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**HIGH PRESSURE STEEL
CYLINDERS IN SERVICE
PERFORMANCE**

FIRST EDITION

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NOTE—Appendix A (Informative) is for information only.

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Summary

Taylor-Wharton issued a report warning of the potential fragmentation hazard associated with “first generation” cylinders defined as carbon steel cylinders made from 1902 to approximately 1930. “First generation” cylinders are still in service and may be designated as 3A type cylinders.

This CGA technical report presents the results of extensive studies on fracture performance of DOT-3A type cylinders (including ICC-3 and 3A cylinders made since 1902). Data on service failures of DOT-3A type and DOT-3AA type cylinders are also compiled and analyzed.

The results of this study indicate that:

- Prevention of cylinder fragmentation during service has always been a consideration in cylinder design specifications. Design and testing acceptance criteria have been in place since the first specifications for high pressure seamless steel cylinders were written (before 1910);
- Regardless of age, there are few reported incidents of either DOT-3A or DOT-3AA cylinders in service that fail by fragmentation. All known incidents were associated with multiple flaws in the cylinders;
- If either DOT-3A or DOT-3AA cylinders fail in service due to a single flaw, they will *not* fragment. The failure mode at pressures higher than the test pressure is not considered in this report because industry standard operating practices limit cylinder pressure. Thus, cylinders are not expected to be pressurized in-service above the test pressure. The following table summarizes the failure modes of DOT-3A type and DOT-3AA type cylinders under pneumatic loading;

Failure pressure	Flaw	DOT-3A failure mode	DOT-3AA failure mode
Less than test pressure	Single crack	1 to 3 pieces	1 to 3 pieces
	Multiple cracks (SCC)	Many pieces	Many pieces
More than test pressure	Single crack	Many pieces	One or many pieces
	Multiple cracks (SCC)	Many pieces	Many pieces

- Both DOT-3A and DOT-3AA cylinders may fragment in service due to multiple cracks, e.g., stress corrosion cracking (SCC);
- Both DOT-3A and DOT-3AA cylinders have equivalent fracture initiation performance during service. This has been verified by extensive testing and analysis that is reported in the technical report ISO/TR 12391-2;
- The safety of DOT-3AA cylinders is obtained by stringent material property requirements that permit higher working stresses (thinner cylinder wall) than for DOT-3A cylinders. The equivalent safety of DOT-3A cylinders is obtained primarily by restricting the working stresses (thicker cylinder wall) to a lower level with less stringent material property requirements than for DOT-3AA cylinders;
- Carbon steel cylinders are currently being manufactured under established national (e.g., DOT-3A) and international (e.g., ISO 9809-3) cylinder specifications;
- DOT-3A cylinders are required to be requalified by periodic retesting in accordance with the rules specified in 49 CFR Part 180. In addition to the safety controls specified for the design and manufacture of the cylinders, the periodic requalification is required to ensure the safe use of DOT-3A type cylinders; and
- From an evaluation of cylinders similar to DOT-3A type cylinders, the European Industrial Gas Association (EIGA) Position Paper 07-03, *Lifetime of pre 1930 Steel Cylinders* has concluded that such cylinders are suitable for continuous service and are currently in use today.

1 Introduction

In a letter entitled “A Century of Cylinders: An Open Letter to the Compressed Gas Industry (June 2002)” and the supporting test report “A Century of Cylinders-Test Program (June 28, 2002)” that were published by Taylor-Wharton, the compressed gas industry was warned of the potential fragmentation hazard associated with “first generation” cylinders defined as carbon steel cylinders made from 1902 to approximately 1930 [1, 2, 3].¹

This CGA technical report reviews the history of steel cylinder specifications and summarizes the procedures used for fracture and fragmentation control since steel cylinders were first manufactured. In addition, a summary and analysis of extensive studies of fracture control is presented to determine if DOT-3A cylinders are more likely to fracture and fragment in service than DOT-3AA specification cylinders [3]. Data on service failures of DOT-3A and DOT-3AA cylinder failures are also compiled and analyzed.

2 Scope

This report reviews the in-service performance of DOT-3A cylinders to determine their suitability for continued use.

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 3A type cylinder

Seamless steel cylinder having the material chemistry, tensile properties, and design wall stress similar to that of the DOT-3A specification cylinder [3]. For example, cylinders meeting the requirements of ISO 9809-3:2000 are considered to be 3A type cylinders [4].

3.2.2 3AA type cylinder

Seamless steel cylinder having the material chemistry, tensile properties, and wall stress similar to that of the DOT-3AA specification cylinder [3]. For example, cylinders meeting the requirements of ISO 9809-1:1999 are considered to be DOT-3AA type cylinders [5].

3.2.3 Brittle fracture

Separation of a metal that occurs with little or no plastic deformation and results in rapid crack propagation requiring little energy.

¹ References are shown by bracketed numbers and are listed in order of appearance in the reference section.