AVOIDANCE OF FAILURE OF CO AND OF CO/CO_2 MIXTURES CYLINDERS

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GLOBALLY HARMONISED DOCUMENT

Asia Industrial Gases Association

298 Tiong Bahru Road, #20-01 Central Plaza, Singapore 168730
Tel : +65 6276 0160 • Fax : +65 6274 9379
Internet : http://www.asiaiga.org

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REVISED BY :

Hervé Barthelemy	AIR LIQUIDE
Wolfgang Dörner	Linde Gas
Giorgio Gabrieli	SIAD
Roy S. Irani	BOC
Alexander Kriese	MESSER GROUP
Joaquin Lleonsi	CARBUROS METALICOS
Herman Puype	EIGA
Andy Webb	AIR PRODUCTS

ASIA INDUSTRIAL GASES ASSOCIATION
298 Tiong Bahru Road #20-01 Central Plaza Singapore 168730
Tel: +65 62760160 Fax: +65 62749379
Internet: http://www.asiaiga.org

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This document is adopted from the European Industrial Gases Association IGC 95/07 Avoidance of failure of CO and of CO/CO_2 mixtures cylinders'. Acknowledgement and thanks are hereby given for permission granted for the use of the document.

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1 Introduction

This document was originally published in 1993 after a number of incidents where steel cylinders violently ruptured. It was revised in 1998, and the present revision reflects recent experiences of some EIGA member companies.

Accidents have occurred in the past with carbon monoxide and carbon monoxide/carbon dioxide mixtures cylinders. These accidents led to either leak or rupture of the cylinders. During 1990 two accidents leading to violent ruptures were reported in Asia and North America, and a similar one in South Africa during 1991.

Following reports of earlier accidents, investigations were performed, and results from some of them were published in the 1976-1979 period [1, 2 and 3].

From these investigations it follows that:

- Low alloy carbon steels are sensitive to cracking in a carbon dioxide-carbon monoxide-water environment (stainless steels and aluminium alloys are not sensitive to this cracking phenomenon);

- It is believed that the three components carbon dioxide, carbon monoxide, and <u>free water</u> are needed at the same time to lead to this cracking phenomenon e.g., cylinders which have contained sufficient moisture to have raised the dew point of the gas above the operational temperature. See also ISO 11114-1 [4];

NOTE - For the purposes of this document, "Low Alloy Carbon Steels" are defined as steels with additions of up to a few percent of elements such as chromium, molybdenum, nickel, manganese etc, e.g. 1% chromium, 0.3% molybdenum;
NOTE - References1, 2, and 3 explain that a content of at least 13% of chromium is necessary to make the steel immune to this stress corrosion cracking (SCC) phenomenon;

- Cracking occurs over a wide range of carbon dioxide /carbon monoxide ratios and down to very low partial pressures;

- Cracking has been observed down to applied loads of 25% to 30% of the yield stress;

- Probability for cracking decreases as temperature increases; and

- The mechanism is proposed to be local dissolution of iron due to the carbonic acid formed between water and carbon dioxide, with general corrosion being inhibited by carbon monoxide. This phenomenon leads normally to transgranular cracks with branching. See Fig. 1 typical example. This phenomenon has nothing to do with hydrogen embrittlement, which normally leads to intergranular cracks. Therefore the recommendations of IGC Doc 100/03 do not apply [5].

Since the first publication of this document in 1993 new incidents, with steel cylinders filled at high pressure have occurred. These incidents and recent experience confirm that a very low moisture level must be ensured.

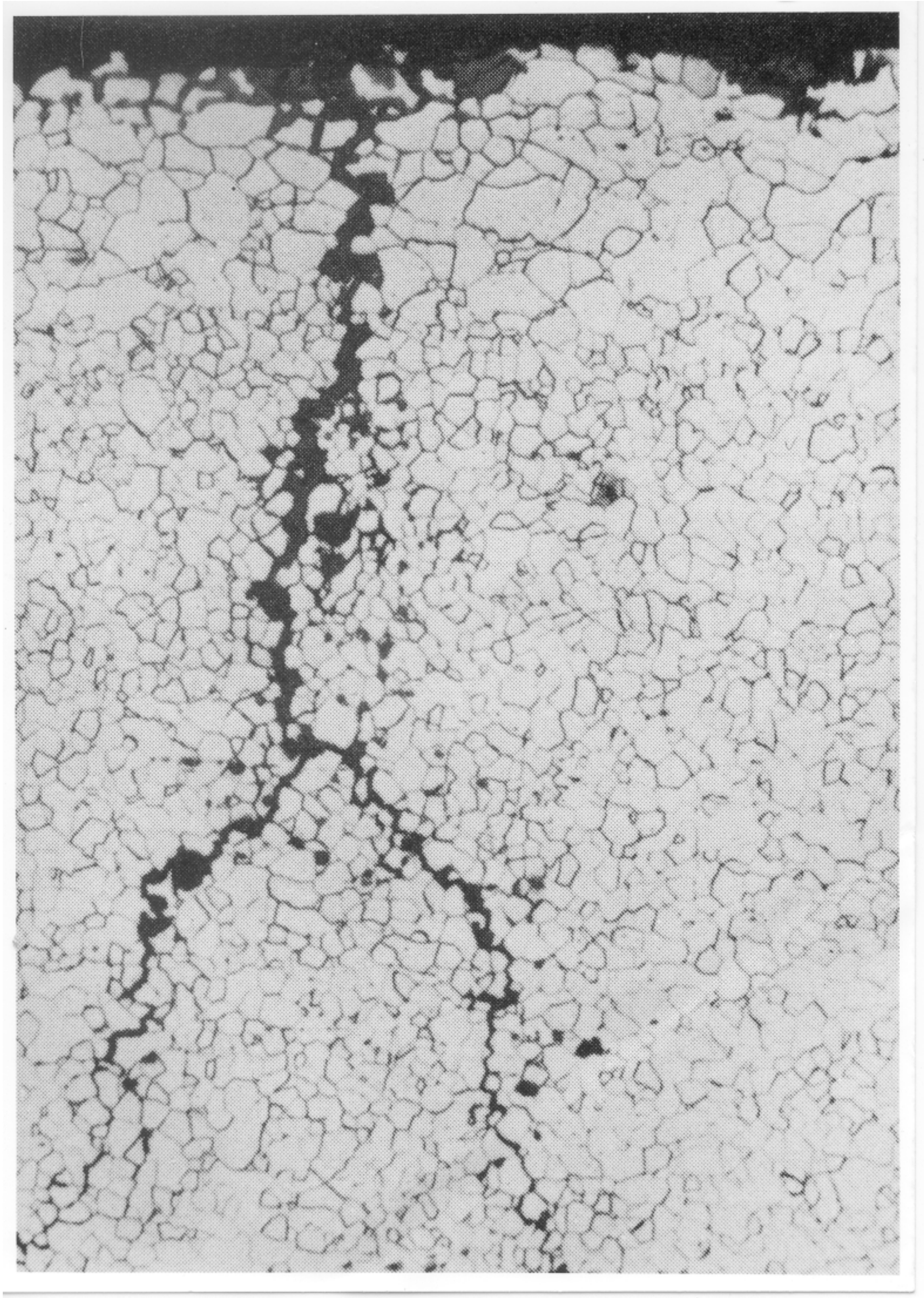

Figure 1—Branching crack-tip in a tempered martensitic structure

2 Scope

This paper covers the selection of gas cylinders; seamless steel cylinders, seamless steel tubes, welded steel cylinders, and non-refillable or disposable steel cylinders, used for carbon monoxide and for carbon monoxide/carbon dioxide mixtures, e.g. laser gases. Intentionally made mixtures containing less than 5 ppmV carbon monoxide or 5 ppmV carbon dioxide are not affected by this document.

3 Recommendations

3.1 Aluminium Alloy Cylinders

Use of aluminium alloy cylinders is strongly recommended for these mixtures. They can be filled at the maximum working pressure [(1)] and the moisture content is not critical.

3.2 High Strength Steel Cylinders

High strength steel cylinders (Rm [(2)] ≥ 1100 MPa) shall not be used.

3.3 Other Steel Cylinders

If steel cylinders are used (except according to 3.2) the 3 following conditions shall be met.

a) The maximum settled pressure [(3)] at 15°C ≤ 100 bar

and

b) $\frac{\text{The maximum working pressure}^{(1)} \text{ of the cylinder}}{\text{Maximum settled pressure}^{(3)} \text{ (at 15°C)}} \geq 1.5$

and

c) A quality system shall be established to make sure that the above “limited“ pressure is not exceeded.

3.4 Other solutions

Use of steel cylinders (other than 3.2) at maximum working pressure provided that the water vapour content of the final product in each cylinder shall be such that it does not exceed:

- a value of 5 ppmV for a maximum working pressure of 200 bar [(4)]
- a value of 7 ppmV for a maximum working pressure of 150 bar

However experience has shown that it is difficult in practice to guarantee on every cylinder such a dryness level. Consequently this solution shall only be used provided that appropriate procedures guaranteeing the moisture level are in place at the first use, after retest and at each filling of the cylinders.

Note: For pure CO some EIGA companies have good experience over the past 30 years using normalized steel cylinders with a maximum yield strength, Re ≤ 390 MPa and a maximum working pressure not exceeding 150bar when limiting the moisture content to a maximum of 20 ppmV.

3.5 Additional Requirements

When conditions 3.3 and/or 3.4 apply it shall be ensured that there are no visible areas of corrosion on the internal cylinder wall at the time of periodic inspection.

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(1) Maximum working pressure allowed for the gas cylinders, usually stamped on the shoulder (normally test pressure/1.5 in Europe and Canada and test pressure/5/3 in the United States

(2) Rm: actual tensile strength of the materials

(3) The maximum pressure in the cylinder at a uniform temperature of 15°Cafter filling.

(4) For cylinders with a maximum settled pressure greater than 200 bara value lower than 5 ppmV will apply

4 Inspection Recommendations

Steel cylinders suspected to have been exposed to a carbon monoxide-carbon dioxide–water environment in conditions not meeting the above recommendations shall be emptied before refilling and subjected to an internal visual inspection to check for localised corrosion. Such cylinders shall be submitted to appropriate NDE (Non Destructive Examination, such as ultrasonic examination) for crack detection. Additionally, it might be advisable, in some circumstances to perform a hydraulic test at cylinder test pressure, see ISO 6406 [6]. Some EIGA member companies report success in detecting defects in such cylinders in CO/CO_2 service using acoustic emission testing. These techniques require fully trained and experienced personnel to perform such testing.

5 References

(1) Kowaka and Nagata, Stress Corrosion Cracking of Mild and Low Alloy Steels in $CO\text{-}CO_2$ – H_2O Environments, CORROSION, Vol. 32, No. 10, 1976

(2) Brown, Harrison and Wilkins, Electrochemical investigation of stress corrosion cracking of plain carbon steel in the CO_2 –H2O system
NACE publn., SCC and hydrogen embrittlement of iron base alloys, 1977.

(3) Berry and Payer, Internal SCC by aqueous solutions of CO and CO_2 , American Gas Journal, 1979.

(4) ISO 11114-1 Transportable Gas Cylinders – Compatibility of cylinder and valve materials with gas contents – Part 1; Metallic materials

(5) IGC Doc 100/03, Hydrogen cylinders and transport vessels

(6) ISO 6406, Periodic inspection and testing of seamless steel gas cylinders.