El Research report

Issues associated with aging combined cycle gas turbine (CCGT) assets



RESEARCH REPORT: ISSUES ASSOCIATED WITH AGING COMBINED CYCLE GAS TURBINE (CCGT) ASSETS

First edition

October 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 El'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 El 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 El, funded by the El's Technical Partners. The El'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

Qatar Petroleum

Repsol Sinopec

RWE npower

Saudi Aramco

Scottish Power

Chrysaor SGS

CLH Shell UK Oil Products Limited

ConocoPhillips Ltd Shell U.K. Exploration and Production Ltd

DCC Energy SSE

EDF Energy
TAQA Bratani
ENI
Total E&P UK Limited
E. ON UK
Total UK Limited
Equinor
Tullow Oil
ExxonMobil International Ltd
Uniper
Innogy
Valero
Kuwait Petroleum International Ltd
Vattenfall

Nexen CNOOC

Ørsted

Perenco

Vittol Energy

Woodside

World Fuel Services

Phillips 66

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.

Copyright © 2019 by the Energy Institute, London.

The Energy Institute is a professional membership body incorporated by Royal Charter 2003.

Registered charity number 1097899, England

All rights reserved

No part of this book may be reproduced by any means, or transmitted or translated into a machine language without the written permission of the publisher.

ISBN 978 1 78725 127 4

Published by the Energy Institute

The information contained in this publication is provided for general information purposes only. Whilst the Energy Institute and the contributors have applied reasonable care in developing this publication, no representations or warranties, express or implied, are made by the Energy Institute or any of the contributors concerning the applicability, suitability, accuracy or completeness of the information contained herein and the Energy Institute and the contributors accept no responsibility whatsoever for the use of this information. Neither the Energy Institute nor any of the contributors shall be liable in any way for any liability, loss, cost or damage incurred as a result of the receipt or use of the information contained herein.

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

Foreword 6 Acknowledgements 7 1 Introduction 8 1.1 What is age? 8 2 Scope 10 3 Approach 11 3.1 Process safety considerations 12 4 General considerations and assumptions 14 4.1 The aged ccgt 14 4.2 Running regime – flexible operation 14 4.3 Corporate risk management 15 4.4 Records 16 4.5 Staff skills 16 4.6 Processes 17 4.7 Monitoring 18 4.8 Revision of inspection practices for aged plant 18 4.9 Spares 19 4.10 Off-line management 20 4.11 Recommissioning 20 4.12 Gas turbine specific issues 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 6.1 Gas turbine plant 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 <th></th> <th></th> <th>Pag</th> <th>e</th>			Pag	e
Introduction 8 1.1 What is age? 8 2 Scope 10 3 Approach 11 3.1 Process safety considerations 12 4 General considerations and assumptions 14 4.1 The aged ccgt 14 4.2 Running regime – flexible operation 14 4.3 Corporate risk management 15 4.4 Records 16 4.5 Staff skills 16 4.6 Processes 17 4.7 Monitoring 18 4.8 Revision of inspection practices for aged plant 18 4.9 Spares 19 4.10 Off-line management 20 4.11 Recommissioning 20 4.12 Gas turbine specific issues 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1 Gas turbine plant 26 6.1.2 Compressor 27 6.1.3 Filter house 26 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1	Forev	vord .		6
1.1 What is age? 8 2 Scope	Ackn	owled	gements	7
1.1 What is age? 8 2 Scope	1	Intro	duction	8
3 Approach 11 3.1 Process safety considerations 12 4 General considerations and assumptions 14 4.1 The aged ccgt 14 4.2 Running regime – flexible operation 14 4.3 Corporate risk management 15 4.4 Records 16 4.5 Staff skills 16 4.6 Processes 17 4.7 Monitoring 18 4.8 Revision of inspection practices for aged plant 18 4.9 Spares 19 4.10 Off-line management 20 4.11 Recommissioning 20 4.12 Gas turbine specific issues 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1 Gas turbine plant 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.2.1 Tubes 34 6.2.2 Headers 35 <				
3.1 Process safety considerations 12 4 General considerations and assumptions. 14 4.1 The aged ccgt 14 4.2 Running regime – flexible operation 14 4.3 Corporate risk management 15 4.4 Records 16 4.5 Staff skills 16 4.6 Processes 17 4.7 Monitoring 18 4.8 Revision of inspection practices for aged plant 18 4.9 Spares 19 4.10 Off-line management 20 4.11 Recommissioning 20 4.12 Gas turbine specific issues 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1 Gas turbine plant 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 <td>2</td> <td>Scope</td> <td>e1</td> <td>0</td>	2	Scope	e1	0
3.1 Process safety considerations 12 4 General considerations and assumptions. 14 4.1 The aged ccgt 14 4.2 Running regime – flexible operation 14 4.3 Corporate risk management 15 4.4 Records 16 4.5 Staff skills 16 4.6 Processes 17 4.7 Monitoring 18 4.8 Revision of inspection practices for aged plant 18 4.9 Spares 19 4.10 Off-line management 20 4.11 Recommissioning 20 4.12 Gas turbine specific issues 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1 Gas turbine plant 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 <td>3</td> <td>Appr</td> <td>oach</td> <td>1</td>	3	Appr	oach	1
4.1 The aged ccgt 14 4.2 Running regime – flexible operation 14 4.3 Corporate risk management 15 4.4 Records 16 4.5 Staff skills 16 4.6 Processes 17 4.7 Monitoring 18 4.8 Revision of inspection practices for aged plant 18 4.9 Spares 19 4.10 Off-line management 20 4.11 Recommissioning 20 4.12 Gas turbine specific issues 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 33 6.2 S				
4.1 The aged ccgt 14 4.2 Running regime – flexible operation 14 4.3 Corporate risk management 15 4.4 Records 16 4.5 Staff skills 16 4.6 Processes 17 4.7 Monitoring 18 4.8 Revision of inspection practices for aged plant 18 4.9 Spares 19 4.10 Off-line management 20 4.11 Recommissioning 20 4.12 Gas turbine specific issues 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 33 6.2 S	4	Gene	ral considerations and assumptions1	4
4.2 Running regime – flexible operation 14 4.3 Corporate risk management 15 4.4 Records 16 4.5 Staff skills 16 4.6 Processes 17 4.7 Monitoring 18 4.8 Revision of inspection practices for aged plant 18 4.9 Spares 19 4.10 Off-line management 20 4.11 Recommissioning 20 4.12 Gas turbine specific issues 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1				
4.3 Corporate risk management 15 4.4 Records 16 4.5 Staff skills 16 4.6 Processes 17 4.7 Monitoring 18 4.8 Revision of inspection practices for aged plant 18 4.9 Spares 19 4.10 Off-line management 20 4.11 Recommissioning 20 4.12 Gas turbine specific issues 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1 Gas turbine plant 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes <td></td> <td>4.2</td> <td></td> <td></td>		4.2		
4.4 Records 16 4.5 Staff skills 16 4.6 Processes 17 4.7 Monitoring 18 4.8 Revision of inspection practices for aged plant 18 4.9 Spares 19 4.10 Off-line management 20 4.11 Recommissioning 20 4.12 Gas turbine specific issues 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1 Gas turbine plant 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 </td <td></td> <td>4.3</td> <td></td> <td></td>		4.3		
4.5 Staff skills 16 4.6 Processes. 17 4.7 Monitoring 18 4.8 Revision of inspection practices for aged plant. 18 4.9 Spares. 19 4.10 Off-line management 20 4.11 Recommissioning. 20 4.12 Gas turbine specific issues 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1 Gas turbine plant 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vesse		4.4		
4.6 Processes. 17 4.7 Monitoring 18 4.8 Revision of inspection practices for aged plant. 18 4.9 Spares. 19 4.10 Off-line management 20 4.11 Recommissioning. 20 4.12 Gas turbine specific issues. 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1 Gas turbine plant 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipewor				
4.7 Monitoring 18 4.8 Revision of inspection practices for aged plant 18 4.9 Spares 19 4.10 Off-line management 20 4.11 Recommissioning 20 4.12 Gas turbine specific issues 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1 Gas turbine plant 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass syst		4.6		
4.8 Revision of inspection practices for aged plant 18 4.9 Spares 19 4.10 Off-line management 20 4.11 Recommissioning 20 4.12 Gas turbine specific issues 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1 Gas turbine plant 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam				
4.9 Spares 19 4.10 Off-line management 20 4.11 Recommissioning. 20 4.12 Gas turbine specific issues 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1 Gas turbine plant 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45				
4.10 Off-line management 20 4.11 Recommissioning. 20 4.12 Gas turbine specific issues 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1 Gas turbine plant 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46				
4.11 Recommissioning. 20 4.12 Gas turbine specific issues. 21 4.13 Pressure systems and HRSG issues. 22 5 Risk overview. 24 6 Risk summaries by system. 26 6.1 Gas turbine plant. 26 6.1.1 Filter house. 26 6.1.2 Compressor. 27 6.1.3 Combustor. 28 6.1.4 Turbine. 30 6.1.5 Rotor. 31 6.1.6 Gas turbine exhaust casing. 32 6.1.7 Transition ducting and HRSG casing. 33 6.2 Steam and water plant. 34 6.2.1 Tubes. 34 6.2.2 Headers. 35 6.2.3 Drums and other vessels. 37 6.2.4 Pipework. 38 6.2.5 Bypass system. 43 6.2.6 Steam turbine. 44 6.2.7 Condenser. 45 6.2.8 Valves. 46				
4.12 Gas turbine specific issues 21 4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1 Gas turbine plant 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46				
4.13 Pressure systems and HRSG issues 22 5 Risk overview 24 6 Risk summaries by system 26 6.1 Gas turbine plant 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 32 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46			<u> </u>	
6 Risk summaries by system. 26 6.1 Gas turbine plant. 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor. 28 6.1.4 Turbine. 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing. 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46			'	
6 Risk summaries by system. 26 6.1 Gas turbine plant. 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor. 28 6.1.4 Turbine. 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing. 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46	5	Risk	overview 2.	4
6.1 Gas turbine plant. 26 6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46	_			
6.1.1 Filter house 26 6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46	6			
6.1.2 Compressor 27 6.1.3 Combustor 28 6.1.4 Turbine 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46		6.1		
6.1.3 Combustor. 28 6.1.4 Turbine. 30 6.1.5 Rotor. 31 6.1.6 Gas turbine exhaust casing. 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46				
6.1.4 Turbine. 30 6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing. 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46				
6.1.5 Rotor 31 6.1.6 Gas turbine exhaust casing 32 6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46				
6.1.6 Gas turbine exhaust casing. 32 6.1.7 Transition ducting and HRSG casing. 33 6.2 Steam and water plant. 34 6.2.1 Tubes. 34 6.2.2 Headers. 35 6.2.3 Drums and other vessels. 37 6.2.4 Pipework. 38 6.2.5 Bypass system. 43 6.2.6 Steam turbine. 44 6.2.7 Condenser. 45 6.2.8 Valves. 46				
6.1.7 Transition ducting and HRSG casing 33 6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46				
6.2 Steam and water plant 34 6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46				
6.2.1 Tubes 34 6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46				
6.2.2 Headers 35 6.2.3 Drums and other vessels 37 6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46		6.2	!	
6.2.3 Drums and other vessels. 37 6.2.4 Pipework. 38 6.2.5 Bypass system. 43 6.2.6 Steam turbine. 44 6.2.7 Condenser. 45 6.2.8 Valves. 46				
6.2.4 Pipework 38 6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46				
6.2.5 Bypass system 43 6.2.6 Steam turbine 44 6.2.7 Condenser 45 6.2.8 Valves 46				
6.2.6 Steam turbine				
6.2.7 Condenser .45 6.2.8 Valves .46			71 7	
6.2.8 Valves				
6.3 Electrical equipment				
		6.3	Electrical equipment	7

Contents continued **Page** 6.3.1 6.3.2 6.3.3 6.3.4 6.3.5 6.4 6.4.1 6.4.2 7 7.1 7.2 7.3 7.4 **Annexes** References......93 Annex A A.1 A.2 Bibliography.......95 Abbreviations and acronyms......96 Annex B

LIST OF FIGURES AND TABLES

Figures		Page
Figure 1 Figure 2	CCGT plant overview	
Figure 3 Figure 4	Adapted risk assessment matrix	13
Tables		
Table 1	Filter house	63
Table 2	Compressor	64
Table 3	Combustor	67
Table 4	Turbine	68
Table 5	Rotor	69
Table 6	Exhaust casing	70
Table 7	Transition ducting and HRSG casing	
Table 8	Tubes	72
Table 9	Headers	73
Table 10	Drums and other vessels	74
Table 11	Pipework	75
Table 12	Steam turbine	
Table 13	Condenser	81
Table 14	Valves	
Table 15	Generators	83
Table 16	Transformers	84
Table 17	Cables	86
Table 18	Switchgear	
Table 19	Motors	
Table 20	Oil systems	
Table 21	Control and instrumentation	
Table 22	Gas supply infrastructure	92

FOREWORD

With the first combined cycle gas turbine (CCGT) power plants being commissioned in the 1990s, and with an expected life of approximately 20 years (not including the possibility of life extension), it is clear that a large number of plants will be (or are being) managed in an 'aged state' until a decision is made to decommission them.

This research report was commissioned to explore the risks that aging CCGT plant components impose on people, environment and the wider plant.

This research report has drawn on many existing sources from the public domain, together with input from practitioners from the power utility industry and good practices from other high reliability industries.

Based on this research, the report identifies:

- example failures to plant that can arise through the wear and tear of aging;
- the expected severity of such as failure, and its likelihood, and
- guidance for additional preventative measures to prevent or mitigate such failures.

It covers the gas turbine (e.g. filter house, compressor, turbine, etc.), steam and water plant (e.g. tube banks, steam turbine, condenser, etc.), electrical equipment (e.g. generator, cables, switchgear, etc.) and auxiliary systems (e.g. the oil systems, control and instrumentation (C&I) and civil structures).

The information contained in this publication is provided for general information purposes only. Whilst the EI and the contributors have applied reasonable care in developing this publication, no representations or warranties, expressed or implied, are made by the EI or any of the contributors concerning the applicability, suitability, accuracy or completeness of the information contained herein and the EI and the contributors accept no responsibility whatsoever for the use of this information. Neither the EI nor any of the contributors shall be liable in any way for any liability, loss, cost or damage incurred as a result of the receipt or use of the information contained herein.

The EI welcomes feedback on its publications. Feedback or suggested revisions should be submitted to:

Technical Department
Energy Institute
61 New Cavendish Street
London, W1G 7AR
e: technical@energyinst.org

ACKNOWLEDGEMENTS

This research report was developed by Alex Simmonds, Bob Dean, Duncan Humphrey, and Mike Wood (RINA), at the request of the El Power Utility Committee (PUC). During this work, committee members included:

Steve Gilmore (Chair) Uniper Edward Jamieson RWE

Stuart King (Secretary) Energy institute

Ian KinnairdDraxToby LantCentricaDaniel RawdinSSEDoug SmartEDF Energy

Doug Smart EDF Energy
Konstantinos Vatopoulos Aramco Overseas

Management of the project and technical editing were carried out by Stuart King (EI).

The EI would also like to acknowledge the following individuals who took part in interviews and/or commented on the research report:

Phil Basildon RWE Steve Calladine, SSE Ronnie Glen SSE

Stephen Harkins Scottish Power

David Holder SSE
Philip Lang Engie
John Leask SSE
Peter Wilkinson Centrica

Names and affiliations are correct at the time of contribution.

1 INTRODUCTION

Combined cycle gas turbine (CCGT) electrical generation plant constitutes a significant contribution to the world energy mix – roughly 30 % or more in some countries – with the first CCGT plants commissioned in the early 1990s. The Energy Institute (EI) has produced guidance on preservation and commission of CCGT plant (see *Guidance on the preservation and recommissioning of existing combined cycle gas turbine (CCGT) plant* and *Guidance on the commissioning of new combined cycle gas turbine (CCGT) plant* respectively). However, CCGT plants have an expected life of approximately 20 years (not including the possibility of life extension). Therefore a large number of plants will increasingly be managed in an 'aged state' until a decision is made to decommission them. Whilst there is extensive experience in managing aging assets in other sectors (such as coal, offshore oil and gas and onshore refining plant), managing aged CCGT is a relatively new experience.

Older plants are often forced to run in ways which were not anticipated when they were designed; this has an impact on the risk profile of these plants. For example, market forces and renewables push older plant to lower tier due to competition from these sources (e.g. due to the efficiency of new plant) – this may affect how operators invest in maintaining or renewing older plants. Regarding aging CCGT plant, there are several areas for clarification, such as:

- identifying emerging technical issues;
- assessing the associated risk for people, plant and environment, and
- identifying what guidance will be needed in the near future to enable operators to manage the risk to as low as reasonably practicable (ALARP).

This high-level report has been written to provide CCGT plant managers with guidance in consideration of the above issues.

This report cannot cover all of the hazards associated with an aging CCGT plant and should be applied with care, common sense and engineering judgement.

1.1 WHAT IS AGE?

As discussed in Health and Safety Executive (HSE) RR 509, 'Ageing is not about how old your equipment is; it's about what you know about its condition, and how that's changing over time'. There are four main factors which influence how the condition of a CCGT plant may change over time:

- time (since commissioning);
- number of running hours;
- number of starts (and the associated ramp rates) and trips, and
- number of hours spent offline (e.g. mothballed plant).

Each of these factors brings with it different modes of plant degradation, which may (or may not) be more likely to occur depending on the operating regime of the plant (for example corrosion of storage tanks, creep of high temperature pipework and fatigue of small bore connections, to highlight just three issues).

The mode of operation (historical and future) of the plant is therefore significant in understanding many aspects of its age in terms of technical issues.

Once the age of the plant is understood, the resulting hazards can be better managed. There are a number of techniques which can be employed, from adapting maintenance, monitoring and inspection routines to performing detailed design and fitness-for-service analysis to develop a safety case for continued service, repair or rerating, for example.

2 SCOPE

The scope of this report covers CCGT plant as represented in Figure 1. It is recognised that this encompasses a large number of components, numerous configurations and a variety of manufacturers. Moreover, many components in a CCGT plant are not unique, but are well understood from the wider industry, for example electrical equipment, civil structures and ancillary systems.

Therefore, this report provides detailed discussion focused on the gas turbine and heat recovery steam generator (HRSG) systems, and more general information on the items of equipment not specific to CCGT plants, referring to other documents where possible.

This report does not cover components such as bypass stacks and dampers, and desalination plants.

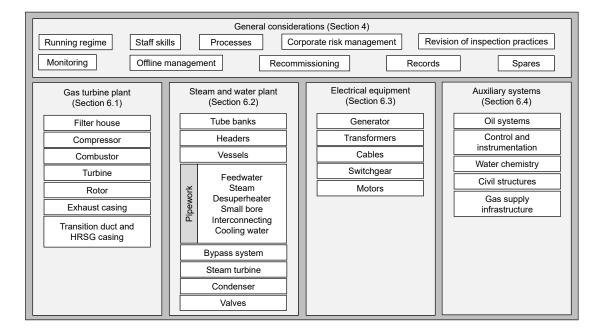


Figure 1: CCGT plant overview