Guidelines on the fatigue life of ageing pressure vessels

energy institute

GUIDELINES ON FATIGUE LIFE OF AGEING PRESSURE VESSELS

First edition

November 2019

Published by
Energy Institute, London
The Energy Institute is a professional membership body incorporated by Royal Charter 2003
Registered charity number 1097899

The Energy Institute (EI) is the chartered professional membership body for the energy industry, supporting over 20 000 individuals working in or studying energy and 200 energy companies worldwide. The EI provides learning and networking opportunities to support professional development, as well as professional recognition and technical and scientific knowledge resources on energy in all its forms and applications.

The EI's purpose is to develop and disseminate knowledge, skills and good practice towards a safe, secure and sustainable energy system. In fulfilling this mission, the EI addresses the depth and breadth of the energy sector, from fuels and fuels distribution to health and safety, sustainability and the environment. It also informs policy by providing a platform for debate and scientifically-sound information on energy issues.

The EI is licensed by:
– the Engineering Council to award Chartered, Incorporated and Engineering Technician status, and
– the Society for the Environment to award Chartered Environmentalist status.

It also offers its own Chartered Energy Engineer, Chartered Petroleum Engineer, and Chartered Energy Manager titles.

A registered charity, the EI serves society with independence, professionalism and a wealth of expertise in all energy matters.

This publication has been produced as a result of work carried out within the Technical Team of the EI, funded by the EI's Technical Partners. The EI's Technical Work Programme provides industry with cost-effective, value-adding knowledge on key current and future issues affecting those operating in the energy sector, both in the UK and internationally.

For further information, please visit **http://www.energyinst.org**

The EI gratefully acknowledges the financial contributions towards the scientific and technical programme from the following companies:

BP Exploration Operating Co Ltd
BP Oil UK Ltd
Centrica
Chevron North Sea Ltd
Chevron Products Company
Chrysaor
CLH
ConocoPhillips Ltd
DCC Energy
EDF Energy
ENI
E. ON UK
Equinor
ExxonMobil International Ltd
Innogy
Kuwait Petroleum International Ltd
Nexen CNOOC
Ørsted
Perenco
Phillips 66
Qatar Petroleum
Repsol Sinopec
RWE npower
Saudi Aramco
Scottish Power
SGS
Shell UK Oil Products Limited
Shell U.K. Exploration and Production Ltd
SSE
TAQA Bratani
Total E&P UK Limited
Total UK Limited
Tullow Oil
Uniper
Valero
Vattenfall
Vitol Energy
Woodside
World Fuel Services

However, it should be noted that the above organisations have not all been directly involved in the development of this publication, nor do they necessarily endorse its content.

ISBN 978 1 78725 110 6

Published by the Energy Institute

Hard copy and electronic access to EI and IP publications is available via our website, **https://publishing.energyinst.org**.
Documents can be purchased online as downloadable pdfs or on an annual subscription for single users and companies.
For more information, contact the EI Publications Team.
e: **pubs@energyinst.org**

CONTENTS

Page

Contents continued

LIST OF FIGURES AND TABLES

Page

Figures

Tables

FOREWORD

These guidelines are intended to assist plant engineers to determine the risk of fatigue failure of their pressure vessels and to assess the remaining fatigue life and/or plan targeted cost-efficient inspections or other measures for vessels most at risk. This publication has been prepared to address the fact that there are many pressure vessels that were designed to now outdated codes that are still in use after many years of operation and whose remaining fatigue life is unknown.

The guidelines are written with vessels on offshore oil and gas installations in mind but are expected to be of wider application as many similar vessels remain in service at on-shore installations, chemicals plants and in other industrial sectors. Whilst the publication is written in the context of the United Kingdom (UK) legislative and regulatory framework and references British Standards, the principles can similarly be applied in other countries provided national and local statutory requirements are met, and to vessels constructed to other codes and standards. The contents are not mandatory but represent good practice.

The publication reviews the factors that are known to increase the risk of fatigue failure to enable operators to screen their vessels for those most at risk. It provides advice on the assessment of remaining fatigue life using modern analysis methods and suggests ways in which further service beyond a calculated fatigue usage of unity may be justified and the fatigue life of welds improved. Annexes describe a process that can be used to screen vessels with a worked example and summarise two studies that offshore operating companies have made to assess the risk of fatigue failure of their ageing pressure vessels.

Although it is anticipated that following this publication will assist those involved in establishing the risk of fatigue failure of their pressure vessels and assessing the remaining fatigue life, the information contained in this publication is provided as guidance only. While every reasonable care has been taken to ensure the accuracy of its contents, the EI, and the technical representatives listed in the acknowledgements, cannot accept any responsibility for any action taken, or not taken, on the basis of this information. The EI shall not be liable to any person for any loss or damage which may arise from the use of any of the information contained in any of its publications.

The above disclaimer is not intended to restrict or exclude liability for death or personal injury caused by own negligence.

Suggested revisions are invited and should be submitted to the Technical Department, Energy Institute, 61 New Cavendish Street, London, W1G 7AR.

ACKNOWLEDGEMENTS

The Energy Institute (EI) wishes to record its appreciation of the work carried out by the following individuals over the project duration.

ALECOM members:

Richard McKeown	Chevron
Don Smith	ENI (Initial Chair)
Alistair Hardy	Shell
Steve Temple	Total (Closing Chair)
Ramsay Fraser	BP
Hugh Borland	BP
Jim Saunderson	Apache
Stuart Gosling	CNOOC International (Deputy Chair)
Konstantinos Vatopoulos	Aramco Overseas
Kingsley Anunobi	ConocoPhillips
Fraser Selfridge	Taqa
Martin Mundy	Spirit Energy
Fergus Stewart	Repsol-Sinopec
Innes Lawtie	Statoil

Also, thanks to observer members of ALECOM:

Sam Blackburn	Marathon
Alex Stacey	HSE
Paul Tallett	Atkins Energy
Mohammad Nabavian	Wood

Technical drafting and editing: John Wintle, TWI Ltd.

John Wintle would like to acknowledge the support of ALECOM Members and Observers for their support and valuable comments during the production of this work. He would also like to acknowledge Emilie Buennagel and Carol Johnson and their colleagues in the Fatigue Management Group of TWI for their review and input on the draft text.

This first edition guidance was coordinated and managed by Dr Cameron Stewart, Energy Institute, Upstream Technical Manager.

1 INTRODUCTION

1.1 BACKGROUND

Understanding the risk of failure from fatigue of ageing pressure vessels is important in the context of assuring ongoing containment of hazardous fluids and stored energy. Most operators rely on costly repeated in-service inspections to gain the necessary assurance for their pressure vessels as they do not know how much of the fatigue life has been used. These guidelines are to enable plant engineers to determine the risk of fatigue failure of their pressure vessels and to assess the remaining fatigue life and/or plan targeted cost-efficient inspections or other measures for vessels most at risk.

In many situations it is difficult for operators to know how much fatigue life remains; vessels could have exceeded their design life, or the original fatigue design analysis may no longer be valid or be available, if it was ever undertaken. Until the 1990s pressure vessels were designed to codes and standards where methods were outdated compared to modern approaches, especially for welds which are particularly susceptible to fatigue. Sometimes vessels have been operated in a way that was different from that assumed for design.

While pressure vessels are usually inspected during service, fatigue cracking is often difficult to detect because of the tightness of the cracks. In practice, the availability and access of vessels and the extent of coverage for a good and thorough inspection can be quite restricted. In contrast to fatigue design of nodal joints of offshore structures, where a fatigue life reduction factor is used to compensate for limitations in inspection, no such factor is applied to the design of vessels. In these circumstances, operators are recommended to undertake an in-service assessment of the risk of failure from fatigue and remaining fatigue life and determine any additional steps necessary for continued service.

The UK Health and Safety Executive's Final Report on Key Programme 4 (HSE, 2014) assessed the ageing and life extension challenges facing hydrocarbon exploration and production installations on the UK continental shelf. It recommended that '*Duty Holders should consider potential pressure and thermal fatigue risks to pressure vessels where these would be of high consequence*'. Hence the guidelines will be useful to operators of vessels on offshore oil and gas installations where many ageing pressure vessels remain in service. As many similar vessels remain in service at on-shore installations, chemical plants and in other industrial sectors, the guidelines are expected to be of wider application.

1.2 SCOPE OF THE GUIDELINES

The guidelines are organised into two main sections plus Annexes. Section 2 reviews the factors that are known to increase the risk of fatigue failure to enable operators to screen their vessels for those most at risk. Section 3 provides advice on the assessment of remaining fatigue life using modern analysis methods and suggests ways in which further service beyond a calculated fatigue usage of unity may be justified and the fatigue life of welds improved.

Annex A describes a process that can be used for screening vessels according to their risk of fatigue failure, while Annex B gives a worked example of how this process can be used.