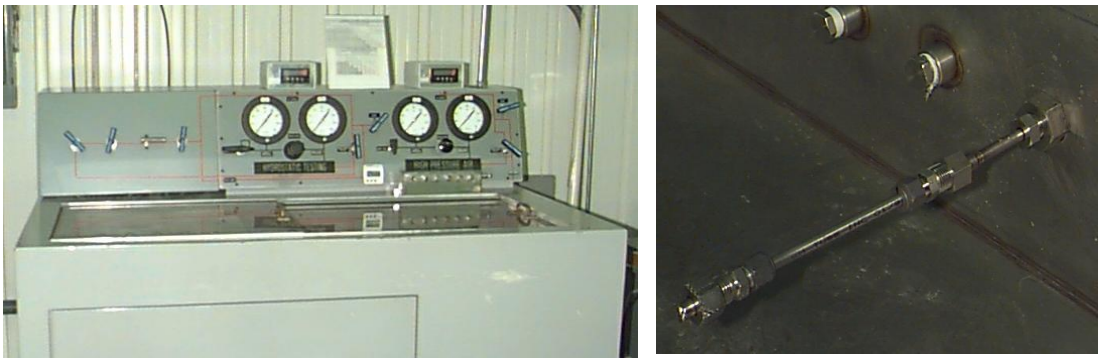


Figure 3.2.1 - 2, Burst Test Configuration

Figure 3.2.3, Burst Test Specimen

Test Procedure: The tube fitting assembly is hydrostatically pressurized in regular pressure increments which increase until tube burst is attained. The digitally displayed maximum pressure, in PSIG, - at which the tubing bursts or tubing pushes out of the fitting - is recorded.

Acceptance Criteria: The tube fitting assembly is to sustain a hydrostatic pressure, without observed leakage, exceeding a minimum of 4 times the ANSI / ASME maximum allowable working pressure of the tubing. Failure is to be by tubing burst, not by tube pushout from fitting.

Test Results: Example results are shown in Table 3.2.0 below.

Results: Burst Test (Sample - Tube ends: A, B)

Test	Sample No.		Tubing / Fitting		Acceptance Criteria		Burst Test		
	A	B	Size	Wall	W.P.	Burst = 4 x W.P.	Actual Burst	Fail Type	Pass Fail
	#	#	#	in	psig	psig	psig	n/a	P / F
Impulse	1	2	6	0.035	3,300	13,200	16,530	Tube	P
	3	4					16,520	Tube	P
	5	6					16,540	Tube	P
	7	8					16,520	Tube	P
	9	10					16,730	Tube	P
	11	12					16,730	Tube	P
	1	2		0.065	6,550	26,200	29,840	Tube	P
	3	4					29,770	Tube	P
	5	6					29,900	Tube	P
	7	8					29,820	Tube	P
	9	10					29,820	Tube	P
	11	12					30,190	Tube	P
Remake	1	2	6	0.035	3,300	13,200	16,450	Tube	P
	3	4					16,710	Tube	P
	5	6					16,730	Tube	P
	1	2		0.065	6,550	26,200	29,580	Tube	P
	3	4					29,380	Tube	P
	5	6					29,700	Tube	P
Vibration	1		6	0.035	3,300	13,200	16,230	Tube	P
	2						16,440	Tube	P
	3						16,500	Tube	P
Caps	1		6	0.065	6,550	26,200	29,980	Tube	P
	2						29,360	Tube	P
	3						29,640	Tube	P
	4						29,980	Tube	P
	5						29,920	Tube	P
	6						29,420	Tube	P

NOTE: A.C. = Acceptance Criteria

Table 3.2.0, Example Burst Test Results

Conclusions: All Duolok assemblies met or exceeded the approved Acceptance Criteria. All Duolok tube fittings sustained the required maximum allowable working pressure without leakage, and held leak free to tubing burst, without exhibiting tube push out from the fitting.

Section 3.3: Hydraulic Impulse Test

Purpose: Test determines if the tube fitting assembly can sustain extended pressure-cycling without leakage.

Equipment & Configuration: For each stand manifold position, two fittings are tested at a time – one on each end of a test tube piece. Both minimum and maximum recommended wall tubing (worst case conditions) are used for each tested product configuration. See Figures 3.3.1 – 2.

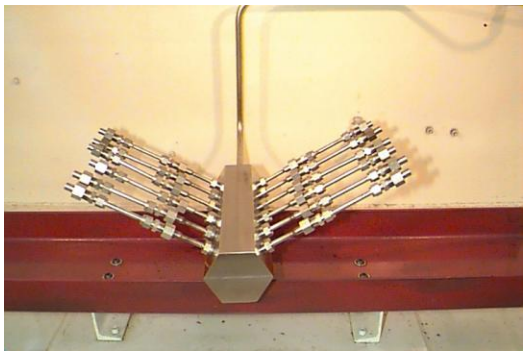


Figure 3.3.1 - 2, Hydraulic Impulse Test Stand and Fixture

Test Procedure: The tube fitting assembly is pressurized with hydraulic test oil in a manifold with up to 24 fittings. The hydraulic fluid temperature and the pressure cycle envelope conform to MIL-H-24135 test specification. Peak test pressure is 5,250 PSIG, sustained at 30 cycles/minute. Test oil temperature is maintained between 120°F-125°F. Following the Hydraulic Impulse Test, samples are also subjected to Burst Test.

Acceptance Criteria:

Hydraulic Impulse Test: The tube fitting assembly is to sustain pressure cycling without observed leakage for 150,000 test cycles.

Burst Test: The tube fitting assembly is to sustain a hydrostatic pressure, without observed leakage, exceeding a minimum of 4 times the ANSI / ASME maximum allowable working pressure of the tubing. Failure is to be by tubing burst, not by tube pushout from fitting.

Test Results: Example results are shown in Table 3.3.0 below.

Results: Impulse Test, followed by Burst Test:

Test	Sample No.		Tubing / Fitting		Acceptance Criteria			Impulse Test		
	A	B	Size	Wall	Impulse Cycles	Test Press.	Leak	Cycles without Failure	Leak	Pass Fail
	#	#	#	in	cycles	psig	Leak / None	cycles x 10^3	Leak / None	P / F
Impulse	1	2	6	0.035	150,000	5,250	None	150	None	P
	3	4						150	None	P
	5	6						150	None	P
	7	8						150	None	P
	9	10						150	None	P
	11	12						150	None	P
	1	2		0.065	150,000	5,250	None	150	None	P
	3	4						150	None	P
	5	6						150	None	P
	7	8						150	None	P
	9	10						150	None	P
	11	12						150	None	P

Test	Sample No.		Tubing / Fitting		Acceptance Criteria		Burst Test		
	A	B	Size	Wall	W.P.	Burst = 4 x W.P.	Burst Actual	Fail Type	Pass Fail
	#	#	#	in	psig	psig	psig	n/a	P / F
Impulse	1	2	6	0.035	3,300	13,200	16,530	Tube	P
	3	4					16,520	Tube	P
	5	6					16,540	Tube	P
	7	8					16,520	Tube	P
	9	10					16,730	Tube	P
	11	12					16,730	Tube	P
	1	2		0.065	6,550	26,200	29,840	Tube	P
	3	4					29,770	Tube	P
	5	6					29,900	Tube	P
	7	8					29,820	Tube	P
	9	10					29,820	Tube	P
	11	12					30,190	Tube	P

NOTE: A.C. = Acceptance Criteria

Table 3.3.0, Example Hydraulic Impulse and Burst Test Results

Conclusions: All Duolok assemblies met or exceeded the approved Acceptance Criteria. No leakage or rupture of a Duolok tube fitting assembly was observed.

Section 3.4: Repeated Remake Test

Purpose: Test determines capability of the tube fitting assembly to successfully seal after repeated assembly and disassembly of a made-up tube assembly with a mating fitting. This test simulates the normal use condition where fittings are repeatedly disassembled from fittings for fluid system service or maintenance, and reassembled with additional tightening.

Equipment & Configuration: Two fittings are tested at a time – one on each end of a 4 ½" long test tube, per Initial Makeup Test (see Section 3). Both minimum and maximum recommended wall tubing (worst case conditions) are used for each tested product configuration. See Figure 3.4.1, Repeated Remake Test

Figure 3.4.1, Repeated Remake Test (Size 8 Duolok)

Test Procedure: To simulate repeated remake conditions, the tube fitting is disassembled and assembled (tightening from the preceeding installation position an additional 1/12 turn – or 30° each time) at each reassembly, for five successive times. This is followed by air pressure testing to the maximum recommended working pressure of the tubing, under water to observe leakage. After each disassembly of the tube fitting assembly it is examined for absence of the following Remake Failure Criteria:

> Tube Sticking, Body Swelling, Nut Sticking, Thread Galling, Ferrule Set, Ferrule Galling, Body Denting, Excessive Torque, Tube pushout or burst.

Acceptance Criteria: The tube fitting assembly is to sustain an air booster test pressure, PSIG, of the ANSI / ASME maximum allowable working pressure of the tubing, up to a maximum pressure of 10,000 PSIG. Failure is either any observed air leakage bubble, or the presence of any of the above Remake Failure Criteria.

Test Results: Example results are shown in Table 3.4.0 below.

Results: Remake Gas Leak Tests

Gas Leak Test					
Tubing Size #:					**6**
Tubing Wall:		**0.035**	**in**	**0.065**	**in**
Gas Leak Test Press.		**3,350**	psig	**6,600**	psig
Acceptance Criteria:		**No Leak**	Leak / None	**No Leak**	Leak / None
Sample	**Remake**	**Leak**	**Pass Fail**	**Leak**	**Pass Fail**
#	#	Leak / None	P / F	Leak / None	P / F
1	1	None	P	None	P
	2	None	P	None	P
	3	None	P	None	P
	4	None	P	None	P
	5	None	P	None	P
2	1	None	P	None	P
	2	None	P	None	P
	3	None	P	None	P
	4	None	P	None	P
	5	None	P	None	P
3	1	None	P	None	P
	2	None	P	None	P
	3	None	P	None	P
	4	None	P	None	P
	5	None	P	None	P
4	1	None	P	None	P
	2	None	P	None	P
	3	None	P	None	P
	4	None	P	None	P
	5	None	P	None	P
5	1	None	P	None	P
	2	None	P	None	P
	3	None	P	None	P
	4	None	P	None	P
	5	None	P	None	P
6	1	None	P	None	P
	2	None	P	None	P
	3	None	P	None	P
	4	None	P	None	P
	5	None	P	None	P

Table 3.4.0, Example Repeated Remake Test Results

Conclusions: All Duolok assemblies met or exceeded the approved Acceptance Criteria. No leakage or Remake failures were observed in any Duolok tube fitting assemblies.

Section 3.5: Tension Test

Purpose: Test determines if the tube fitting assembly has the capability to sustain axial forces equivalent to the hydrostatic end force caused by approaching four times tubing working pressure. This test simulates end loading of straight, stiff, tube assemblies subjected to high end loads, as occur with structural deflection and thermal expansions.

Equipment & Configuration: One fitting is assembled on the end of a test tube, per Initial Makeup Test (see Section 3). Tensile loads are applied by a Tensile Test machine. Both minimum and maximum recommended wall tubing (worst case conditions) are used for each tested product configuration. See Figure 3.5.1.

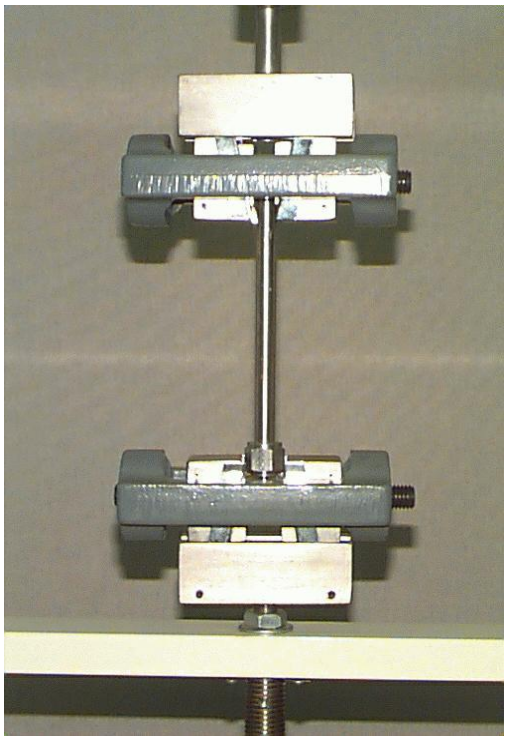


Figure 3.5.1, Tension Test Configuration.

Test Procedure: The tube fitting assembly is axially loaded in tension, and increasing loads are applied until tubing pull out is observed. The maximum load sustained by the fitting, in pounds, is recorded by digital force instrumentation.

Acceptance Criteria: The tube fitting assembly is to sustain an end force approaching that equivalent to the end force produced by 4 times the ANSI / ASME maximum allowable working pressure of the tubing. Failure is a pull out force less than this equivalent end load.

Test Results: Example results are shown in Table 3.5.0 below.

Results: Tension Test

Sample No.	Tubing / Fitting		Acceptance Criteria		Tension Test				
	Size	Wall	W.P.	Burst = 4 x W.P. (basis of Pullout Force)	Tubing O.D.	Pullout Force (based on 4 x W.P.)	Actual Pullout Force	Fail Type	Pass Fail
#	#	in	psig	psig	in	lb	lb	#	P / F
1	6	0.035	3,300	13,200	0.3755	1,462	1,850	1	P
2					0.3755	1,462	1,800	1	P
3					0.3755	1,462	1,994	1	P
4					0.3755	1,462	2,464	1	P
5					0.3755	1,462	1,712	1	P

NOTE: A.C. = Acceptance Criteria

FAIL TYPE #:

*1 Pullout
*2 Broke in Tension at the rear ferrule.
*3 Tube broke in Tension at mid-length.

Table 3.5.0, Example Tension Test Results

Conclusions: All Duolok assemblies met or exceeded the approved Acceptance Criteria. Observed pull out forces generally exceeded the equivalent of four times tubing working pressure for all Duolok tube fitting assemblies.

Section 3.6: Vibration Test

Purpose: Test determines if the tube fitting assembly has high resistance to vibration-based fatigue when simultaneously exposed to 1.6 times tubing maximum allowable working pressure, based on the ANSI / ASME B 31.3 maximum allowable working pressure of the tubing.

Equipment & Configuration: One fitting is tested at a time in each station of the stand. The fitting is assembled to one end of a test tube, made up per Initial Makeup Test (see Section 3). A small format strain gage is mounted axially on the tube next to the fitting nut, and the gage is read by peak stress detecting strain gage instrumentation. A motor coaxial to the fitting axis turns a faceplate containing a spherical bearing that is radially offset to produce cyclic strain on the tested tube fitting assembly.

Minimum recommended wall tubing (worst case condition) is used for each tested product configuration. See Figures 3.6.1 - 2.

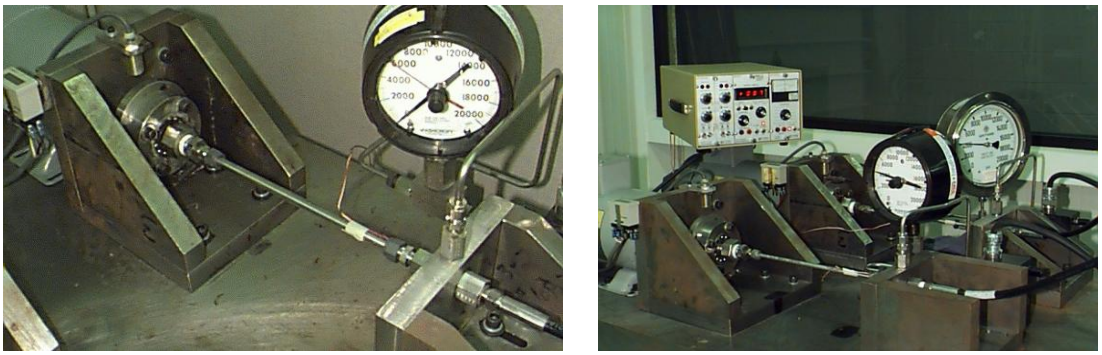


Figure 3.6.1 - 2, Vibration Test Stand and Test Configuration

Test Procedure: The motor faceplate is adjusted to produce a maximum stress adjacent the tube fitting nut equal to 60% of the tubing yield stress (YS), in KSI, as digitally indicated on the strain gage instrumentation. The tube fitting assembly is hydrostatically pressurized to 1.6 times the tubing maximum allowable working pressure and isolated from the pump by a valve. A digital counter counts revolutions of the motor faceplate (equal to the number of complete stress cycles from maximum tensile to maximum compressive stress of 60% of YS). A pressure switch stops the test on any loss of pressure during the test.

Acceptance Criteria: The tube fitting assembly is to sustain a combination of hydrostatic pressure equal to 1.6 times the ANSI / ASME maximum allowable working pressure of the tubing, and 10 million stress cycles. Failure is any loss of pressure in the tube fitting assembly.

Test Results: Example results are shown in Table 3.6.0 below.

Configuration: Vibration Test

Strain gage data:		
Item	**Value**	**Unit**
Lot number:	R-A48BE13	n/a
Stock number:	EA-09-062EN-350	n/a
Gage factor:	2.085 ± 0.5% @ 24°C	dmls
Gage Excitation Voltage:	5	V
Peak Stress value:	17,000	psi
Modulus of Elasticity:	29,000,000	psi
Strain setting:	586.2	με

Results: Vibration Test

Test	Sample No.	Tubing / Fitting		Acceptance Criteria			Vibration Test		
		Size	Wall	Vibr. Cycles	Test Press.	Leak	Cycles without Failure	Leak	Pass Fail
	#	#	in	cycles	psig	Leak / None	cycles x 10^6	Leak / None	P / F
Vibration	1	**6**	0.035	10,000,000	5,280	None	10	None	P
	3						10	None	P
	3						10	None	P

Results: Burst Test after Vibration Test

Test	Sample No.	Tubing				Burst Test		
		Size	Wall	W.P.	Burst A.C. = 4 x W.P.	Actual Burst	Fail Type	Pass Fail
	#	#	in	psig	psig	psig	n/a	P / F
Vibration	1	**6**	0.035	3,300	13,200	16,230	Tube	P
	2					16,440	Tube	P
	3					16,500	Tube	P

NOTE: A.C. = Acceptance Criteria

Table 3.6.0, Example Vibration Test Results

Conclusions: All Duolok assemblies met or exceeded the approved Acceptance Criteria. No observed leaks or loss of pressure occurred in any Duolok tube fitting assemblies.

Section 3.7: Intermix Test

Purpose: Test determines if all combinations of tube fitting components (nut, back ferrule, front ferrule and fitting body) of Duolok and Swagelok can be intermixed in a tube fitting assembly, resulting in both adequate gas and liquid pressure-retaining capability, based on ANSI / ASME B 31.3 maximum allowable working pressure of the tubing.

This test simulates the random intermixing of inventoried Duolok and Swagelok fitting components in the field to make up tube fitting assemblies.

Equipment & Configuration: Two fittings of a given combination of fitting components are tested at a time – one on each end of a 4 ½" long test tube, per Initial Makeup Test (see Section 3). Maximum recommended wall tubing (worst case condition) is used for each tested product configuration. See Figure 3.7.1, and Table 3.7.1.

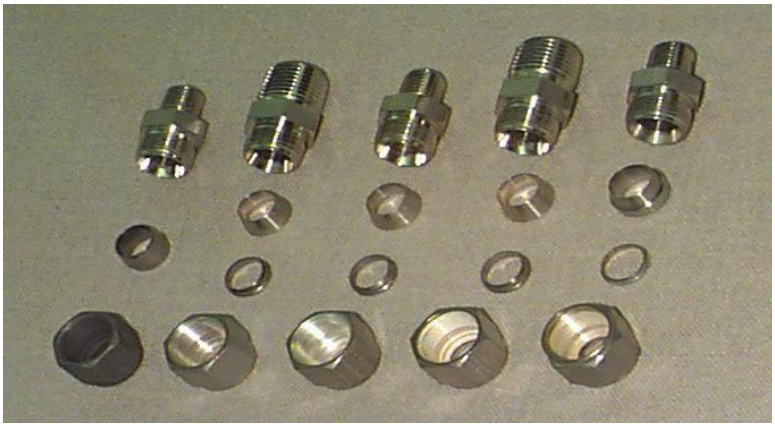


Figure 3.7.1, Intermix Test Configuration.

Components	Combination						
	1	2	3	4	5	6	7
Body	*Swagelok*	*Swagelok*	*Swagelok*	*Duolok*	*Swagelok*	*Duolok*	*Swagelok*
Front Ferrule	*Swagelok*	*Swagelok*	*Duolok*	*Swagelok*	*Swagelok*	*Duolok*	*Duolok*
Back Ferrule	*Swagelok*	*Duolok*	*Swagelok*	*Swagelok*	*Duolok*	*Swagelok*	*Duolok*
Nut	*Duolok*	*Swagelok*	*Swagelok*	*Swagelok*	*Duolok*	*Swagelok*	*Duolok*

Components	Combination						
	8	9	10	11	12	13	14
Body	*Duolok*	*Duolok*	*Duolok*	*Swagelok*	*Duolok*	*Swagelok*	*Duolok*
Front Ferrule	*Duolok*	*Duolok*	*Swagelok*	*Duolok*	*Swagelok*	*Duolok*	*Swagelok*
Back Ferrule	*Duolok*	*Swagelok*	*Duolok*	*Duolok*	*Swagelok*	*Swagelok*	*Duolok*
Nut	*Swagelok*	*Duolok*	*Duolok*	*Swagelok*	*Duolok*	*Duolok*	*Swagelok*

Table 3.7.1: Intermix Test Combinations

Test Procedure: The tube fitting assembly is subjected to the Gas Leak Test (see Section 3.9), and then the Burst Test (see Section 3.2).

Acceptance Criteria: Gas Leak Test: The tube fitting assembly is to sustain an air booster test pressure, PSIG, of the ANSI / ASME maximum allowable working pressure of the tubing, up to a maximum pressure of 10,000 PSIG. Failure is any observed air leakage bubble.

Burst Test: The tube fitting assembly is to sustain a hydrostatic pressure, without observed leakage, exceeding a minimum of 4 times the ANSI / ASME maximum allowable working pressure of the tubing. Failure is to be by tubing burst, not by tube pushout from fitting.

Test Results: Example results are shown in Table 3.7.2 below.

Results: Intermix Test

Sample	Tubing / Fitting		Acceptance Criteria					Gas Leak Test		Burst Test		
	Size No.	Wall	W.P.	Burst = 4 X W.P.	Gas Leak Press.	Leak	Combin-ation	Leak	Pass Fail	Actual Burst	Fail Type	Pass Fail
#	#	in	psig	psig	psig	Leak / None	#	Leak / None	P / F	psig	n/a	P / F
1	6	0.065	6,550	26,200	6,550	None	1	None	P	29,930	Tube	P
2								None	P	29,930	Tube	P
3							2	None	P	29,970	Tube	P
4								None	P	29,970	Tube	P
5							3	None	P	30,190	Tube	P
6								None	P	30,190	Tube	P
7							4	None	P	29,680	Tube	P
8								None	P	29,680	Tube	P
9							5	None	P	29,990	Tube	P
10								None	P	29,990	Tube	P
11							6	None	P	29,910	Tube	P
12								None	P	29,910	Tube	P
13							7	None	P	30,280	Tube	P
14								None	P	30,280	Tube	P
15							8	None	P	29,800	Tube	P
16								None	P	29,800	Tube	P

Table 3.7.2, Example Intermix Test Results

Conclusions: All Duolok assemblies met or exceeded the approved Acceptance Criteria. All Duolok tube fittings sustained the required maximum allowable working pressure without leakage, and held leak free to tubing burst without exhibiting tube push out from the fitting.

Section 3.8: Interchange Test

Purpose: Test determines if all combinations of both a tube fitting body and a tubing assembly (tube, nut, back ferrule, and front ferrule, assembled together per standard assembly instructions) of Duolok and a competitive fitting brand can be Interchanged in a complete tube fitting assembly, resulting in both adequate gas and liquid pressure-retaining capability, based on ANSI / ASME B 31.3 maximum allowable working pressure of the tubing.

This test simulates the interchange of fitting bodies with already made up tube assemblies in the field, for components from either Duolok, Swagelok, Parker CPI or Hoke Gyrolok fittings.

Equipment & Configuration: Two fittings of a given combination of fitting components are tested at a time – one on each end of a 4 ½" long test tube, per Initial Makeup Test (see Section 3). Maximum recommended wall tubing (worst case condition) is used for each tested product configuration. See Figures 3.8.1 – 2.

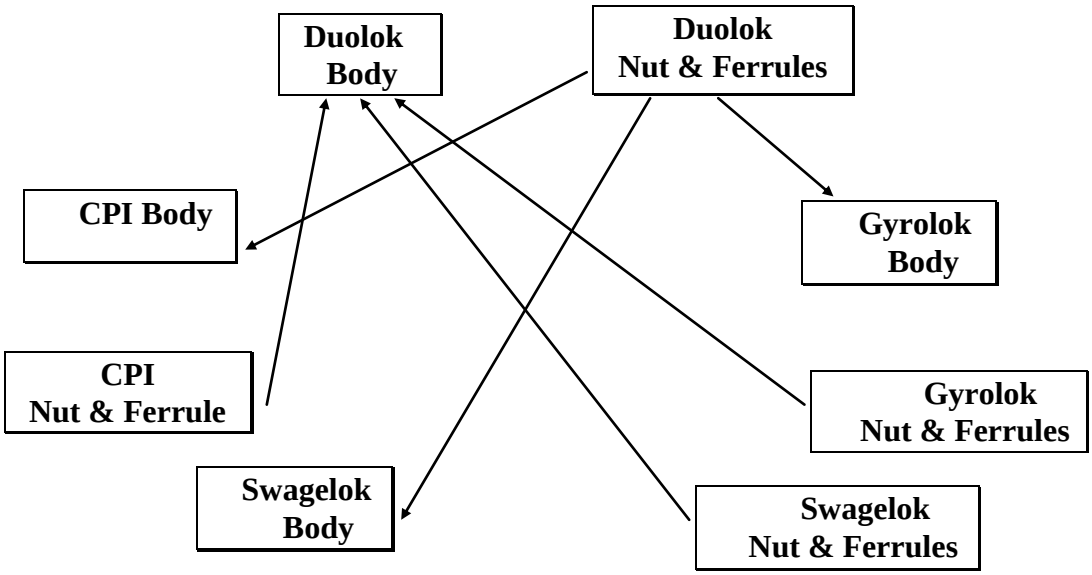


Figure 3.8.1, Interchange Test Combinations

Figure 3.8.2, Interchange Test Fittings and Components

Test Procedure: The tube fitting assembly is subjected to the Gas Leak Test (see Section 3.9), and then the Burst Test (see Section 3.2).

Acceptance Criteria: Gas Leak Test: The tube fitting assembly is to sustain an air booster test pressure, PSIG, of the ANSI / ASME maximum allowable working pressure of the tubing, up to a maximum pressure of 10,000 PSIG. Failure is any observed air leakage bubble.

Burst Test: The tube fitting assembly is to sustain a hydrostatic pressure, without observed leakage, exceeding a minimum of 4 times the ANSI / ASME maximum allowable working pressure of the tubing. Failure is to be by tubing burst, not by tube pushout from fitting.

Test Results: Example results are shown in Table 3.8.0 below.

Results: Interchange Test

Sample	Tubing / Fitting		Acceptance Criteria				Combinations:		Gas Leak Test		Burst Test		
	Size No.	Wall	W.P.	Burst = 4 X W.P.	Gas Leak Press.	Leak	Nut & Ferrule (s)	Body	Leak	Pass Fail	Actual Burst	Fail Type	Pass Fail
#	#	in	psig	psig	psig	Leak / None	name	name	Leak / None	P / F	psig	n/a	P / F
1	6	0.065	6,550	26,200	6,550		Swagelok	Duolok	None	P	29,600	Tube	P
2									None	P	29,600	Tube	P
3							Gyrolok	Duolok	None	P	29,860	Tube	P
4									None	P	29,860	Tube	P
5							CPI	Duolok	None	P	29,720	Tube	P
6									None	P	29,720	Tube	P
7							Duolok	CPI	None	P	29,720	Tube	P
8									None	P	29,720	Tube	P
9							Duolok	Swagelok	None	P	29,790	Tube	P
10									None	P	29,790	Tube	P
11							Duolok	Gyrolok	None	P	30,140	Tube	P
12									None	P	30,140	Tube	P

Table 3.8.0 Example Interchange Test Results

Conclusions: All interchanged Duolok assemblies met or exceeded the approved Acceptance Criteria. All Duolok tube fittings sustained the required maximum allowable working pressure without leakage, and held leak free to tubing burst without exhibiting tube push out from the fitting.

Section 3.9: Gas Leak Test

Purpose: Test determines if the tube fitting assembly has adequate gas pressure-retaining capability, based on the ANSI / ASME B 31.3 maximum allowable working pressure of the tubing.

Equipment & Configuration: Two fittings are tested at a time – one on each end of a 4 ½" long test tube, per Initial Makeup Test (see Section 3). Both minimum and maximum recommended wall tubing (worst case conditions) are used for each tested product configuration. See Figure 3.9.1 - 2, Gas Leak Test Configuration.

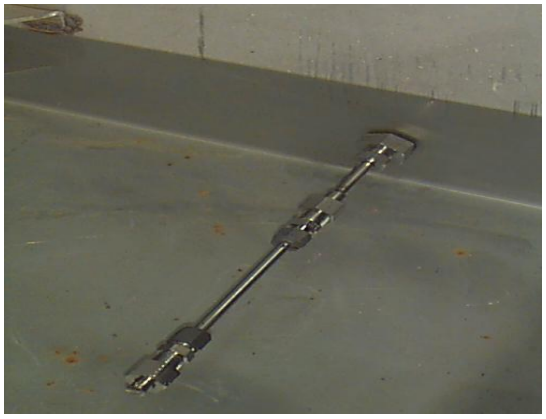


Figure 3.9.1 - 2, Gas Leak Test Configuration.

Test Procedure: The tube fitting assembly is pressurized, under water, with air in regular pressure increments to the lower of either the maximum allowable working pressure of the tubing or 10,000 PSIG, is attained. This pressure is held for a minimum of five minutes. The digitally displayed maximum pressure, in PSIG, is recorded

Acceptance Criteria: The tube fitting assembly is to sustain an air booster test pressure, PSIG, of the ANSI / ASME maximum allowable working pressure of the tubing, up to a maximum pressure of 10,000 PSIG. Failure is any observed air leakage bubble.

Test Results: Example results are shown in Table 3.9.0 below.

Results: Gas Leak Test

Test	Sample No.		Tubing / Fitting		Acceptance Criteria				Gas Leak Test	
	A	B	Size	Wall	W.P.	Burst = 4 x W.P.	Test Press.	Leak	A.C. Leak	Pass Fail
	#	#	#	in	psig	psig	psig	Leak / None	Leak / None	P / F
Gas Leak	1	2	6	0.035	3,300	13,200	3,300	None	None	P
	3	4							None	P
	5	6							None	P
	7	8							None	P
	9	10							None	P
	11	12							None	P
	1	2		0.065	6,550	26,200	6,550	None	None	P
	3	4							None	P
	5	6							None	P
	7	8							None	P
	9	10							None	P
	11	12							None	P

NOTE: A.C. = Acceptance Criteria

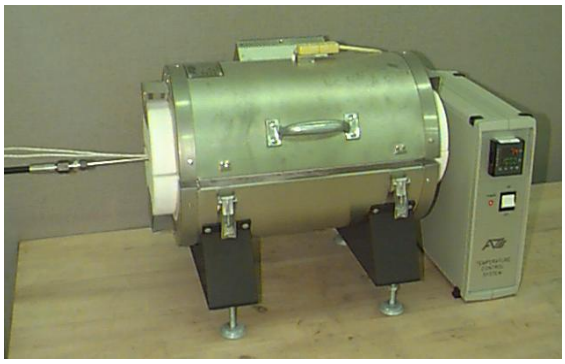
Table 3.9.0 Example Gas Leak Test Results

Conclusions: All Duolok assemblies met or exceeded the approved Acceptance Criteria. No Duolok tube fitting assemblies developed observable Gas Leakage.

Section 3.10: Thermal Cycle, Thermal Shock Test

Purpose: Test determines if the tube fitting assembly has the capability to sustain substantial and rapid temperature cycling while maintaining vacuum and pressure retention capabilities.

Equipment & Configuration: One fitting is tested at a time on the end of a test tube, assembled per Initial Makeup Test (see Section 3). Both minimum and maximum recommended wall tubing (worst case conditions) are used for each tested product configuration. See Figure 3.10.1 - 2, Thermal Cycle, Thermal Shock Test Configuration.



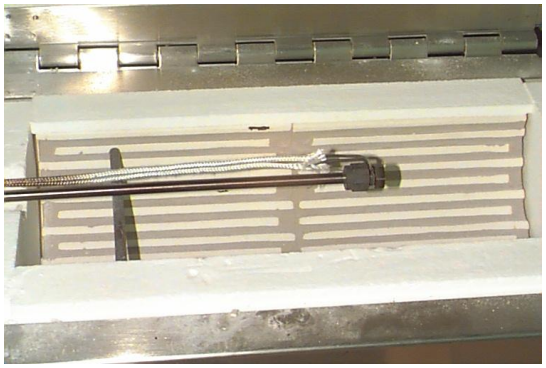


Figure 3.10.1 - 2, Thermal Cycle, Thermal Shock Test Configuration.

Test Procedure: A thermocouple is directly attached to the fitting to ensure accurate achievement of test temperature. The tube fitting assembly is pressurized with air to 1,000 PSIG, and simultaneously heated in a tubular furnace to 1,000 °F (538 °C). The digitally displayed maximum pressure, in PSIG, and temperature is recorded. On reaching both pressure and temperature the tube fitting assembly is removed and rapidly cooled to ambient temperature. This cycle is repeated three times.

The above thermal cycling is followed by a vacuum test whereby a high vacuum is drawn on the inside of the fitting by Vacuum Test Equipment, helium gas is sprayed over the outside of the fitting and a leakage rate is recorded.

Acceptance Criteria: The tube fitting assembly is to sustain the above thermal cycling under air pressure, and after quenching to room temperature not exhibit any detectable leakage when immersed in water. Additionally, when subsequently subjected to the vacuum test, the fitting must not exhibit a helium vacuum test leak rate in excess of $< 4 \times 10^{-9}$ mbar l/s.

Test Results: Example results are shown in Table 3.10.0 below.

Results: Thermal Cycle, Vacuum Tests

Sample	Tubing		Acceptance Criteria				Vacuum Test	
	Size No.	Wall	Temperature Range	Test Press.	Leak Rate	Cycle No.	Actual Leak Rate	Pass Fail
#	in	in	°F	psig	atm cc/s	#	atm cc/s	P / F
1	6	0.035	Amb. to 1,000	1,000	1.00E-09	1		
						2		
						3	6.0E-10	P
2						1		
						2		
						3	2.8E-10	P
3						1		
						2		
						3	5.0E-10	P
1		0.065	Amb. to 1,000	1,000	1.00E-09	1		
						2		
						3	3.2E-10	P
2						1		
						2		
						3	4.0E-10	P
3						1		
						2		
						3	4.3E-10	P

NOTE: A.C. = Acceptance Criteria

Table 3.10.0 Example Thermal Cycle Test Results

Conclusions: All Duolok assemblies met or exceeded the approved Acceptance Criteria. Observed leak rates of tested Duolok tube fitting assemblies performed consistently better than the required Acceptance Criteria, and published competitive results.

Section 3.11: Vacuum Test

Purpose: Test determines if the tube fitting assembly has the capability to seal at high vacuums, with ultra low leakage rates.

Equipment & Configuration: One fitting is tested at a time on the end of a test tube, assembled per Initial Makeup Test (see Section 3). Both minimum and maximum recommended wall tubing (worst case conditions) are used for each tested product configuration. See Figure 3.11.1 - 2, Vacuum Test Configuration.

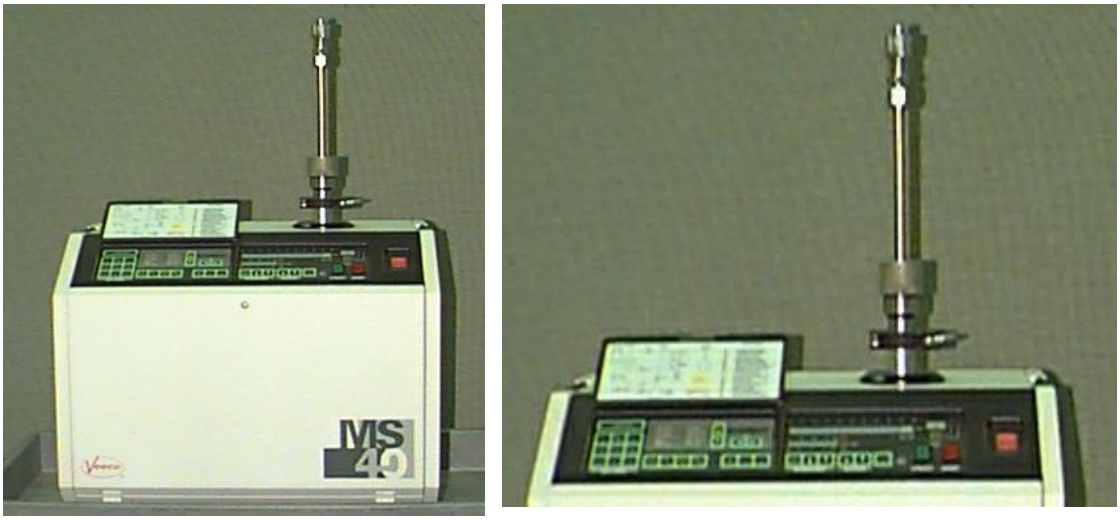


Figure 3.11.1 - 2, Vacuum Test Configuration

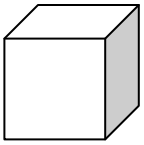
The Leak Rate Sensitivity of the Veeco MS-40 Helium Leak Detection Test Equipment is 4.0 x 10^{-11} mbar l/s. Duolok fittings have been tested and shown results in the 10^{-11} mbar l/s range.

> Test Port pressures are displayed in units of milli-Torr. The vacuum levels developed during testing are as low as 4 mT - 9mT. This equates to an absolute pressure of .0000744 - 0.000174 PSIA.

Test Procedure: The internal volume of the tube fitting assembly is evacuated to a vacuum of 4 mT – 9 mT (milliTorr). The digitally displayed vacuum pressure, in mT, is recorded. On achieving full vacuum pressure, helium gas is sprayed around the outside of the fitting, and the leakage rate is recorded.

Acceptance Criteria: The tube fitting assembly is to sustain the above vacuum pressure, and not exhibit a helium test leak rate in excess of < 4 x 10^{-9} mbar l/s.

What this ultra low level Leak Rate means in practical terms is shown in the following table, which gives the time (in months, years) it would take for the listed Leak Rates to fill one cubic inch of volume with air to atmospheric pressure at ambient temperature:



1 Cubic Inch

Fitting Leak Rate	Time for Fitting Leak to fill 1.0 in^3 @ 1 Atmosphere Pressure
1.0 X 10^{-6} mbar l/s	6.3 months (192 days)
1.0 X 10^{-9} mbar l/s	527 years
1.0 X 10^{-11} mbar l/s	52,655 years

Test Results: Example results are shown in Table 3.11.0 below.

Results: Vacuum Leak Test

Sample No.		Tubing / Fitting		A.C.	Vacuum Leak Test		
A	B	Size	Wall	Leak Rate	Port Vac.	Leak Rate	Pass Fail
#	#	#	in	atm cc/s	mT	atm-cc/s	P / F
1	2	6	0.035	1.00E-08	4	8.00E-10	P
3	4				4	7.00E-10	P
5	6				4	5.50E-10	P
7	8				4	1.30E-10	P
9	10				4	1.40E-10	P
11	12				4	6.50E-10	P
1	2		0.065	1.00E-08	4	7.00E-10	P
3	4				4	1.90E-09	P
5	6				4	8.00E-10	P
7	8				4	6.70E-10	P
9	10				4	6.00E-10	P
11	12				4	5.30E-10	P

NOTE: A.C. = Acceptance Criteria

Table 3.11.0 Example Vacuum Test Results

Conclusions: All Duolok assemblies met or exceeded the approved Acceptance Criteria. Observed leak rates of tested Duolok tube fitting assemblies performed consistently better than the required Acceptance Criteria, and published competitive results.

Section 3.12: Low Temperature (Cryogenic) Helium Leak Test

Purpose: Test determines if the tube fitting assembly has the capability to seal in low temperature (cryogenic) applications with ultra low leakage rates.

Equipment & Configuration: One fitting is tested at a time on the end of a test tube, assembled per Initial Makeup Test (see Section 3). Minimum recommended wall tubing (worst case condition) is used for each tested product configuration. See Figure 3.12.1, Low Temperature Helium Leak Test Configuration.

Figure 3.12.1, Low Temperature Helium Leak Test Configuration.

The Leak Rate Sensitivity of the Veeco MS-40 40 Helium Leak Detection Test Equipment is 4.0 x 10^{-11} std cc/sec. Duolok tube fittings have been tested and shown results in the 10^{-11} mbar l/s range.

> Test Port pressures are displayed in units of milli-Torr. The vacuum levels developed during testing are as low as 4 mT - 9mT. This equates to an absolute pressure of .0000744 - 0.000174 PSIA.

Test Procedure: The tube fitting assembly is immersed in a liquid nitrogen bath, -320 °F (-196 °C), and the internal volume of the tube fitting assembly is evacuated to a vacuum of 4 mT – 9 mT (milliTorr). The digitally displayed Low Temperature Helium Leak pressure, in mT, is recorded. Helium is also cooled to the liquid nitrogen temperature before being sprayed on the cold fitting exterior. On achieving full Low Temperature Helium Leak pressure, -320 °F (-196 °C) helium gas is sprayed around the outside of the fitting, and the leakage rate is recorded.

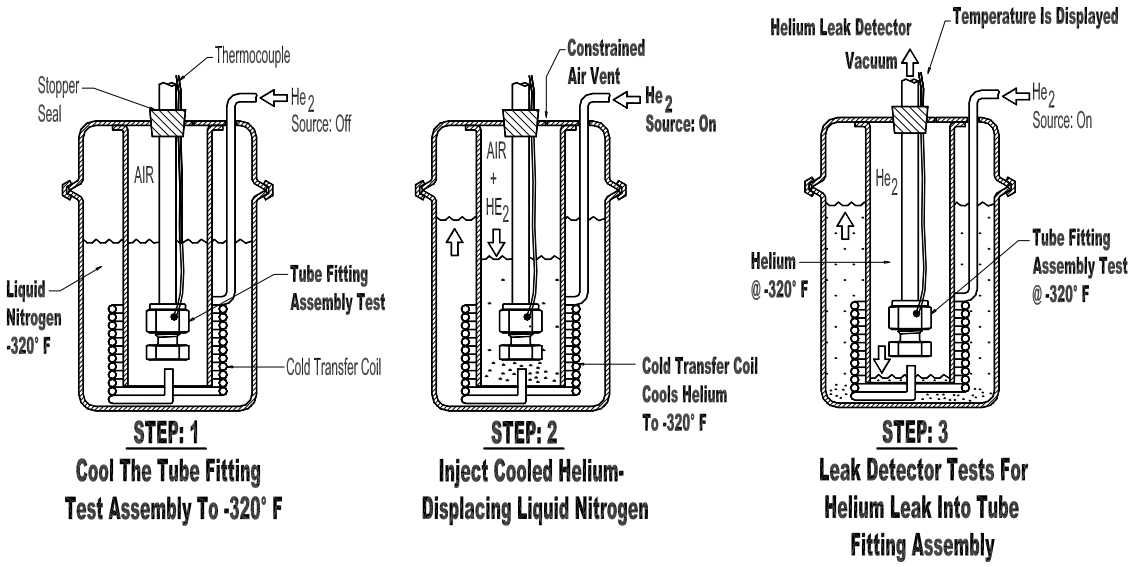
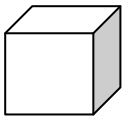


Figure 3.12.2, Low Temperature Helium Leak Test Sequence.

Acceptance Criteria: The tube fitting assembly is to sustain the above low temperature, and not exhibit a helium test leak rate in excess of $< 4 \times 10^{-9}$ mbar l/s.

What this ultra low level Leak Rate means in practical terms is shown in the following table, which gives the time (in months, years) it would for the listed Leak Rates to fill one cubic inch of volume with air to atmospheric pressure at ambient temperature:

1 Cubic Inch



Fitting Leak Rate	**Time for Fitting Leak to fill 1.0 in^3 @ 1 Atmosphere Pressure**
1.0 X 10^{-6} mbar l/s	6.3 months (192 days)
1.0 X 10^{-9} mbar l/s	527 years
1.0 X 10^{-11} mbar l/s	52,655 years

Test Results: Example results are shown in Table 3.12.0 below.

Results: Low Temperature Leak Test

Vacuum Unit Conversion:		
1 atm cc/s =	1.01325	mbar l/s

Sample	Tubing / Fitting		Acceptance Criteria	Low Temperature Test			
	Size	Wall	A.C. Leak Rate	Test Port Vacuum	Test Temp.	Low Temp. Leak Rate	Pass Fail
#	#	in	mbar l/s	mT	°F	mbar l/s	P / F
1	6	0.035	4.00E-09	4	-310	3.24E-10	P
2				1	-310	4.36E-10	P
3				4	-310	5.27E-10	P
4				4	-310	3.45E-10	P
5				4	-310	4.46E-10	P
6				4	-310	1.72E-10	P
7				4	-310	3.65E-10	P
8				4	-310	6.69E-10	P
9				4	-310	2.63E-10	P
10				4	-310	5.17E-10	P
				Average:		4.06E-10	
				Standard Deviation:		1.44E-10	

NOTE: A.C. = Acceptance Criteria

Table 3.12.0 Example Low Temperature Leak Test Results

Conclusions: All Duolok assemblies met or exceeded the approved Acceptance Criteria. Observed leak rates of tested Duolok tube fitting assemblies performed consistently better than the required Acceptance Criteria, and published competitive results.

Section 14: Bibliography, Equipment, References

Table 4.1: ASTM Material Standards

Standard	Material Shape	Description
A 182	Forged Fittings, Parts	Standard Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
A 276	Bars	Standard Specification for Stainless Steel Bars and Shapes
A 479	Bar, Shapes	Standard Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
B 16	Bar, Shapes	Standard Specification for Free-Cutting Brass Rod, Bar and Shapes for Use in Screw Machines
B 124	Bar, Shapes	Standard Specification for Copper and Copper Alloy Forging Rod, Bar, and Shapes
B 453	Bar, Shapes	Standard Specification for Copper-Zinc-Lead Alloy (Leaded-Brass) Rod
A 179	Tube	Standard Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes
A 213	Tube	Standard Specification for Seamless Ferritic and Austinitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes
A 249	Tube	Standard Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes
A 269	Tubing	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
B 68	Tube	Standard Specification for Copper Tube, Bright Annealed
B 75	Tube	Standard Specification for Seamless Copper Tube
B 88	Tube	Standard Specification for Seamless Copper Water Tube

Table 4.2: Applicable Codes and Standards

Section	Test Description
ANSI / ASME B 31.1	Power Piping Code
ANSI / ASME B 31.3	Process Piping Code
ANSI / ASME BPV Section VIII	Boiler & Pressure Vessel Code
ISO 7257	Aircraft - Hydraulic tubing joints and fittings - Rotary flexure test

Table 4.3: Validation Test Equipment

Section	Test Description	Test Equipment Description
3.1	Initial Makeup Test	1016702 Torque Wrench
3.2	Hydrostatic Burst Pressure Test	1279 Ashcroft Pressure Gage
		L-400 Maximator Liquid Pump
3.3	Hydraulic Impulse Pressure Test	PDCR 911 Druck Pressure Transducer
		451279 SSL 02B Ashcroft Pressure Gage
3.4	Repeated Remake Test	DLE 15-75 Maximator Air Booster Pump
		L-400 Maximator Liquid Pump
3.5	Tension Force Test	FI-90 Force Indicator
		31910 Load Cell
		DTM Dillon Tensile Tester
3.6	Vibration Stress / Endurance Test	42-05000W160S SC Hydraulic Engineering
		Booster Pump
		2100 Strain Gage Conditioner System.
		The Measurements Group
3.7	Intermix Assurance Test	DLE 15-75 Maximator Air Booster Pump
		L-400 Maximator Liquid Pump
3.8	Interchange Assurance Test	DLE 15-75 Maximator Air Booster Pump
		L-400 Maximator Liquid Pump
3.9	Gas Pressure Leak Test	HP 224 McDaniels Pressure Gage
		DLE 15-75 Maximator Air Booster Pump
3.10	Thermal Cycle, Thermal Shock Test	3210 Applied Test Systems Split Furnace
		XT16 Athena Temperature Controller
		MS-40 Veeco Helium Leak Detector
3.11	Vacuum Test	MS-40 Veeco Helium Leak Detector
3.12	Low Temperature (Cryogenic) Helium Leak Test	MS-40 Veeco Helium Leak Detector
		Type K TC Thermocouple

TRADEMARKS: