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

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Amendments to 95/07

Section	Change
	Editorial to align style with IHC associations
3.2	Addition of section on stainless steel cylinders
3.5	Addition of 3.5 to move “other solutions” into one section
4	Further information provided on “Inspection recommendations”

Note: Technical changes from the previous edition are underlined

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.

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

Following reports of earlier incidents, 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 free water 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 EIGA Doc 100 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 shall be ensured.

NOTE—By ensuring a low moisture level, the conversion of carbon monoxide to carbon dioxide can be minimized.

The publication is part of the programme to develop Globally Harmonised publications amongst Regional Gas Associations.

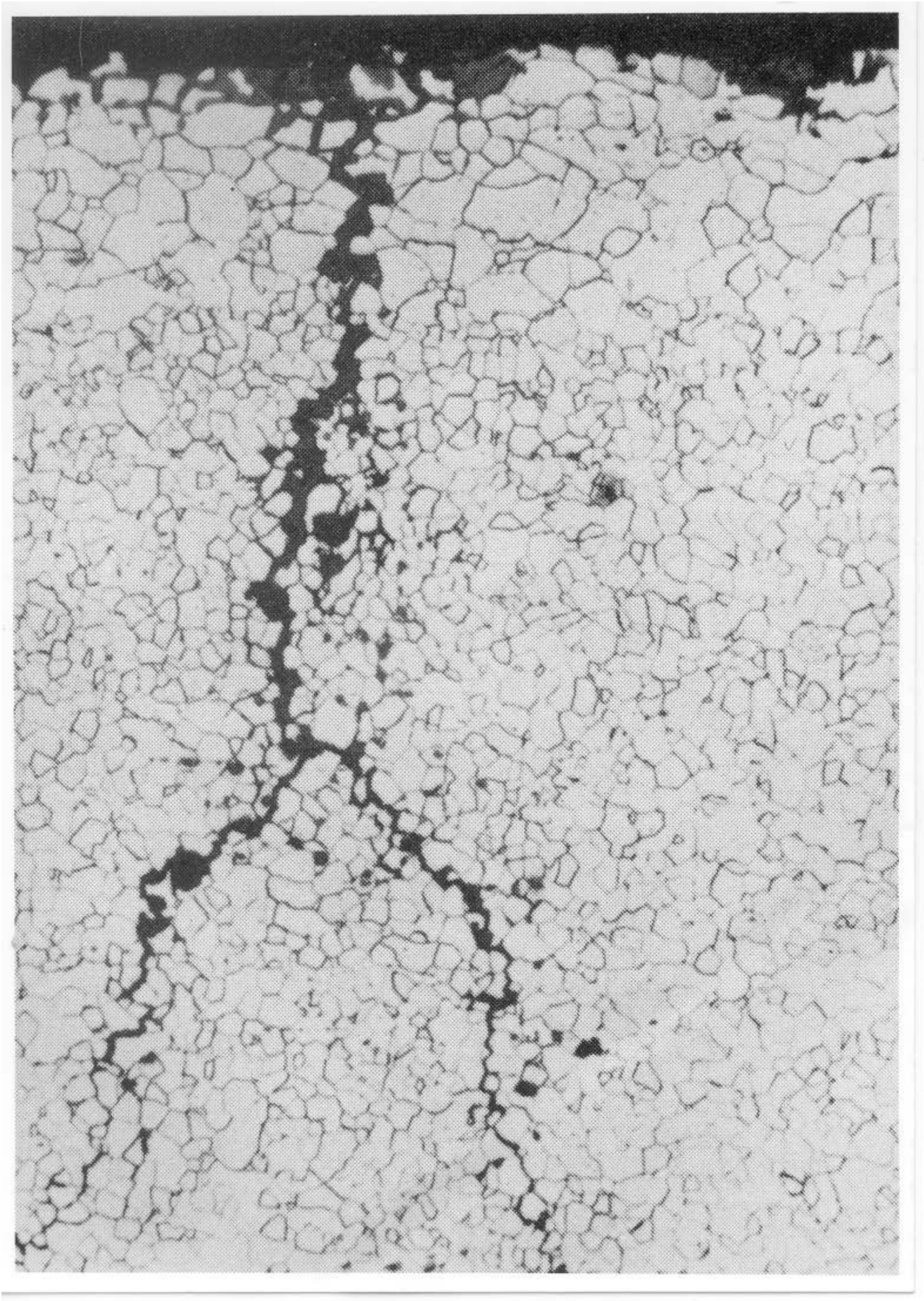

Figure 1—Branching crack-tip in a tempered martensitic structure

2 Scope

This document 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

Aluminium alloy cylinders may be used for carbon monoxide and are strongly recommended for carbon monoxide/carbon dioxide mixtures. They may be filled to the maximum working pressure[(1)].

3.2 Stainless Steel Cylinders

Stainless steel cylinders may also be used for carbon monoxide and carbon monoxide/carbon dioxide mixtures. They may be filled at the maximum working pressure.

3.3 High Strength Steel Cylinders

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

3.4 Other Steel Cylinders

For steel cylinders where moisture content is not controlled (except high strength steel cylinders, see 3.3) the three 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.

3.5 Other Solutions

For steel cylinders (except high strength steel, see 3.3) where pressure is not limited as per 3.4, 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 2900 psig (200 bar)[(4)]

– a value of 7 ppmV for a maximum working pressure of 2180 psig (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.

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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°C after filling.

(4) For cylinders with a maximum settled pressure greater than 2900 psig (200 bar) a value lower than 5 ppmV will apply.

NOTE: US DOT regulations require that carbon monoxide and carbon monoxide/carbon dioxide mixtures in steel cylinders shall be dry and sulfur free [49 CFR 173.302a(c)].

NOTE: For pure carbon monoxide some EIGA companies have good experience over the past 30 years using normalized steel cylinders with a maximum yield strength, Re < 390 MPa (56.6 ksi) and a maximum working pressure not exceeding 150 bar (2180 psig) when limiting the moisture content to a maximum of 20ppmV.

4 Inspection recommendations

When changing carbon monoxide/carbon dioxide mixture cylinders to another service, specific precautions shall be taken, see ISO 11621 [6]. 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 appropriate non-destructive examination (NDE), such as ultrasonic examination as specified in ISO 6406 for crack detection. Some EIGA member companies report success in detecting defects in such cylinders as carbon monoxide/carbon dioxide service using acoustic emission testing. These techniques require fully trained and experienced personal to perform such testing. Additionally, it might be advisable, in some circumstances to perform a hydraulic test at cylinder test pressure, see ISO 6406 [7].

5 References

(1) Kowaka and Nagata, Stress Corrosion Cracking of Mild and Low Alloy Steels in CO-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 –H_2O 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) EIGA Doc 100 Hydrogen Cylinders and Transport Vessels

(6) ISO 11621 Gas cylinders -- Procedures for change of gas service

(7) ISO 6406 Periodic inspection and testing of seamless steel gas cylinders