

High-pressure High-temperature (HPHT) Flange Design Methodology

API RECOMMENDED PRACTICE 6AF3
SECOND EDITION, MAY 2024



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. 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.

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.

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, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001-5571.

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.

Currently in preview, click buy full version

Contents

	Page
1 Scope.....	1
2 Normative References	1
3 Terms, Definitions, Acronyms, Abbreviations, and Symbols	1
3.1 Definitions	1
3.2 Acronyms, Abbreviations, and Symbols	1
4 Summary of Methodology.....	2
5 HPHT End Flange Initial Sizing Methodology.....	2
5.1 General.....	2
5.2 Gasket Selection.....	2
5.3 Calculate Bolting and Flange Dimensions.....	3
6 HPHT End Flange Design Verification Analysis.....	4
6.1 Determine Flange Capabilities.....	4
6.2 High Temperature Effects	4
6.3 Flange Body Plastic Collapse	4
6.4 Service Criteria	4
6.5 Excessive Bolt Stress	5
6.6 Design Validation	5
7 Results.....	5
Annex A (informative) Verifying Gasket Suitable for Internal Pressure Requirements	6
Annex B (informative) API 6BX 5 1/8 in. 15K Using Described Methodology	13
Annex C (informative) Examples of API 6BX Flange Capability Charts Using Annex B Methodology.....	20
Bibliography.....	25

Figures

A.1 Example Element Plot of 6BX Gasket—Initial Condition and Loading	7
A.2 3D Model of Flange Assembly	8
A.3 Example Stress Plot of 3D Model	9
A.4 Example Stress Plot of Axisymmetric Model	9
A.5 2D and 3D Gasket Behavior Assessment.....	10
A.6 Results of Gasket Assessment for Axisymmetric Model.....	11
A.7 Results of Gasket Assessment for 3D Model	12
B.1 Effective Sealing Diameter and Gasket Wedging Load	14
B.2 FEA Model Used to Determine Stiffness Ratio	17
B.3 Element Plot of Model.....	18
B.4 5 1/8 in. 15K 6BX Flange 80ksi Studs 50 % Assembly Stress	19
C.1 1 13/16 in. 20K 6BX Flange 80ksi Studs 50 % Assembly Stress.....	20
C.2 2 1/16 in. 20K 6BX Flange 80ksi Studs 50 % Assembly Stress	21

Contents

	Page
C.3 2 $\frac{9}{16}$ in. 20K 6BX Flange 80ksi Studs 50 % Assembly Stress	21
C.4 3 $\frac{1}{16}$ in. 20K 6BX Flange 80ksi Studs 50 % Assembly Stress	22
C.5 4 $\frac{1}{16}$ in. 20K 6BX Flange 80ksi Studs 50 % Assembly Stress	22
C.6 7 $\frac{1}{16}$ in. 20K 6BX Flange 80ksi Studs 50 % Assembly Stress	23
C.7 9 in. 20K 6BX Flange 80ksi Studs 50 % Assembly Stress	23
C.8 11 in. 20K 6BX Flange 80ksi Studs 50 % Assembly Stress.....	24
C.9 13 $\frac{5}{8}$ in. 20K 6BX Flange 80ksi Studs 50 % Assembly Stress	24

Tables

B.1 Calculation of Hub Thickness	13
B.2 Calculating Effective Sealing Diameter for Pressure End Load.....	14
B.3 Calculation of Gasket Vertical Reaction Load.....	15
B.4 Calculate Total Pressure Loading	15
B.5 Calculate the Minimum Required Total Root Area	15
B.6 Calculate Possible Bolt Circles and Flange ODs.....	16

Introduction

This document is intended to provide design guidance for high-pressure high-temperature (HPHT) API 6BX style flanges. The current revision of this document focuses on recommending methods for quantifying flange capabilities subjected to combinations of pressure, bending, tension, and thermal loads. It intends to expand upon the work documented in API Technical Report 6AF2 by recommending methods using more advanced analysis modeling, such as 3D geometry, nonlinear material models, and large displacement theory. It also provides guidance on initial sizing of flange geometry based on the work presented in Robert Eichenberg's ASME paper 57-PET-23 "Design Considerations for AWHEM 15,000 psi Flanges" of 1957 and his Journal of Engineering for Industry paper of 1964. Eichenberg's work established the foundations for the API 6BX style flange.

It is not the intent of this document to restrict users from performing project or application specific analyses that could provide capabilities different to those using the methodology summarized herein. Alternative methods may be acceptable if justified by alternative industry accepted design codes. When other industry-approved HPHT design methods are employed, the methodology presented here shall not be viewed as an extra requirement nor is it intended to supplant other industry-approved HPHT design methodologies.

The intent of this design guideline is to enable the user to generate baseline capability charts similar to those seen in API Technical Report 6AF2, but using nonlinear FEA models, methods, and criteria.

The methodology is demonstrated on the API 6BX 5 in. 15K flange in [Annex B](#). [Annex C](#) contains capability charts for all the 20K API 6BX flanges using a possible interpretation of the method described in the guideline.

At the time of writing, not all methodologies in this document have been validated. Therefore, this document serves as an example of the types of calculations and considerations necessary to define capabilities of API 6BX flanges.

Fatigue is intended be added to this document later under a future revision.

Currently in preview, click buy full version

High-pressure High-temperature (HPHT) Flange Design Methodology

1 Scope

The scope of this document is to provide design guidelines for API 6BX style flanges used as end and outlet connectors in high-pressure, high-temperature (HPHT) surface and subsea applications. For this document, HPHT applications are intended to mean flanges assigned a temperature rating greater than 350 °F or a pressure rating greater than 15,000 psi.

Service temperature ratings above 550 °F (288 °C) are outside the scope of this document.

2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies.

API Specification 6A, *Specification for Wellhead and Tree Equipment*

API Standard 6X, *Design Calculations for Pressure-containing Equipment*

API Technical Report 6AF, *Technical Report on Capabilities of API Flanges under Combinations of Load*

API Technical Report 6AF1, *Technical Report on Temperature Derating on API Flanges under Combination of Loading*

API Technical Report 6AF2, *Technical Report on Capabilities of API Integral Flanges under Combination of Loading—Phase II*

API Technical Report 17TR8, *High-Pressure High-Temperature Design Guidelines*

ASME, *Boiler and Pressure Vessel Code Section VIII, Division 2—Alternative Rules*

ASME, *Boiler and Pressure Vessel Code Section VIII, Division 3—Alternative Rules for Construction of High Pressure Vessels*

3 Terms, Definitions, Acronyms, Abbreviations, and Symbols

3.1 Definitions

For the purposes of this document, the following terms and definitions, and those terms and definitions in API 6A, apply.

3.1.1

Stiffness ratio

Stiffness of the bolt divided by the stiffness of the bolt plus the stiffness of the flange body.

NOTE: Refer to [B.2.5](#).

3.2 Acronyms, Abbreviations, and Symbols

For the purposes of this document, the following acronyms, abbreviations, and symbols apply.

FEA finite element analysis