Fluid Power Institute

EPCO Products Inc.

Zero-Leak Gold® –2 Anodized Aluminum Plug Fatigue Testing

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The undersigned testify, that to the best of their knowledge, the data contained in this report was collected using the instrumentation described and utilizing proper laboratory procedures and techniques.

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Background

EPCO Products Inc. contracted the Fluid Power Institute® to evaluate the performance of their –02 anodized aluminum Zero-Leak Gold plug (225-A02) fitting with 6 samples of the plug undergoing controlled fatigue, and 3 samples undergoing proof, and burst testing. The Fluid Power Institute® established the minimum torque value required to seal the EPCO Products, Inc. anodized aluminum Zero-Leak Gold® Plug in a SAE ORB J1926 port at the rated pressure. Once the minimum torque value had been established for the plug a 1,000,000-cycle endurance test and a proof and burst test were performed on the plug.

Project Scope

The objective was to determine the minimum torque value for the –02 anodized aluminum Zero-Leak Gold Plug fitting as supplied by EPCO Products, Inc. Six samples of the plug fitting were torqued to a percentage of prior test results. With the plug fittings at their minimum torque values they must complete a 1,000,000-cycle pressure fatigue test in accordance to NFPA fatigue standard T2.6.1R2-2000, a proof test in accordance to the SAE J343 4.2 MAR 1999, and a burst test in accordance to the SAE J343 4.4 MAR 1999.

Test Procedure

The plugs were initially torqued to approximately 1.5 ft-lbs a value obtained from a previous test[1] for aluminum and installed into a commercial grade aluminum manifolds that had port positions specially located for this test. The manifold was designed (6061 T6 Aluminum) with (3) ports on (3) sides. This manifold was altered for this test. The fourth side of the manifold was machined to have (3) more –02 SAE J1926 ports, for a total of (6) –02 SAE J1926 ports. The –03 and –04 ports were plugged for testing. The rated working pressure of aluminum was 3000 psi. The manifold was then plumbed into the impulse stand.

[1] Test Report titled "Anodized Aluminum Zero Leak Plug Fatigue Testing" Project number 51579 dated 2/24/99 page 6 performed by the Fluid Power Institute at the Milwaukee School of Engineering.

The test setup used conventional petroleum base ISO VG 32 oil at a temperature of 100°F+/-10°F. A relief valve was plumbed into control the pressure required to pass the NFPA standard T2.6.1R2-2000. The manifold was installed so that the fluid flowed through the setup. This method ensures the most uniform fluid temperature and pressure waveform characteristics, as well as efficiently bleeding out any entrained air. The test was set up to meet the NFPA fatigue standard T2.6.1R2-2000.

The fatigue testing parameters outlined by the NFPA standards T2.6.1R2-2000 were as follows:

Test Duration.....1,000,000 cycles

Cycle Rate.....1.0 Hz

Test Pressure.....3688 psi

Test Temperature.....100° F ± 10°F

Test Oil.....Benz Oil petroleum base ISO VG 32

The goal of this project at the Fluid Power Institute® was to establish a torque value that successfully passes the 1,000,000 cycles Endurance Test specified in paragraph 8 of NFPA T2.6.1R2-2000. To determine torque values for EPCO –02 anodized aluminum Zero-Leak Gold Plugs an iterative procedure was established. The plugs were anodized and dyed gold per MIL-A-8626 TYPE II Class 2 per Fort Wayne Anodizing.

Starting torque value for this evaluation was 18 in-ibs. When the plug moved or leaked, they were all removed and torqued again with a new torque value. Torque was increased by 20% in succession until successful completion of the NFPA 1,000,000-cycle Endurance Test.

For each test, the torque value was applied to all of the plugs. The manifold was plumbed into the impulse chamber and the Rated Fatigue Pressure Endurance Cycle Test started. The Cyclic Test Pressure (CTP) applied was 3688 psi for Aluminum. Pressure waveforms for the 1,000,000 cycles Endurance Test were in accordance with characteristics specified by paragraph 8 of T2.6.1R2-2000. The basic criteria for the wave shape is maximum rate of pressure rise did not exceed 80,000 psi/sec. The NFPA T2.6.1R2-2000, paragraph 8.4.4 states, "The Pulse Duration must be held to 100±10 milliseconds".

When a failure occured, a new Daltek Inc. 6X1 mm 70 nitrile O-Ring was installed on the plug that failed and the torque was increased to the next value for all of the plugs. The port surface area and the plug was cleaned to remove any fluid or residue prior to replacing the plug in the manifold to resume the testing. This process was followed until all plugs passed the 1,000,000 cycles Endurance Test. A failure defined by NFPA T2.6.1R2-2000 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 final tests conducted on the plugs was the Proof and Burst Tests. These tests require new –02 anodized aluminum Zero-Leak Gold Plugs with Daltek Inc. 6X1 mm 70 nitrile O-Ring 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".

During the test, O-Ring Ports were labeled and scribed with a scratch across the –02 anodized aluminum Zero-Leak Gold plug leading into the manifold. From this mark it was determined if any movement of the plug in relation to manifold has occurred. Removal torque values were recorded after the test to determine if original torque values had changed. The pressure fatigue test was ran until the plugs began to showed signs of leakage or o-ring extrusion.

When leakage or o-ring extrusion occured on a plug, all six were removed to examine the o-rings and plugs. If the o-ring or plug was damaged, it was replaced. The plugs were then torqued to a new torque value, approximately 20% greater then the previous value. This procedure was repeated until the plugs achieved the minimum torque value needed to pass the million cycles without leaking. The impulse stand ran 24 hours a day, seven days a week for 1,000,000 cycles, except being shut down for maintenance or part failure.

After the fatigue testing was completed, the plugs were torqued to their minimum values in high-pressure fittings. In the high-pressure fittings, the plugs were subjected to a proof test (SAE J343 4.2 MAR 1999) and burst test (SAE J343 4.4 MAR 1999). The proof test consisted of three fittings passing a 2 to 1 working pressure of 3000 psi (6000 psi) for a duration of no less then 30 seconds nor more than 60 seconds. After passing the proof test, the three fittings were subjected to a burst test. In the burst test the pressure was increased at a constant rate to obtain the minimum burst pressure within a period of not less than 15 seconds nor more than 60 seconds. To pass the burst test the minimum burst pressure must equal to or greater than 4 times the working pressure of 3000 psi (12000 psi).

Results and Data

The –02 (1/8 inch) size Anodized Aluminum Zero-Leak Gold Plugs did successfully passed the impulse testing, the proof, and burst to the above stated specifications.

The final torque value to pass the impulse, proof and burst tests was 36 in-lbs.

Table 1: -02 Anodized Aluminum Zero-Leak Gold®Torque Value History.

Torque (ft-ibs)	Torque (in-ibs)	Leaked At (cycles)	Total Cycles at torque value	Mode of leakage
1.50	18.00	3211	3211	Extruded O-rings, All O-rings were replaced and the test was continued with next torque value
1.70	20.40	5001	1790	Extruded O-rings, All O-rings were replaced and the test was continued with next torque value
2.10	25.20	10007	5006	Extruded O-rings, All O-rings were replaced and the test was continued with next torque value
2.50	30.00	15361	5354	Extruded O-rings, All O-rings were replaced and the test was continued with next torque value
3.00	36.00	Did Not Leak	1000000	No Apparent Failures, Passed 1,000,000 cycles at this torque Value

Table 2: -02 Anodized Aluminum Zero-Leak Gold® Removal Torque data.

Plug Number	Removal Torque Value (in-lbs)	Average Removal Torque Value (in-lbs)
1	42	61.8
2	72	
3	Hex socket stripped out	
4	63	
5	66	
6	66	

When the impulse testing was successfully finished each plug was removed from the manifold. Removal Torque values were recorded and listed in Table 2.

Table 3: -02 Anodized Aluminum Zero-Leak Gold® Proof and burst test data

Anodized Aluminum Plugs	Proof Testing			Burst Testing		
Plug Sizes	Proof Pressure (PSI)	Proof Time at Pressure (sec)	Proof (pass/fail)	Burst Pressure (PSI)	Burst Mode Of Failure	Burst (pass/fail)
2	6000	120	Passed	25059	Stripped Plug Threads	Passed
2	6000	120	Passed	25339	Stripped Plug Threads	Passed
2	6000	120	Passed	24500	Stripped Plug Threads	Passed

Conclusion

All of the EPCO –02 anodized aluminum Zero-Leak Gold Plugs successfully completed the 1,000,000 cycle impulse test. The EPCO –02 anodized aluminum Zero-Leak Gold plugs passed the one million-cycle impulse requirement by NFPA fatigue standard T2.6.1R2-2000. The test ran continuously 24 hours a day, seven days a week with the exception of being shut down for equipment maintenance or failures should they occur. The marks placed on the plugs and manifold concluded that there was no movement of the plug relative to the manifold for the entire million cycles. The plugs also successfully completed the proof and burst evaluation.

The EPCO anodized aluminum Zero-Leak Gold plug passed the burst test with pressures ranging from 24,500 psi to 25,339 psi, with the requirement of 12,000 psi to pass. The client requested all plugs be pressurized beyond the 4:1 requirement (12,000 psi) and continue increasing pressure until failure of the fitting or limitations of the equipment are reached. The –02 anodized aluminum Zero-Leak Gold Plugs also successfully passed the proof test.