Inspection, Assessment, and Repair of Heavy Wall Reactor Vessels in High-temperature High-pressure Hydrogen Service

API TECHNICAL REPORT 934-H
FIRST EDITION, MAY 2022

Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed. The use of API publications is voluntary. In some cases, third parties or authorities having jurisdiction may choose to incorporate API standards by reference and may mandate compliance.

Classified areas may vary depending on the location, conditions, equipment, and substances involved in any given situation. Users of this technical report (TR) should consult with the appropriate authorities having jurisdiction.

Users of this TR should not rely exclusively on the information contained in this document. Sound business, scientific, engineering, and safety judgment should be used in employing the information contained herein.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to ensure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be used. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

API is not undertaking to meet the duties of employers, manufacturers, or suppliers to warn and properly train and equip their employees, and others exposed, concerning health and safety risks and precautions, nor undertaking their obligations to comply with authorities having jurisdiction.

Information concerning safety and health risks and proper precautions with respect to particular materials and conditions should be obtained from the employer, the manufacturer or supplier of that material, or the material safety data sheet.

Work sites and equipment operations may differ. Users are solely responsible for assessing their specific equipment and premises in determining the appropriateness of applying the TR. At all times, users should employ sound business, scientific, engineering, and judgment safety when using this TR.

Foreword

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

The verbal forms used to express the provisions in this document are as follows.

Shall: As used in a standard, "shall" denotes a minimum requirement to conform to the standard.

Should: As used in a standard, "should" denotes a recommendation or that which is advised but not required to conform to the standard.

May: As used in a standard, "may" denotes a course of action permissible within the limits of a standard.

Can: As used in a standard, "can" denotes a statement of possibility or capability.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually by API, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001.

Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001, standards@api.org.

Contents

Contents

Figures

Contents

Tables

Inspection, Assessment, and Repair of Heavy Wall Reactor Vessels in High-temperature High-pressure Hydrogen Service

1 Scope

This TR documents guidance for the inspection, assessment, and repair of heavy wall reactor vessels (nominally considered a wall thickness of 50 mm (2 in.) and greater) in high-pressure hydrogen service operating at temperatures below 455 °C (850 °F). It provides industry practices dealing with reactor vessels after construction and exposure to operating conditions. It focuses on reactor vessels fabricated from 2¼Cr-1Mo, 3Cr-1Mo, 2¼Cr-1Mo-¼V, and 3Cr-1Mo-¼V steels. It also offers some guidance for heavy wall reactor vessels fabricated from 1Cr-½Mo and 1¼Cr-½Mo steels, but specifically does not pertain to C-½Mo steel vessels. However, guidance included in this document can be used for C-½Mo steel reactor vessels at the owner's discretion and with modifications as appropriate.

This document does not address damage found in hot wall catalytic reforming reactors, fluid catalytic cracking unit (FCCU) reactors, and delayed coking drums as they generally operate at higher temperatures and have thinner walls.

Since this is a technical report, it does not provide recommendations, but instead presents industry experience with case histories of repairs and recognized practices, much of which was documented as part of a Joint Industry Program (JIP) on Aging Reactor Vessels, conducted in two phases between 1995 and 2004.

2 Normative References

There are no normative references in this document.

3 Terms, Definitions, Abbreviations, and Acronyms

3.1 Terms and Definitions

For this report, the following terms and definitions apply in addition to those given in API Recommended Practices 934-A and 934-C.

3.1.1
cladding
Internal integrally bonded corrosion-resistant lining applied as a wrought product to the internal surface of a vessel, i.e. the vessel is constructed from clad plate. Clad plate is fabricated using a hot roll bonding process or an explosive bonding process and is mostly used for thinner wall reactor vessels. See also lining, overlay, and loose lining.

3.1.2
disbonding
Areas of cladding or overlay that do not have a metallurgical bond to the base metal. Disbonding can occur during fabrication, and testing is typically done to detect and repair any locations. It can also occur due to high-temperature high-pressure hydrogen service depending on the characteristics of the bond areas. Testing of cladding and overlay procedures are done before fabrication to minimize the susceptibility to disbonding.

3.1.3
J-factor
An empirical relationship used to predict temper embrittlement susceptibility of some low alloy steel grade base materials

$$\text{J-factor} = (Si + Mn) \times (P + Sn) \times 10,000$$