

Heat Recovery Steam Generators

API RECOMMENDED PRACTICE 534
SECOND EDITION, FEBRUARY 2007

REAFFIRMED, MARCH 2023



American
Petroleum
Institute

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 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 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.

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.

All rights reserved. No part of this work may be reproduced, 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, 200 Massachusetts Avenue, NW, Washington, DC 20001.

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.

Shall: As used in a standard, “shall” denotes a minimum requirement in order to conform to the specification.

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

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, 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 and updated quarterly by API, 200 Massachusetts Avenue, NW, Washington, DC 20001.

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

CONTENTS

	Page
1 GENERAL.....	1
1.1 Scope.....	1
1.2 Referenced Publications.....	1
1.3 Definition of Terms.....	2
1.4 Regulatory Requirements.....	3
2 FIRETUBE HEAT RECOVERY STEAM GENERATORS.....	3
2.1 General.....	3
2.2 Application.....	4
2.3 System Consideration.....	5
2.4 Advantages of Firetube Over Watertube Hrsgs.....	7
2.5 Disadvantages of Firetube Relative to Watertube HRSGs.....	7
2.6 Mechanical Description.....	8
2.7 Operational Description.....	17
3 WATERTUBE HEAT RECOVERY STEAM GENERATORS.....	18
3.1 General.....	18
3.2 Application.....	18
3.3 Gas Turbine Exhaust HRSG.....	19
3.4 Fired Heater Convection Section HRSG.....	37
3.5 FCC Regenerator Flue Gas HRSG.....	38
APPENDIX A STEAM DRUMS.....	43
APPENDIX B HEAT FLUX AND CIRCULATION RATIO.....	51
APPENDIX C SOOTBLOWERS.....	55
Figures	
1 Horizontal Firetube with External Drum HRSG.....	3
2 Vertical Firetube with External Drum HRSG.....	4
3 Firetube Kettle Type HRSG.....	4
4 Insulated Metal Ferrule.....	9
5 Insulated Ceramic Ferrule.....	9
6 Conventional Strength Weld.....	10
7 Full-depth Strength Weld.....	10
8 Back (Shell-side) Face Weld.....	11
9 Channel-tubesheet-shell Interconnection.....	12
10 Dual Compartment Firetube HRSG.....	13
11 Two Tube Pass Firetube HRSG.....	14
12 Internal Bypass System with Valve and Dampers.....	14
13 Partially Tubed Firetube HRSG.....	16
14 Basic Tubular Arrangement.....	19
15 Interlaced Tubular Arrangement.....	19
16 Natural Circulation HRSG.....	20
17 Typical Natural Circulation Gas Turbine Exhaust HRSG.....	20
18 Typical Fire Heater Convection Section HRSG.....	38
A-1 Typical Steam Drum.....	43
B-1 Typical Watertube HRSG.....	53
B-2 Typical Circulation Rate.....	53
B-3 Typical Forced Circulation System.....	54

	Page
C-1 Sootblower Cleaning Lanes	55
C-2 Typical Fixed Position Rotary Mounting Arrangement.	56
C-3 Typical Steam Flow Rate for Fixed Rotary Soot Blowers.	57
C-4 Typical Air Flow Rate for Fixed Rotary Soot Blowers	57
C-5 Typical Retractable Mounting Arrangement	58
C-6 Typical Steam Flow Rate for Retractable Soot Blowers	59

Tables

1 Typical Pinch and Approach Temperatures	24
A-1 Watertube Boilers Recommended Boiler Water Limits and Associated Steam Purity at Steady State Full Load Operation	44
A-2 Suggested Water Quality Limits	45
B-1 HRSG Firetube and Watertube Local Heat Flux	52

Heat Recovery Steam Generators

1 General

1.1 SCOPE

This publication provides guidelines for the selection or evaluation of heat recovery steam generator (HRSG) systems. Details of related equipment designs are considered only where they interact with the HRSG system design. This publication does not provide rules for design, but indicates areas that need attention and offers information and description of HRSG types available to the designer or user to aid in the selection of the appropriate HRSG system.

The HRSG systems discussed are those currently in industry use. A general description of each HRSG system begins Sections 2 and 3. Selection of an HRSG system for description does not imply other systems are not available nor recommended. Many individual features described in these guidelines will be applicable to any type of HRSG system.

Appendices A, B, and C refer to Sections 1 through 3.

1.2 REFERENCED PUBLICATIONS

1.2.1 The editions of the following standards, codes and specifications that are in effect at the time of publication of this publication shall, to the extent specified herein, form a part of this publication.

API/ISO¹

- Std 530/ISO 13704 *Petroleum and natural gas industries—Calculation of heater-tube thickness in petroleum refineries*
- RP 536 *Post Combustion NO_x Control for Fired Equipment in General Refinery Services*
- Std 560/ISO 13705 *Petroleum and natural gas industries—Fired heaters for general refinery service*
- Std 660/ISO 16812 *Petroleum and natural gas industries—Shell-and-tube heat exchangers for general refinery service*

ABMA²

- Boiler 402 *Boiler Water Quality Requirements and Associated Steam Quality for Industrial/Commercial and Institutional Boilers*

ANSI³/ASME⁴

- ANSI 14.3 *Fixed Ladders—Safety Requirements*
- PTC 4.4 *Gas Turbine Heat Recovery Steam Generators Performance Test Code*

ASME

- Boiler and Pressure Vessel Code*, Section I: “Power Boilers” and Section VIII, Division 1, “Pressure Vessels.”
- Consensus Operating Practices for Control of Feedwater/Boiler Water Chemistry in Modern Industrial Boilers CRTD—Vol. 34*
- SA-106 *Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service*
- SA-178/SA-178M *Standard Specification for Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes*
- SA-214/SA-214M *Specification for Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes*
- STS-1 *Steel Stacks*

ASTM⁵

- D 1066-97(2001) *Standard Practice for Sampling Steam*

NFPA⁶

- 8502 *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers*

¹International Organization for Standards, 25 West 43rd Street, 4 Floor, New York, New York, 10036, www.iso.org.

²American Boiler Manufacturers Association, 8221 Old Courthouse Road, Suite 207, Vienna, Virginia 22182, www.abma.com.

³American National Standards Institute, 25 West 43rd Street, 4th floor, New York, New York, 10036, www.ansi.org.

⁴ASME International, 3 Park Avenue, New York, New York, 10016, www.asme.org.

⁵ASTM International, 100 Bar Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

⁶National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, Massachusetts 02269-9101, www.nfpa.org.