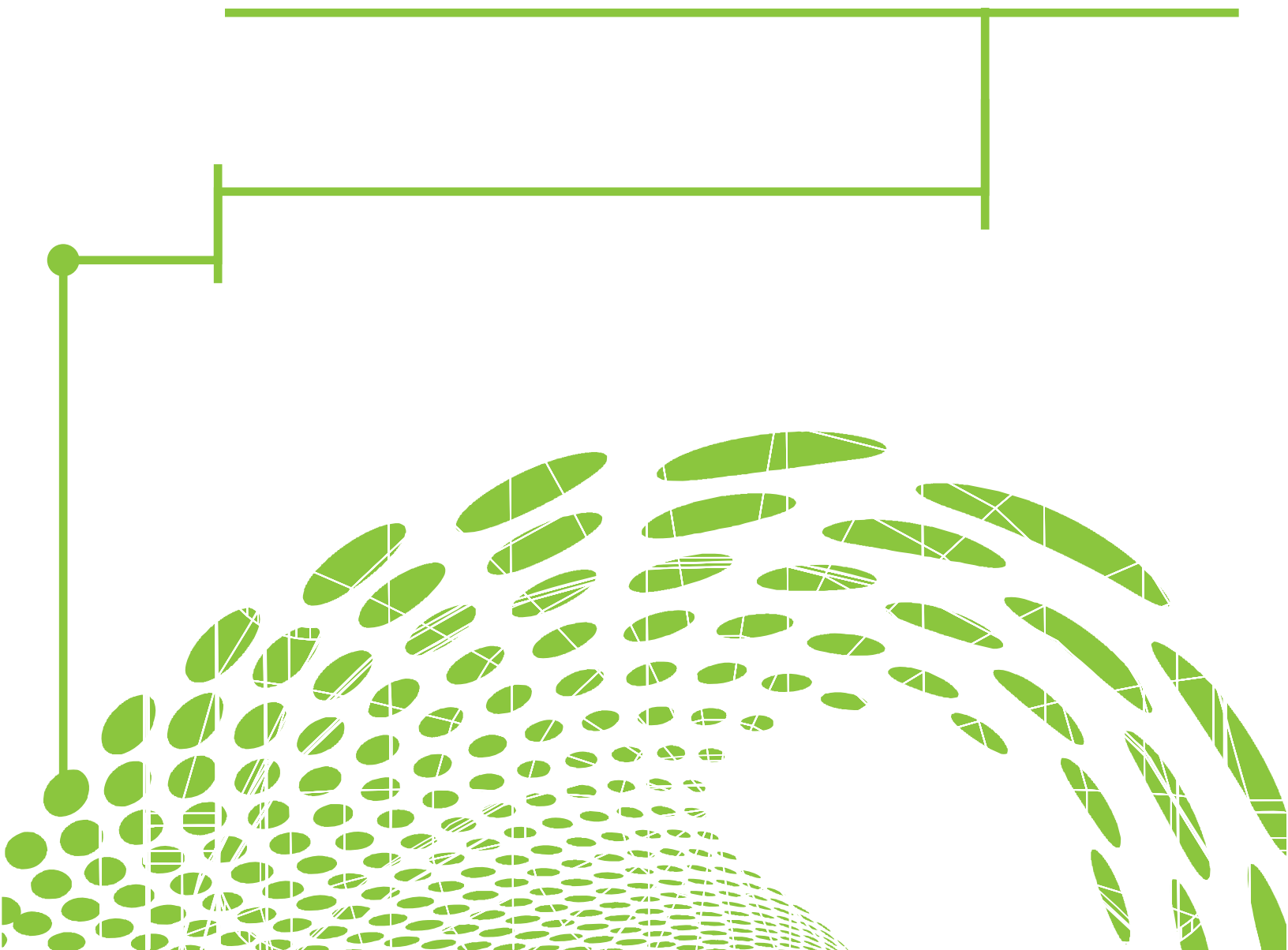




# STRESS INTENSIFICATION FACTOR, K-FACTOR, AND SUSTAINED STRESS INDEX DEVELOPMENT-PHASE II



**STP-PT-097**

**STRESS INTENSIFICATION  
FACTOR, K-FACTOR, AND  
SUSTAINED STRESS INDEX  
DEVELOPMENT – PHASE II**

*Prepared by:*

Anthony W. Paulin, P.E.  
Paulin Research Group  
Houston, TX, USA

And

Chris Hinnant, P.E.  
K&H Fabricators, Inc.  
Smithville, TX, USA

The logo for ASME Standards Technology, LLC features the text "ASME STANDARDS TECHNOLOGY, LLC" in a bold, sans-serif font. The text is centered and partially enclosed by a large, light gray, curved line that starts on the left and sweeps under the text towards the right.

**ASME STANDARDS  
TECHNOLOGY, LLC**

Date of Issuance: August 16, 2023

This publication was prepared by ASME Standards Technology, LLC (“ASME ST-LLC”) and sponsored by The American Society of Mechanical Engineers (“ASME”).

Neither ASME, ASME ST-LLC, the author(s), nor others involved in the preparation or review of this publication, nor any of their respective employees, members, or persons acting on their behalf, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe upon privately owned rights.

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by ASME ST-LLC or others involved in the preparation or review of this publication, or any agency thereof. The views and opinions of the authors, contributors and reviewers of the publication expressed herein do not necessarily reflect those of ASME ST-LLC or others involved in the preparation or review of this publication, or any agency thereof.

ASME ST-LLC does not take any position with respect to the validity of any patent rights asserted in connection with any items mentioned in this document, and does not undertake to insure anyone utilizing a publication against liability for infringement of any applicable Letters Patent, nor assumes any such liability. Users of a publication are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Participation by federal agency representative(s) or person(s) affiliated with industry is not to be interpreted as government or industry endorsement of this publication.

ASME is the registered trademark of The American Society of Mechanical Engineers.

No part of this document may be reproduced in any form,  
in an electronic retrieval system or otherwise,  
without the prior written permission of the publisher.

ASME Standards Technology, LLC  
Two Park Avenue, New York, NY 10016-5990

ISBN No. 9780791876398  
Copyright © 2023  
ASME Standards Technology, LLC  
All Rights Reserved

## TABLE OF CONTENTS

FOREWARD .....	iv
ABSTRACT.....	v
ABBREVIATIONS AND ACRONYMS .....	vi
1 INTRODUCTION.....	1
2 TEST PROGRAM.....	2
3 EXPERIMENTAL RESULTS .....	10
4 DISCUSSION OF RESULTS .....	16
5 CONCLUSIONS.....	17
REFERENCES .....	18
APPENDIX I .....	19
APPENDIX II.....	29
APPENDIX III.....	64

## LIST OF FIGURES

Figure 2-1 – Typical Test Specimen Design. See Table 2-1 for Dimensions. Drawing Not to Scale. .2	
Figure 2-2 – Experimental Arrangement for Burst Tests.....	4
Figure 2-3 – Labeled and Shifted Results for Pressure vs. Time for Tests 1 - 9 .....	5
Figure 2-4 – Pressure vs. Time History for Tests 1, 2, and 3.....	6
Figure 2-5 – Pressure vs Time History for Tests 4, 5, and 6.....	7
Figure 2-6 – Pressure vs. Time History for Tests 7, 8, and 9.....	8
Figure 2-7 – Pressure vs. Time History for Tests 10, 11, and 12.....	9
Figure 3-1 – Carbon Steel Samples Prior to Burst Testing Showing As-Built Thickness Measurements. .....	10
Figure 3-2 – Stainless Steel Samples Prior to Burst Testing Undergoing Thickness Measurements...10	
Figure 3-3 – 12” Welded Stainless Steel Specimen (Left) Undergoing Pressurization With 10” Seamless Stainless Samples (Right) Ready for Testing.....	11
Figure 3-4 – 10” Carbon Steel Specimen at Moment of Rupture. ....	11
Figure 3-5 – Carbon Steel Specimens Captured at the Moment of Rupture (CS1W bottom and CS3W top). ....	12
Figure 3-6 – 10” Carbon Steel and 12” Stainless Steel Samples after Rupture. ....	12
Figure 3-7 – Specimen #10 (SS1W) After Rupture .....	13
Figure 3-8 – Specimen #10 (SS1W) After Rupture.....	13
Figure 3-9 - Stainless Steel Specimens After Rupture.....	14

## LIST OF TABLES

Table 2-1 – Summary of Test Specimens and Burst Pressure .....	2
Table 2-2 - Summary of Measured Material Properties in Hoop Direction.....	3
Table 2-3 – Measured Wall Thickness Before Burst Test .....	4
Table 3-1 – Detailed Rupture Pressure Results .....	15
Table 4-1 – Comparison of Calculated and Actual Burst Pressure.....	16

## FOREWORD

We would like to express our thanks to Mr. Glynn Woods, GCS Consulting Services., Mr. Willy Lock and Dr. Delin Wang of PRG (Paulin Research Group), Dr. Hans Bos of Dynaflo Research Group bv., Mr. Ron Haupt of Pressure Piping Engineering Associates, Inc., Mr. Randy Bethea, Tim Pline, and Russ Diedrich of Huntington Ingalls Industries – Newport News Shipbuilding, and Mr. Doug Knode and Edwin Avila of Evident Scientific/Olympus. Their assistance, comments and recommendations are very much appreciated.

Established in 1880, the ASME is a professional not-for-profit organization with more than 135,000 members and volunteers promoting the art, science and practice of mechanical and multidisciplinary engineering and allied sciences. ASME develops codes and standards that enhance public safety, and provides lifelong learning and technical exchange opportunities benefiting the engineering and technology community. Visit <https://www.asme.org/> for more information.

ASME ST-LLC is a not-for-profit Limited Liability Company, with ASME as the sole member, formed in 2004 to carry out work related to new and developing technology. ASME ST-LLC's mission includes meeting the needs of industry and government by providing new standards-related products and services, which advance the application of emerging and newly commercialized science and technology, and providing the research and technology development needed to establish and maintain the technical relevance of codes and standards. Visit <http://asmestllc.org/> for more information.

## **ABSTRACT**

In support of ASME B31J and B31H standards, physical testing for stress intensification factors (SIFs), flexibility factors (k-Factors), and sustained stress indices (SSIs) can be used to confirm differences between the Markl and Hinnant curves in the low-cycle ranges and finite element predictions of fatigue, stiffness, collapse and burst.

Improvement in analytical capability since the 1950s (when Markl developed the basic rules in the B31 piping codes used today) has improved the ability to numerically predict stress states. Unfortunately, not all piping components are well defined geometrically or dimensionally in ASME standard documents. Large D/T (ratio of mean header diameter to header nominal thickness) and d/D (ratio of mean branch diameter to mean header diameter) failures involve nonlinear characteristics that may not be well represented by elastic analyses. In these cases, verification by test is considered essential to verify the predicted values and the method of analysis considered.

This publication documents the results of phase II of work undertaken to investigate deficiencies in the existing test data sets identified during the data collection effort from ST-LLC Publication STP-PT-073.

## **ABBREVIATIONS AND ACRONYMS**

ASME	- American Society of Mechanical Engineers
MTR	- Material Test Reports
NPS	- Nominal Pipe Size
NPT	- American National Standard Taper Pipe Thread
PRG	- Paulin Research Group
SCH	- Pipe Schedule
SIF	- Stress Intensification Factors
SSI	- Sustained Stress Indicators
STD	- Standard
ST-LLC	- Standards Technology, Limited Liability Company
WRC	- Weld Research Council

## **1 INTRODUCTION**

Twelve straight pipe specimens were fabricated, material properties independently evaluated, and each specimen was pressurized to rupture at K&H Fabricator's facility in Smithville, Texas. The specimens were segregated into stainless and carbon groups, each group consisting of six specimens: three seamless specimens and three longitudinally welded specimens. Pipe specimens for each group of three tests were made from the same heat so that theoretically three identical specimens could be tested. A significant finding of these results is stainless steel samples failed at a consistently lower pressure than would otherwise be predicted for the same specimen made of carbon steel. This supports prior findings by Rodabaugh in [1].