

Fluid Power Institute

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SUBMITTED TO: EPCO Products, Inc.
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Revised Report
EPCO Products, Inc.
Zero-Leak Gold Plug
Testing

SUBMITTED TO: EPCO Products, Inc.

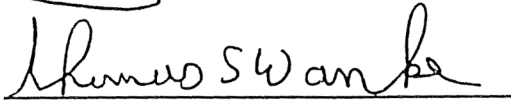
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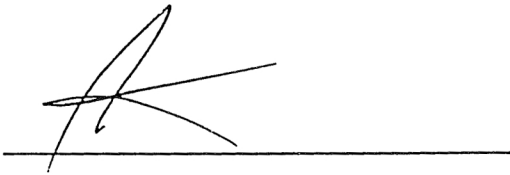
SIGNATURE PAGE

The undersigned testify that to the best of their knowledge the data contained in this report was collected using instruments as described on the reference pages and that the testing and measurement procedures utilized good laboratory technique.



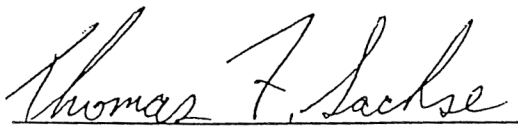
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EPCO Products, Inc. Notice

This is an abbreviated version of the complete Fluid Power Institute Test Report.
It contains copies of pages 2 through 9 of the original FPI Test Report.
Copies of Appendixes A and B may be obtained by contacting EPCO.

This FPI Test Report does not contain leak performance test data for the interchangeable SAE J514 straight thread ORB plug, the tapered NPT plug, nor any other type plug.
Contact a supplier of that plug for its leak performance test data.

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Background

The Zero-Leak Gold product line of EPCO Products Inc., a Fort Wayne, IN based company, is a revolutionary line of Zero-Leak plugs and fittings. The fittings developed a zero leak seal at very low assembly torque values and EPCO wanted to determine more accurately the torque values at which the fittings would not leak under accepted industry practices and established measuring methods.

Project Scope

Evaluation at MSOE will determine the lowest torque values to pass the NFPA/T2.6.1 R1-1991 standard titled “ Fluid Power Systems and Products- Methods for Verifying the Fatigue and Establishing the Burst Pressure Ratings of The Pressure Containing Envelope of a Metal Fluid Power Component”. Additional testing will be conducted to determine Proof and failure pressure of the plugs.

Testing

EPCO Zero-Leak Gold plugs were installed into (6) specially designed manifolds. The manifolds tested were made from standard industry Ductile Iron and Aluminum. Three manifolds were made of each material. The (6) manifolds were designed to install (8) different fittings allowing (3) samples of each size to be mounted. Two manifolds were designed with (3) ports on (3) sides and manifold # 3 had (2) ports on (2) sides. The manifolds allowed testing (3) samples of each SAE J1926 port sizes #2, #3, #4, #5, #6, #8, #10, and #12 on (3) manifolds in both Aluminum and Ductile Iron (see detail drawings in Appendix A pages 18-23). The rated working pressure of Ductile Iron is 5000 psi and 3000 psi for aluminum. The goal of the project at MSOE was to establish torque values that successfully pass the 1,000,000 cycle Endurance Test specified in paragraph 8 of NFPA /T2.6.1 R1-1991.

Testing (continued)

The SAE published values for torque were used as a bench mark for this test. To determine torque values for EPCO Zero-Leak Gold plugs an iteration procedure was established. Torque values of 25%, 40%, 60%, 70% and 90% of SAE numbers would be tested in succession until successful completion of the NFPA 1,000,000-cycle Endurance Test.

For each test, the torque value was applied to the plugs and the manifold assemblies were plumbed into the impulse chamber and the Rated Fatigue Pressure Endurance Cycle Test was started (see Figure 1. Test Stand Schematic). The Cyclic Test Pressure (CTP) applied was 3688 psi for Aluminum and 6156 psi for Ductile Iron (see Calculations in Appendix A). Pressure waveforms for the 1,000,000 cycle Endurance Test conformed to the characteristics specified by paragraph 8 of NFPA /T2.6.1 R1-1991 (see Appendix A for waveform plots). The basic criteria for the wave shape is maximum rate of pressure rise must not exceed 50,000 psi/sec, the values at MSOE were 49,363 psi/sec for Ductile Iron and 39,769 for Aluminum. The NFPA /T2.6.1 R1-1991, paragraph 8.4.4 states, "The Pulse Duration must be held to 100 ± 10 milliseconds" and the tests at MSOE ran at 92 milliseconds for Ductile Iron and 98 milliseconds for Aluminum (see Appendix A page 1 and 2 for Ductile Iron and 3 & 4 for Aluminum).

Testing was started and if a failure occurred new O-Rings would be installed and the torque would be increased to the next value. This process was followed until all fittings passed the 1,000,000 cycle Endurance Test specified in paragraph 8 of NFPA /T2.6.1 R1-1991. A failure defined by NFPA /T2.6.1 R1-1991 states "The inability to sustain a given load or to contain pressure in a pressure containing envelope". By the stated definition a leak would cause a failure. The initial test was done with 0.5 ft-lbs. torque applied to each plug. This torque was successful at sealing at static rated pressures, however it failed early into the endurance test.

Initial torque values were 25% of SAE values. There were (5) test torque trials (.5ft-lbs, 25%, 40%, and 2 trials at 60%) until the value of 60% of listed SAE values passed the 1,000,000 cycle Endurance Test (final values are listed in Table 1).

Table 1.

EPCO ZERO-LEAK GOLD PLUG TESTING TORQUE VALUES		
SAE & Zero-Leak Gold plug size	Torque (ft lbs)	
	MATERIAL	
	Ductile Iron	Aluminum
#2	2	2
#3	3	3
#4	7	7
#5	9	9
#6	11	11
#8	28	28
#10	46	46
#12	51	51

The final tests conducted on the plugs were the Proof and Burst Tests. For these tests new Zero-Leak Gold plugs and O-Rings were installed. The Proof and Burst Tests were conducted in accordance with paragraphs 4.1 and 4.2 of SAE J1644 May93. Stated briefly “the Proof Pressure Test requires (3) samples to meet or exceed a ratio of 2:1 between proof and working pressure for 60 seconds minimum”. The Burst Test requirement states “ (3) samples be capable of withstanding the minimum of four times working pressure without failing”. All EPCO Zero-Leak Gold plugs passed both the Proof and Burst Tests criteria (see Table 2 below).

BLOCK NUMBER	Proof Test			BURST Test		
	Pressure (psi)		Fitting sizes on Manifold	TIME AT PRESSURE	Burst Pressure (psi)	Mode of Failure
	Aluminum	Ductile Iron				
1	6000		SAE 2,3,4	120 sec	21,769	No failure
2	6000		5,6,8	120 sec	23,111	No failure
3	6000		10,12	120 sec	23,339	Manifold thread failure (SAE #10 Port)
4		10,000	2,3,4	120 sec	21,699	No failure
5		10,000	5,6,8	120 sec	26,453	No failure
6		10,000	10,12	120 sec	22,567	No failure

Analysis of Data

The 1,000,000 cycle Endurance Test concluded with no leaks from all of the Zero-Leak Gold plugs being tested. It was noted that during the 1,000,000 cycle Endurance Test that a slight, discernible amount of O-Ring material was observed at several test ports (see Appendix B pages 35-43). This material was observed on SAE port size #10 for Aluminum and SAE #8 and #12 in Ductile Iron (see pictures in Appendix B). Although this condition was noted, there were no leaks from the corresponding Zero-Leak Gold plugs. It should also be noted that the EPCO Zero-Leak plugs did run continuously for 1,000,000 cycles (except for short shut downs for stand maintenance).

The Zero-Leak Gold plugs passed the 1,000,000 cycle Endurance, Proof and Burst Tests at a value of 60% of SAE stated values with no leaks from any plugs (see Tables 1&2).

During the test O-Ring Ports were labeled and scribed with a scratch across the fitting leading into the manifold. From this mark it could be determined if any movement of the fitting in relation to manifold had occurred (see-attached photographs). There had been no movement from these marks during the test. Torque values were recorded after the test to check if values had changed (see Table 3). The torque removal values for the EPCO Zero-Leak Gold plugs were very high. From marks placed on plug and manifold there was no noticeable rotation of plugs and the plug threads were not distorted.

Removal Torque Table 3.

Zero-Leak Gold Plug Size						
	Aluminum		Average removal Torque (ft-lbs)	Ductile Iron		Average removal Torque (ft-lbs)
	initial torque (ft-lbs)	removal torque (ft-lbs)		initial torque (ft-lbs)	removal torque (ft-lbs)	
2	2	3.75	5.2	2	3	4.0
2	2	6.5		2	2.75	
2	2	5.25		2	6.25	
3	3	4	5.5	3	4.25	4.3
3	3	6.25		3	4.25	
3	3	6.25		3	4.5	
4	7	28.5	29.0	7	7.25	8.6
4	7	31.5		7	6.75	
4	7	27		7	11.75	
5	9	27.5	28.8	9	11	11.1
5	9	28		9	11.5	
5	9	31		9	10.75	
6	11	34.25	33.1	11	22.5	16.2
6	11	34		11	12	
6	11	31		11	14	
8	28	80	76.7	28	40	33.5*
8	28	75		28	31.5	
8	28	75		28	29	
10	45	115	120.0	45	135	118.3
10	45	125		45	95	
10	45	120		45	125	
12	51	155	166.7	51	60	76.7
12	51	160		51	85	
12	51	185		51	85	

* Note: Value was 100.5, value should have been an average of the three numbers (33.5) not the sum. Value changed by Fluid Power Institute from 100.5 to 33.5 on 4/5/99 and is recorded in the official file.

Conclusion

EPCO Zero-Leak Gold plugs passed the Proof and Burst Tests conducted in accordance with paragraphs 4.1 and 4.2 of SAE J1644 May93, sections 4.1 and 4.2 and the NFPA/T2.6.1 R1-1991 standard titled “ Fluid Power Systems and Products- Methods for Verifying the Fatigue and Establishing the Burst Pressure Ratings of The Pressure Containing Envelope of a Metal Fluid Power Component paragraph 8 titled Rated Fatigue Verification Test Program”.