



CGA H-16—2022

GUIDELINE ON REMEDIAL ACTIONS FOR HYCO PLANT COMPONENTS SUBJECT TO HIGH TEMPERATURE HYDROGEN ATTACK

FIRST EDITION

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PREFACE

As part of a program of harmonization of industry standards, the Compressed Gas Association (CGA) has published CGA H-16, *Guideline on Remedial Actions for HYCO Plant Components Subject to High Temperature Hydrogen Attack*, jointly produced by members of the International Harmonization Council.

This publication is intended as an international harmonized standard for the worldwide use and application of all members of the Asia Industrial Gases Association (AIGA), CGA, European Industrial Gases Association (EIGA), and Japan Industrial and Medical Gases Association (JIMGA). Each association's technical content is identical, except for regional regulatory requirements and minor changes in formatting and spelling.

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1 Introduction

Industrial gas companies operate and maintain hydrogen production facilities worldwide ranging in scale from small (< 1MM SCF per day) to the world's largest facilities (> 150MM SCF per day). These plants, and the related HYCO facilities that produce carbon monoxide and syngas products, generally involve the handling of flammable gases at high temperatures typically up to 1700 °F (925 °C) and moderate to high pressures. These processing conditions can present inherent hazards that should be recognized and properly managed to ensure the mechanical integrity and safe operation of the facilities. One such hazard is a phenomenon known as high temperature hydrogen attack (HTHA).

HTHA is a mechanism that can significantly weaken and damage a variety of steel materials that are used in the construction of hydrogen plants, including carbon steel and various low alloy steels. The hydrogen molecules contained in many hydrogen plant process streams can dissociate to atomic hydrogen and diffuse into the steel and react with carbon to form methane that creates fissures that will grow and weaken the steel structure. The initiation of this reaction and the rate of reaction is primarily dependent on steel type, hydrogen partial pressure, and temperature. The cumulative amount of exposure time to these conditions will dictate the degree of degradation of the material strength. For this reason, equipment operated in the HTHA concern zone becomes more susceptible to damage over time and requires regular examination.

The issue of HTHA is known and documented within the oil and gas industry, most notably in the API RP 941, *Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants* [1].¹ However, HTHA related failures have not been eliminated in part because API RP 941 is empirically based [1]. A significant incident that occurred in 2010 was the HTHA-induced catastrophic failure of a heat exchanger at a Tesoro refinery in Anacortes, Washington, United States. This tragic event led to an investigation by the United States Chemical Safety and Hazard Investigation Board (CSB) and subsequently a revision of API RP 941 [1]. That revision included a change to the HTHA limits, known as the Nelson Curves, which are used to determine the maximum operating temperature and pressure for carbon and low alloy steels in hydrogen-rich service. For more details, see CSB Report 2010-08-I-WA, May 2014, *Tesoro Refinery Fatal Explosion and Fire* and API RP 941 [2, 1].

Based on the revisions made to API RP 941, CGA has identified this API document as the Recognized and Generally Accepted Good Engineering Practice for assessing HTHA risk [1].

Given the API RP 941 revised Nelson Curves, carbon steel might no longer be considered an appropriate material in certain services in HYCO plants (e.g., the mixing tee where steam and feed are mixed in a steam methane reformer [SMR] process gas boiler outlet line), although the damage mechanism can take a long time to develop to failure [1]. Operational HYCO plants (including hydrogen/CO/syngas plants) need to be aware that the design criteria for carbon steel and other low alloy steels in hydrogen-rich service have changed. A review of existing components that are vulnerable to HTHA (per API RP 941) in hydrogen-containing services is likely required [1].

This publication will provide guidance, heuristics, and some examples of methodologies for the review of existing HYCO plant assets to determine their potential for HTHA-initiated cumulative damage. It will also provide guidelines for risk categorization, inspection strategies, and recommendations on risk mitigation.

2 Scope

This publication will identify actions for the owners and operators of HYCO plants (including carbon monoxide and syngas plants) in response to the updated guidance on the HTHA mechanism documented in API RP 941 [1]. The guidance in CGA H-16 can apply to all scales of hydrogen production and consumption facilities that utilize the relevant materials of construction.

Risk of the HTHA mechanism will be determined for the components that are exposed to hydrogen-containing gas at a temperature above 400 °F (205 °C) (with some margin below 400 °F [205 °C] to allow for uncertainties). Examples of services in a HYCO plant that would typically require assessment are provided in Section 8.

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

It should be noted that there are other industries that operate hydrogen or syngas producing plants for purposes other than hydrogen production. For example, the ammonia and methanol industry operate syngas production facilities and should find relevant guidance from this publication.

This publication is not intended to address the details of design or construction of new facilities relative to HTHA. Please note that in this publication, the term “low alloy steels” refers to chromium-molybdenum (CrMo) steels.

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 Chromium-molybdenum

Grades of steel with chromium and molybdenum added to increase strength and hardness compared to carbon steel.

NOTE—They have lower levels of chromium compared to stainless steel and thus lower corrosion resistance.

3.2.2 Cladding/weld overlays

Use of a corrosion-resistant alloy to protect a lower grade metal which is the primary pressure boundary. The cladding can be bonded to the base layer through one of several methods (e.g., weld overlay, explosive bonding, etc.).

3.2.3 Decarburization

Loss of carbon in metal that results in loss of hardness and strength. In the case of HTHA, the carbon is lost via reaction with hydrogen to methane.

3.2.4 Hydrogen partial pressures

Pressure attributed to only the hydrogen portion of a process fluid.

NOTE—See 7.2.2 for more information on calculating hydrogen partial pressure.

3.2.5 Inspection test plans

Program of inspection and monitoring to prevent loss of containment.

NOTE—Inspection test plans are also sometimes referred to as mechanical integrity inspection plans.