

# Guidelines for Avoiding Sulfidation (Sulfidic) Corrosion Failures in Oil Refineries

API RECOMMENDED PRACTICE 939-C  
SECOND EDITION, JANUARY 2019



AMERICAN PETROLEUM INSTITUTE

[This is a preview. Click here to purchase the full publication.](#)

## 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.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees makes any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assumes 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 assure 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 utilized. 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.

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

Users of this Recommended Practice 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.

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.

Where applicable, authorities having jurisdiction should be consulted.

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 Recommended Practice. At all times users should employ sound business, scientific, engineering, and judgment safety when using this Recommended Practice.

All rights reserved. No part of this work may be reproduced, translated, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the publisher. Contact the Publisher, API Publishing Services, 1220 L Street, NW, Washington, DC 20005.

*Copyright © 2019 American Petroleum Institute*

[This is a preview. Click here to purchase the full publication.](#)

## 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 in order to conform to the standard.

**Should:** As used in a standard, “should” denotes a recommendation or that which is advised but not required in order 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, 1220 L Street, NW, Washington, DC 20005. 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, 1220 L Street, NW, Washington, DC 20005.

Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, [standards@api.org](mailto:standards@api.org).

This is a preview. [Click here to purchase the full publication.](#)

## Contents

	Page
1	Scope . . . . . 1
2	Normative References . . . . . 1
3	Terms, Definitions, Abbreviations, and Acronyms . . . . . 1
3.1	Terms and Definitions . . . . . 1
3.2	Abbreviations and Acronyms . . . . . 3
4	Basics of Sulfidation Corrosion. . . . . 4
5	Location of Sulfidation Corrosion . . . . . 7
6	Effects of Process and Material Variables on Corrosion Rates . . . . . 8
6.1	Introduction . . . . . 8
6.2	H <sub>2</sub> -free Sulfidation. . . . . 8
6.3	H <sub>2</sub> /H <sub>2</sub> S Corrosion . . . . . 11
7	Practical Guidelines for Avoiding Sulfidation Corrosion Failures . . . . . 12
7.1	General. . . . . 12
7.2	Existing Units and Components . . . . . 12
7.3	New and Replacement Components . . . . . 18
8	Limitations of Current Knowledge Base. . . . . 19
9	Incidents . . . . . 20
	Annex A (informative) Failure Experience Summary . . . . . 22
	Annex B (informative) Sulfidation Corrosion Prediction Tools . . . . . 24
	Annex C (informative) Corrosion Data for Carbon Steel Piping with Higher and Lower Si Contents . . . . . 36
	Annex D (informative) Overview of Sulfidation Corrosion Throughout Refinery Units. . . . . 40
	Annex E (informative) Simplified Inspection Checklist for Refinery Piping and Equipment in Sulfidation Service . . . . . 44
	Bibliography . . . . . 48
<b>Figures</b>	
1	NPS 8 Carbon Steel Piping Failed Due to Sulfidation Corrosion (H <sub>2</sub> Free) . . . . . 5
2	Corroded Carbon Steel Sight Glass Nipple . . . . . 5
3	FCC Fractionator Bottoms Carbon Steel Piping Operating at 150 psig (1 MPa) and 650 °F to 700 °F (340 °C to 370 °C) . . . . . 6
4	FCC Fractionator Bottoms Carbon Steel Piping Shown in Figure 3 Operating at 150 psig (1 MPa) and 650 °F to 700 °F (340 °C to 370 °C) . . . . . 7
5	Summary of Reported Failures by Type, Number of Reported Instances, and Percentage of the Total . . . . . 21
B.1	Modified McConomy Curves (0.6 % Sulfur Content) (USC Units) . . . . . 26
B.2	Modified McConomy Curves (0.6 % Sulfur Content) (SI Units). . . . . 26
B.3	Couper-Gorman H <sub>2</sub> /H <sub>2</sub> S Curves for Carbon Steel for Both Naphtha and Gas Oil . . . . . 27
B.4	Couper-Gorman H <sub>2</sub> /H <sub>2</sub> S Curves for 1.25Cr-0.5Mo Steel for Both Naphtha and Gas Oil . . . . . 28
B.5	Couper-Gorman H <sub>2</sub> /H <sub>2</sub> S Curves for 2.25Cr-1Mo Steel for Both Naphtha and Gas Oil . . . . . 29
B.6	Couper-Gorman H <sub>2</sub> /H <sub>2</sub> S Curves for 5Cr-0.5Mo Steel for Both Naphtha and Gas Oil . . . . . 30
B.7	Couper-Gorman H <sub>2</sub> /H <sub>2</sub> S Curves for 7Cr-0.5Mo Steel for Both Naphtha and Gas Oil . . . . . 31
B.8	Couper-Gorman H <sub>2</sub> /H <sub>2</sub> S Curves for 9Cr-1Mo Steel for Both Naphtha and Gas Oil . . . . . 32

## Contents

	Page
<b>B.9 Couper-Gorman H<sub>2</sub>/H<sub>2</sub>S Curves for 12Cr Steel (Same for Both Naphtha and Gas Oil)</b> . . . . .	33
<b>B.10 Couper-Gorman H<sub>2</sub>/H<sub>2</sub>S Curves for 18Cr 8 Ni Steel (Same for Both Naphtha and Gas Oil)</b> . . . . .	33
<b>B.11 Corrosion Rate in H<sub>2</sub>S/High H<sub>2</sub> Partial Pressure—All Vapor</b> . . . . .	34
<b>B.12 Corrosion Rate in H<sub>2</sub>S/High H<sub>2</sub> Partial Pressure—Liquid Shifted by a Factor of 6 Lower vs Vapor</b> . . . . .	34
<b>B.13 Corrosion Rate in H<sub>2</sub>S/H<sub>2</sub> Vapor—Low H<sub>2</sub> Partial Pressure (High H<sub>2</sub> Partial Pressure— All Vapor Curves Adjusted by Experience)</b> . . . . .	35
<b>C.1 Corrosion Rate vs Si Content for FCC Slurry Carbon Steel Piping Failure (Shown in Figure 3 and Figure 4) (Operating Conditions: 150 psig and 650 °F to 700 °F)</b> . . . . .	37
<b>C.2 Corrosion Rate vs Si Content for FCC Slurry Carbon Steel Piping Failure (Shown in Figure 3 and Figure 4) (Operating Conditions: 1 MPa and 340 °C to 370 °C)</b> . . . . .	38
<b>C.3 Corrosion Rate vs Si Content for Various H<sub>2</sub>-free Services (USC Units)</b> . . . . .	39
<b>C.4 Corrosion Rate vs Si Content for Various H<sub>2</sub>-free Services (SI Units)</b> . . . . .	39

This is a preview. [Click here to purchase the full publication.](#)