Technical Report on Capabilities of API Integral Flanges Under Combination of Loading—Phase II

API TECHNICAL REPORT 6AF2
FOURTH EDITION, OCTOBER 2010

AMERICAN PETROLEUM INSTITUTE

Technical Report on Capabilities of API Integral Flanges Under Combination of Loading—Phase II

Upstream Segment

API TECHNICAL REPORT 6AF2
FOURTH EDITION, OCTOBER 2010

energy API®

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.

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 © 2010 American Petroleum Institute

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.

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, N.W., Washington, D.C. 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 and updated quarterly by API, 1220 L Street, N.W., Washington, D.C. 20005.

Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, D.C. 20005, standards@api.org.

Contents

Page

Technical Report on Capabilities of API Integral Flanges Under Combination of Loading—Phase II

1 Scope

The evaluation of the load carrying capacity of API 6A integral flanges is the objective of this work. The applied loading includes the end tension and bending moment in addition to the conventional rated pressure and makeup forces. The effect of a temperature difference corresponding to 250 °F on the inside and 30 °F on the outside was also evaluated.

Three-dimensional finite element meshes were generated for the Type 6B, and Type 6BX flanges. The bending moment load case required a model of one quarter of the flange which was built up from the smaller segments and the half-bolt superelements. The computer program SESAM was used to obtain the stresses at selected critical flange and hub sections and to determine the gasket reaction due to each of the four unit load cases and the temperature difference load case. Leakage criterion was defined as the load combination which reduces the initial makeup compressive forces in the gasket to zero. The stresses in each defined section were linearized in accordance with the ASME *Section VIII*, *Division 2*, procedure to determine the membrane and membrane-plus-bending stress intensities. These stress intensities were checked against the allowables specified in API 6A, and the limiting loads were determined. A computer program LCCP was written to carry out this code check and a LOTUS 1-2-3 Release 3 worksheet was used to plot the load combination charts.

The results of the analysis carried out indicate that the leakage criterion governs the capacity of the smaller flanges in the Type 6B flanges. Leakage was governing for up to 9 in. size flanges in both the 52.5 ksi and 40 ksi makeups for the 2000 psi pressure. Leakage was governing the 5 $^{1}/_{8}$ in. for the higher pressures. Leakage was also found to be governing all Type 6BX flanges for working pressures of up to 5,000 psi. For the 10,000 psi and 15,000 psi flanges, leakage governed only in the larger size range greater than 2 $^{9}/_{16}$ in. Leakage was governing in all the 20,000 psi API 6BX flanges. The leakage model adopted in this study employs several approximations that have not yet been evaluated. Therefore, the actual leakage forces, i.e. load combinations leading to leakage, may be considerably higher than assumed herein. In reality, the gasket only leaks when its energized capacity is exceeded.

The state of stress at the stress governing hub section under the combined loading of makeup, pressure, tension and bending moment is considered to be “secondary.” However, when pressure, tension, and bending moments are applied together with the necessary makeup to resist these actions without leakage, the state of stress is rendered “primary” and, therefore, the allowable stress intensities are halved. This does not seem to be consistent, and it may by far exceed the intention of the code. However, the oversight subcommittee preferred to adopt the conservative route, which may be overly conservative pending further evaluation. Therefore, it may be concluded that when the hub stresses are treated as primary, most flanges do not possess significant reserve strength beyond the leakage condition. In fact, if the leakage condition was somewhat conservative, the stress condition may become governing for most flanges.

The temperature difference of 250 °F internal and 30 °F external leads to increases in the load-carrying capacity of the flanges. This condition is caused by the compressive forces generated in the gasket due to this temperature difference, and the increase in the allowable stresses when the self-limiting temperature load condition is included. It is recommended that a 3-D finite element, nonlinear material and geometric models of approximately eight flanges be carried out to determine the actual failure mechanism that governs the behavior of these flanges. This includes the prediction of the response of the gasket under increasing load and a more accurate definition of the leakage mechanism. The elimination of the raised face does not significantly reduce the stresses in the hub which caused six Type 6B flanges to fail to meet the ASME criterion for makeup load only (52.5 ksi for 105 ksi bolting). The stress intensities were reduced only by about 5 % when the raised face was eliminated, increasing the thickness of the flange by about 10 %. The hub thickness for these flanges had to be increased by up to about 27 % of their existing thicknesses together with the elimination of the raised face.

The bolt stresses did not govern for any of the flanges analyzed. Bolt stresses are typically within approximately 67 % of their yield strength due to makeup, pressure, tension, and bending moment loads. The bolts are expected to be made up to half their yield. The stresses in the bolts due to temperature differences increase by about 5 ksi to 7 ksi, which is