PACKER ENGINEERING INC,
1950 North Washington Street,
Naperville, IL 60566

Hydraulic Pressure Cycling and Performance Evaluation of a DOT-3AA 2265 Cylinder, M9501

FINAL REPORT

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Prepared for
Mark Toughiry
Office of Hazardous Materials Technology
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1.0 INTRODUCTION

Objective: - The purpose of this project was to perform hydraulic pressure cycling and evaluation of a DOT-3AA 2265 cylinder, M9501.

1.1 Technical Approach

In this project the DOT – 3AA cylinder with serial number 441098 was pressure cycled and hydraulically burst tested to evaluate its performance. Before testing an external visual observation was performed to document any markings or surface defects. After the burst test the cylinder was examined from the inside and samples were cut to allow the mechanical properties such as tensile strength, yield strength, ductility and hardness to be measured.

2.0 GENERAL DOCUMENTATION OF THE CYLINDER

2.1 Visual Documentation and Cylinder Specifications

The cylinder was identified as a DOT - 3AA cylinder with serial number 441098 as shown in Figure 1. The indented markings on the cylinder are as shown in Figure 2.

- The cylinder is marked as DOT –3AA 2265 GL Limited 441106 M9501 X6A 06 TP3775 PSI W53.8 VA3.3
- As per the information provided to Packer Engineering Inc by DOT the service pressure of the cylinder is 2,265 psi.
- There were no visible cracks observed on the outer surface of the cylinder. The paint on the cylinder was scratched at several locations.
- Internal observation of the cylinder was done after the burst test. The cylinder showed no major signs of corrosion on the inside. Figure 3 shows a typical view of the inside surface of the cylinder.

3.0 PRESSURE CYCLING TEST:

The cylinder was filled with hydraulic fluid and was subjected to successive pressure reversals from a lower cyclic pressure of about 350 psi to an upper cyclic pressure of about 3,775 psi. The rate of reversals of pressure was 0.25 Hz (15 cycles/min). The cylinder successfully completed 12,000 cycles without leaking. The test set up is shown in Figure 4. The pressure was measured using a CEC Model 4-326-0001 pressure transducer, and cycling was run and monitored using an MTS Model 407 controller. Figure 5 shows the maximum and the minimum pressure observed during the 12,000 cycle test of the cylinder.

4.0 HYDRAULIC BURSTING TEST:

The cylinder was filled with hydraulic fluid and hydrostatically tested to failure. An air-over-water pump was used to apply the pressure to the cylinder. Pressure was measured using an Omegadyne Model PX91N0 pressure transducer, and was recorded using computerized data acquisition equipment at a rate of 5 samples per second. Care was taken to avoid air entrapment in the circuit. The test setup is as shown in Figures 6 to 9. The pressure data is shown in Figure 10. The cylinder reached a maximum pressure of 7,755 psi in about 13.71 min (13 min 42 sec) and failed after 14.18 min (14 min and 10 sec). The cylinder burst along the length of the cylinder. The failure location is as shown in Figures 11 and 12.

5.0 MECHANICAL PROPERTY EVALUATION:

5.1 Tensile Test

Tensile sample was obtained from the location as shown in Figure 13. The testing was performed in accordance with 49 CFR 178.37-K [1]. The results are as shown in Table III. The tensile properties of the subject DOT 3AA cylinder was compared to the mechanical property of 4130 steel at tempering temperatures of 1000 ºF and 1200 ºF [2]. Part 178.37 (g) (4) of 49 CFR indicates that the minimum tempering temperature may not be less than 1000 ºF hence the tensile test results were compared to only the values listed at 1000 ºF and above. As seen in the table the tensile properties of the subject DOT 3AA meets the specifications of 4130 steel.

TABLE I
Tensile test results of DOT 3AA cylinder compared to the tensile properties of 4130 steel

Property	DOT 3AA cylinder sample 1	4130 Steel (Tempered at 1000 ºF) [ref -2]	4130 Steel (Tempered at 1200 ºF) [ref - 2]
Tensile Strength	126.5 ksi	150 ksi	118 ksi
Yield Strength (0.2% offset)	113.9 ksi	132 ksi	102 ksi
% Elongation in 2 inches	20.8%	17%	22%

5.2 Rockwell Hardness Test

The Rockwell Hardness Test was performed along the largest piece of the cylinder in accordance with ASTM E18-98. The hardness tester was calibrated using Patriot Manufacturing Company standard block with serial number 00B5167 and standard

hardness value of 32.3 +/- 1.0 HRC. The hardness measured using the standard block was 32.8 at the beginning of the test and 33.1 at the end of the test. The results are as shown in Table II. The hardness values of the 4130 steel at tempering temperatures of 1000 ºF and 1200 ºF are 34 HRC and 24 HRC respectively [2]. As shown in Table 2, the hardness value of the DOT 3AA cylinder meets the specifications for the 4130 steel at tempering temperatures of 1000 ºF and above.

Table II
Rockwell hardness results of the DOT 3AA cylinder compared to the hardness values of 4130 steel

Location	**DOT 3AA cylinder (HRC)**	**4130 Steel (Tempered at 1000 ºF) (HRC) [ref - 2]**	**4130 Steel (Tempered at 1200 ºF) (HRC) [ref -2]**
1	25	34	24
2	26		
3	26		
4	25		
5	26		
6	26		

6.0 RESULTS & DISCUSSION

Hydraulic pressure cycling and performance evaluation was done on the DOT - 3AA 2265 cylinder, M9501 with serial number 441098.

External observation of the received DOT – 3AA cylinder showed no signs of leaks or cracks. The paint had come off the cylinder at some locations and there were some scratches on the cylinder. Internal observation of the cylinder was done after the burst test. The cylinder showed no signs of corrosion on the inside.

The cylinder passed the 12,000 cycle pressure cycling test. The maximum test pressure was 3,782 psi and minimum was 331 psi. The frequency of reversals was 0.25 Hz (15 cycles/min). No leak was detected during the 12,000 cycle pressure testing.

During the hydraulic burst test, the cylinder reached a maximum pressure of 7,755 psi in about 13.71 min (13 min 42 sec) and failed after 14.18 min (14 min and 10 sec). The cylinder burst along the length of the cylinder. The maximum pressure that the cylinder could withstand is greater than the service pressure of 2,265 psi.

The tensile strength, yield strength, elongation and hardness of the DOT - 3AA cylinder indicate it was tempered above 1000^{o}F as required in 49 CFR, part § 178.37 (g) – 4.

This concludes the hydraulic pressure cycling and performance evaluation of a DOT 3AA cylinder with serial no. 441098. If you have questions or need additional information please email us at mpareek@packereng.com or call at 630-577-1930.

Sincerely,

PACKER ENGINEERING, INC.

Mridula L Pareek
Engineering Technologist

John E Meyers, Ph.D., P.E.*
Technical Vice President

* Registered professional Engineer in the state of Wisconsin

7.0 FIGURES

Figure 1: DOT-3AA cylinder as received.

Figure 2: Indented marking on the DOT-3AA cylinder

Figure 3: Inside surface of the DOT-3AA cylinder. No major corrosion observed.

Figure 4: Test set up for pressure cycling test of DOT-3AA cylinder

Figure 5: Shows the maximum/minimum pressure and cycles completed during cyclic testing of the DOT – 3AA cylinder.

Figure 6: Test set up for hydraulic burst testing.

Figure 7: Test set up for hydraulic burst testing.

Figure 8: Test set up for hydraulic burst testing.

Figure 9: Test set up for hydraulic burst testing.

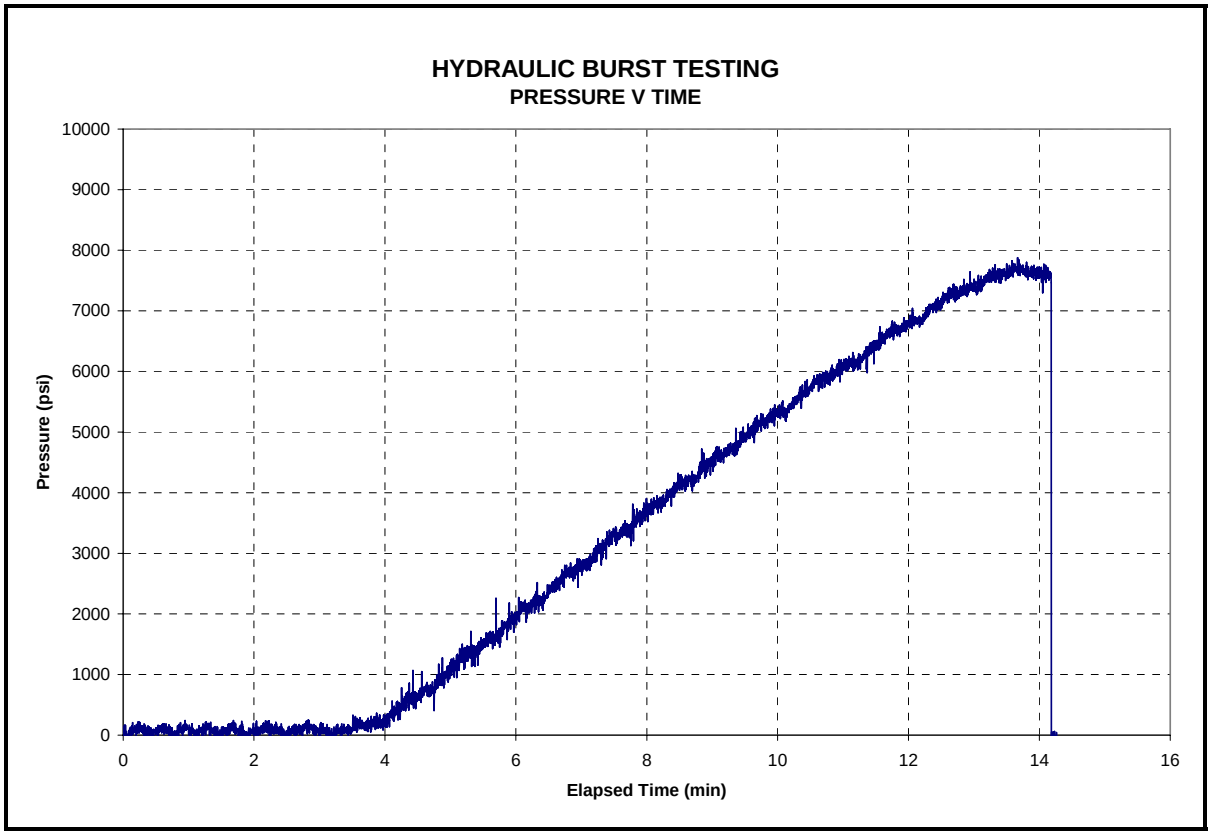

Figure 10: Pressure v Time data for Hydraulic burst test.

Figure 11: Ruptured cylinder after hydraulic burst testing.

Figure 12: Ruptured cylinder after hydraulic burst testing.

Figure 13: Location from which the samples were cut for mechanical property evaluation.

8.0 REFERENCES

1. Code of Federal Regulations (CFR) 49, Chapter I – Research and Special Programs Administration, Department of Transportation, Subchapter C-Hazardous Material Regulations, part § 178.37, pg 729 – 733, 2002.

2. ASM Metals Reference Book, 3rd edition, pg 309, 1993.