

**Summary Test Report
Ball Joint Life Cycle Test
Solar Plant Installations**

A Hyspan Barco Ball Joint, drawing number 58840 Rev. D, was tested under conditions simulating the operating environment of the heat transfer fluid piping that connects the solar collectors to the main header, and to the crossover pipe between adjacent rows of parabolic collectors on solar fields.

The test involved simultaneous rotational and angular motions of the Ball Joint while pressurized with heat transfer oil at pressures and temperatures equivalent to the operating conditions of the solar field. A total of 11,095 cycles were completed simulating the thirty year design life of the system.

Test Conditions

The Ball Joint assembly was installed in a test apparatus capable of simulating the angular and rotational movements of solar panels while pressurized with Dowtherm A® heat transfer fluid at the maximum operating pressure and temperature. The following is a tabulation of the daily test results. The rotational and angular torque measurements were continually monitored to ensure compliance with the specification. The test were conducted by the Hyspan Quality Assurance Department and witnessed by a Customer Representative.

March 2007	Test Conditions	Beginning Cycles	Ending Cycles	Rotational Torque (ft-lbs)	Angular Torque (ft-lbs)	Comments
7	1	0	784	+102/-118	+55/-57	
8	2	784	1153	+142/-118	+39/-97	
	1	1153	1545			
9	1	1545	1782	+110/-109	+40/-50	Note 7
	2	1742	2264			
10	2	2264	2449	+50/-50	+36/-55	Note 8
12	2	2449	3083	+57/-50	+33/-22	Note 8
13	2	3083	3671	+69/-50	+30/-31	Note 8
14	1	3671	4656	+70/-41	+30/-40	Note 8
15	2	4656	4810	+148/-80	+75/-85	Note 8
	1	4810	5525			
16	1	5525	6481	+82/-60	+59/-88	Note 7
17	1	6481	7165	+57/-48	+67/-78	
18	1	7165	7864	+55/-45	+53/-48	
19	1	7864	9079	+114/-105	+26/-34	
20	2	9079	9907	+134/-136	+30/-22	
21	2	9907	11095	+80/-106	+16/-20	
22		Final	11095	+56/-53	+16/-25	

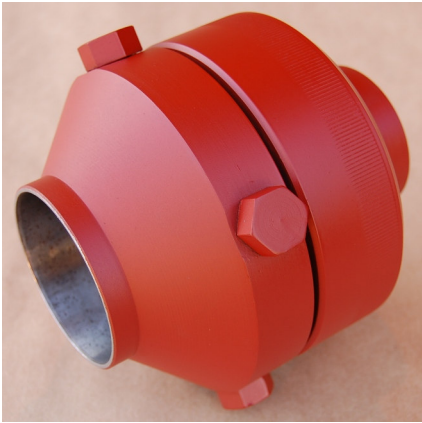
Notes Relating to Tabulated Data:

- 1) Cycle rate is one (1) minute per cycle. Each cycle is -7° to $+7^{\circ}$ and 0° - 215° rotation and return to 0° while at the Test Conditions.
- 2) Rotational motion: + is clockwise looking from the Case to the Ball.
- 3) Angular motion: + is downward.
- 4) Condition 1: "cold header" 30 Bar (435 psig) 293°C (559°F).
- 5) Condition 2: "hot header" 23 Bar (334 psig) 393°C (740°F).
- 6) Total cycles at Condition 1: 6667, Condition 2: 4428.
- 7) Ball Joint was serviced by removing a packing plug and an adjacent plug, and injecting packing until packing extrudes from the adjacent plug. The process is repeated until packing is injected into all four (4) plugs.
- 8) Test rig heated replaced.

Conclusions

- The Ball Joint functioned in accordance with the specifications throughout the 11,095 cycles (30.3 years). There was no leakage detected at any time during the cyclic testing or during the daily pressure tests, and the breakaway torque was within specifications.
- The service performed on the Ball Joint at 1782 cycles (5 years) was in accordance with the Maintenance Instructions of the Installation and Maintenance Procedures for Hyspan Barco Style II Ball Joints was not required to meet specifications. It was performed to evaluate the condition of the injected sealant, and to add sealant that was more fluid. It did not change the performance of the ball joint, and is not recommended except in the event of leakage.
- The sealing surface of the Outer Gasket exhibited wear but no indication of galling, seizing or excessive removal of material.
- The sealing surface of the Inner Gasket did not indicate any wear although there was an indication of contact with the ball. In service the pressure thrust is reacted by the Outer Gasket. The purpose of the Inner Gasket is to maintain the position of the Ball and to provide sufficient pressure on the Outer Gasket to seal during startup. There is no substantial bearing stress reacted by this gasket.
- The surface of the Ball in contact with the Outer Gasket had extensive wear but it did not detrimentally affect the performance of the Ball Joint. Even though the surface is worn it remained smooth and there was not indication of galling, seizing or a leakage path.
- The Ball Joint remained serviceable throughout the test. At the conclusion it was easily disassembled for inspection.

Quality Test Report



Hyspan Barco 2" NPS Ball Joint designed for solar collector applications life cycle tested for 30 years (11,095 cycles) service.

Life cycle test rig capable of $\pm 7^\circ$ angular travel and 215° rotational while operating at pressures and temperatures up to 30 Bar and 393°C . Continuous measurement of angular and rotational torque.

