

El Research report

Investigation into the ignition risks due to the ageing effects of Ex electrical equipment

EI RESEARCH REPORT

INVESTIGATION INTO THE IGNITION RISKS DUE TO THE AGEING
EFFECTS OF EX ELECTRICAL EQUIPMENT

May 2020

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 250 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	Qatar Petroleum
BP Oil UK Ltd	Repsol Sinopec
Centrica	RWE npower
Chevron North Sea Ltd	Saudi Aramco
Chevron Products Company	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	Vitol Energy
Ørsted	Woodside
Phillips 66	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.

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 134 2

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

	Page
Foreword	7
Acknowledgements	9
Executive summary	10
1 Introduction objectives and scope	12
2 Methodology	14
2.1 Questionnaire	14
2.2 Site assessments	15
2.3 Laboratory assessment and testing	15
2.4 Review of standards and their requirements related to ageing	16
2.5 Commentary on standards review	18
3 Survey	19
3.1 Questionnaire responses	19
3.2 Questionnaire analysis	19
3.6 Questionnaire analysis results	20
4 On-site assessments	21
4.1 Site one – coastal refinery	22
4.2 Site two – inland gas plant	37
4.3 Site three – coastal terminal	52
4.4 Site four – coastal terminal	63
4.5 Site five – coastal terminal	74
4.6 Site six – coastal terminal	85
4.7 Analysis of site surveys	101
5 Sample selection and testing	104
5.1 Typical test standards	104
5.1.1 Test criteria overview	105
5.2 Tests results	106
5.3 Summary of tests and assessments	117
5.4 Correlation of survey, site assessments and test/visual assessments	118
6 Conclusions and observation	121
Annexes	
Annex A Questionnaire guidance and response base data	124
Annex B Flame transmission test data sheets	142
Annex C References	152
Annex D Abbreviations	153

LIST OF FIGURES AND TABLES

	Page
Tables	
Table 1	Summary of included protection concepts 13
Table 2	Laboratory tests and related protection concept 16
Table 3	Summary of materials ageing requirements in standards 18
Table 4	Number of items of equipment visually inspected by age. 102
Table 5	Percentage of inspected items of equipment that could require further investigation 102
Table 6	Degradation identified from questionnaire relating to equipment examined on site . . 103
Table 7	Products selected for test 104
Table 8	Tests for resistance to impact. 106
Table 9	Equipment issues identified by questionnaire survey 117
Table 10	Results of questionnaire survey and laboratory testing 119
Figures	
Figure 1	Flameproof switch. 22
Figure 2	Motors (two) and winch 23
Figure 3	Junction box flame-path 24
Figure 4	Junction box flame-path 24
Figure 5	Flameproof enclosure 24
Figure 6	Luminaire and control box. 25
Figure 7	Klaxon sounder 26
Figure 8	Bulkhead light fitting. 27
Figure 9	Distribution board 28
Figure 10	Flameproof enclosure 29
Figure 11	Junction box 30
Figure 12	Fire alarm bell 31
Figure 13	Lighting distribution board 32
Figure 14	Lighting distribution board 32
Figure 15	Pump motor 33
Figure 16	Small motor 34
Figure 17	Junction box 35
Figure 18	Fluorescent light fitting 36
Figure 19	Valve position switch. 37
Figure 20	Plastic enclosure 38
Figure 21	I/P positioner 39
Figure 22	Switch. 40
Figure 23	Pressure gauge 41
Figure 24	Terminal box 42
Figure 25	Solenoid valve. 43
Figure 26	Distribution panel 44
Figure 27	Pump motor 45
Figure 28	Distribution panel 46
Figure 29	Motor 47
Figure 30	Switch. 48
Figure 31	Junction box 49
Figure 32	Terminal housing. 50
Figure 33	Limit switch. 51
Figure 34	Distribution panel 52

List of figures and tables continued

	Page
Figure 35 Control and display units	53
Figure 36 Control station	54
Figure 37 Control station	55
Figure 38 Control station	55
Figure 39 Distribution panel	56
Figure 40 Motor	57
Figure 41 Enclosure	58
Figure 42 Switch	59
Figure 43 Motor	60
Figure 44 Motor	61
Figure 45 Heater	62
Figure 46 Motor control panel	63
Figure 47 Motor control panel	64
Figure 48 Motor	65
Figure 49 Motor	66
Figure 50 Distribution panel	67
Figure 51 Distribution panel	68
Figure 52 Distribution panel	69
Figure 53 Fire pump control panel	70
Figure 54 Distribution panel	71
Figure 55 Switch	72
Figure 56 Luminaire	73
Figure 57 Motor	74
Figure 58 Control station	75
Figure 59 Junction box	76
Figure 60 Tank level transmitter	77
Figure 61 Control switch	78
Figure 62 Control switch	79
Figure 63 Solenoid valve	80
Figure 64 Switchboard	81
Figure 65 Junction boxes	82
Figure 66 Junction box	83
Figure 67 Switches	84
Figure 68 Junction box	85
Figure 69 Junction boxes	86
Figure 70 Motor	86
Figure 71 Control switch	87
Figure 72 Junction box	88
Figure 73 Control switches	89
Figure 74 Junction boxes	90
Figure 75 Junction boxes	90
Figure 76 Junction box	91
Figure 77 Temperature controller	92
Figure 78 Junction boxes	93
Figure 79 Junction boxes	93
Figure 80 Switch/ammeter unit	94
Figure 81 Transformer	95
Figure 82 Distribution panel	96
Figure 83 Transformer	97

List of figures and tables continued

	Page
Figure 84 Valve actuator/terminal enclosure	98
Figure 85 Valve actuator/terminal enclosure	98
Figure 86 Wellglass indicator	99
Figure 87 Switch.	100
Figure 88 Motor	101

FOREWORD

The presence of ageing explosion-protected (Ex) electrical equipment in hazardous areas related to potentially explosive atmospheres, onshore and offshore, causes serious concern for those responsible for its operation and maintenance. It is essential that operations continue without planned interruption, but when equipment is 30, 40, or more years old, for how long can it be expected to operate effectively and safely? Its integrity will end sometime. The danger to life, adverse environmental effects and loss of production resulting from equipment failure and ignition can result in swingeing penalties.

In order to create some practical guidance for plant operators, the Electrical Committee of the Energy Institute (EI) commissioned Intertek Testing and Certification Ltd. to carry out an investigation and report on ageing Ex electrical equipment.

The work detailed in this report was carried out in three sections: site-based questionnaire to EI member companies; site surveys by an Intertek engineer, and laboratory testing of selected/available equipment. Whilst it was not possible to carry out internal examination of equipment in operation, external examination of a range of equipment was undertaken and is documented in the report. Some member companies supplied samples of equipment, withdrawn from service, for detailed laboratory examination and testing.

The conclusion in the report states that '*.... there does not seem to be much evidence that ageing of hazardous area electrical equipment introduces an inherent additional ignition hazard risk*'. However, this is tempered by the statement '*it must be recognised that the scope of this work could not examine all types of equipment and caution must be exercised in applying these conclusions outside of the range of equipment types tested*'.

Whilst sample numbers of each type of equipment were small and the range of equipment types was limited, significant common detrimental effects were identified, confirming the experience of engineers in the field. The report illustrates and highlights four main modes of degradation that lead to eventual failure of Ex electrical equipment to meet certification requirements and possible catastrophic failure:

- corrosion;
- water ingress and inadequate gaskets/seals protection;
- degradation of plastics (e.g. glass reinforced plastic (GRP)) enclosures and components, due to ultraviolet (UV) or other environmental factors, and
- absence of adequate labelling/ID of equipment to confirm its type of Ex protection related to its location.

A major negative factor in determining the ongoing integrity of ageing Ex electrical equipment is the inability to identify the certified Ex characteristics of equipment because of the degradation or absence of the original labelling showing the necessary characteristics. Evidence shows that generally only data that are substantially embossed or engraved on equipment, or securely attached labels that survive into decades of use. Some EI member companies have overcome this problem by securing well engraved and securely attached site ID tags to equipment and maintaining site records of the related data for the equipment.

The report does not give recommendations as to the frequency of inspections for ageing Ex equipment, but acknowledges that the frequency and degree of inspection will depend on a number of factors, including the age of the equipment and severity of environmental conditions. It is logical that as equipment ages into decades, it should be inspected with increasing frequency. Whereas early in its life, for example, equipment may be closely inspected every three years, it will reach an age or condition when it should be inspected more frequently. Some member companies have reported that they carry out annual inspections, with vulnerable equipment receiving detailed inspection. Clearly the legal responsibility for maintenance lies with the relevant Duty Holder and it would be prudent to afford an appropriate degree of attention to the possible outcome of not providing adequate surveillance of ageing Ex electrical equipment.

Testing of enclosures which visibly appeared to be degraded for impact resistance and water ingress did not show that the integrity of the enclosures had been affected. Greater clarification is necessary to help personnel inspecting this type of equipment make correct judgement as to condition and suitability for continued use. Further research is therefore justified to establish what level of degradation is unacceptable before a plastic enclosure can no longer reliably fulfil its protective function. Such research could offer some guidance as to the appropriate frequency of inspection as equipment ages.

ACKNOWLEDGEMENTS

This research report was commissioned by the EI's Electrical Committee. The following members contributed to the research and were committee members at the time of publication. The research work was undertaken by Intertek Consulting on behalf of the EI.

Dibyendu Bhattacharya	BP Limited
Ian Edwards	Shell U.K Limited
Peter Evans	Health and Safety Executive
Martin Fleetwood	British Pipeline Association
Geoff Fulcher	F.E.S (EX)
Neville Harris	Valero Energy Limited
Gary Holcroft	Health and Safety Executive
Martin Manchester	Total Lindsey Oil Refinery
Robert Marshall	Health and Safety Executive
Justin Mason	BP Limited
Zaur Sadikhov	Shell International Limited
Steve Wilkinson	Phillips 66 Limited
Rajesh Sidharthan	Woodside Energy Limited
Graeme Wilson	Chrysaor
Agshin Yusifzada	Shell U.K. Limited

The EI wishes to thank those who contributed to the research by completing questionnaires, those who provided Ex-electrical equipment for testing and those who catered for site visits to enable visual inspections to be conducted.

The work was coordinated by Toni Needham (EI), Technical Manager.

1 INTRODUCTION, OBJECTIVES AND SCOPE

The Electrical Committee of the EI wished to investigate the potential safety risk of electrical equipment designed for use in hazardous areas as this equipment ages. This work was carried out by Intertek Testing and Certification in two parts. Firstly, whether degraded electrical equipment represents a real source of ignition, and secondly to comment on the viability of inspections to provide reassurance as to the continued integrity of Ex equipment. This report (produced by Intertek Testing and Certification Ltd.) forms part of this investigation. Intertek Testing and Certification is a wholly owned part of Intertek PLC, is a Notified Body for ATEX Directive, a certification body and test laboratory within the IEC Ex scheme.

In order that the aims of this project can be achieved, it was decided to limit the work in the following manner. These limitations were discussed and agreed with the Electrical Committee and detailed as follows. The investigation looked at hazardous area electrical equipment installed in areas as defined in IEC/EN 60079-14 and in the presence of flammable gases and vapours. Hazardous areas caused by the presence of dusts were excluded from this work. The environments to be considered are the oil and gas industries both on- and offshore. It was considered that these represent harsh operating conditions and so should give worst-case results.

The range of equipment and protection concepts (defined in the IEC/EN 60079 series of standards) is large. The concepts are identified by the use of the most recent standard designations. It was decided to initially limit the investigation to the most commonly used protection concepts for the reasons identified here:

IEC/EN 60079-1 Flameproof enclosure 'd'

Included in the investigation, due to the large number of installed units with the potential for very old equipment, as the protection concept has been used for over 90 years with the first publication of BS229 in 1929, and equipment tested before this by independent bodies. The characteristics of flameproof equipment make it susceptible to corrosion, wear and poor maintenance. Corrosion and wear of moving parts can affect the ability of the flameproof joints to prevent flame transmission. In extreme cases, the strength of the enclosure could be affected.

IEC/EN 60079-2 Pressurised enclosure 'p'

Excluded from this investigation due to the relatively small number of installed units and failsafe nature of the primary protection.

IEC/EN 60079-5 Powder filling 'q'

Excluded from this investigation due to the relatively small number of installed units.

IEC/EN 60079-6 Oil immersion 'o'

Excluded from this investigation due to the relatively small number of installed units.

IEC/EN 60079-7 Increased safety 'e'

Included in the investigation due to the large number of installed units. This protection concept is considered particularly susceptible to ageing. In general, this protection concept depends on the effective sealing of the equipment to prevent the ingress of dust and water that could contaminate internal equipment. This ingress could lead to the electrical breakdown of equipment and introduce the potential for incendive sparking.

IEC/EN 60079-11 Intrinsic safety

Initially, it was intended to include intrinsically safe (IS) equipment in the investigation. However, in discussion with the committee, it was decided to include this equipment in the survey but exclude it from further investigation. This was based on the view that IS equipment tends to be replaced more frequently than other types of equipment, due to the changes in technology requiring equipment updating, the reliability of electronic components, and the redundancy built in to this type of equipment. Also, the likelihood of any ageing effects being identified in this investigation are small as the basis for certification may not be apparent without access to the certification reports and detailed drawings.

IEC/EN 60079-15 Type of protection n

Included in the investigation due to the large number of installed units. In addition, equipment for Division 2 equipment specified in Code of Practice CP1003 (the forerunner of Zone 2) is still be in use, and could date from at least 1967. This protection concept is considered particularly susceptible to ageing. In general, this protection concept depends on the effective sealing of the equipment to prevent the ingress of dust and water that could contaminate internal components. This ingress could lead to the electrical breakdown of equipment and introduce the potential for incendive sparking.

IEC/60079-18 Encapsulation

Excluded from this investigation due to the relatively small number of installed units.

Table 1 lists the protection concepts included in this project.

Table 1: Summary of included protection concepts

IEC/EN 60079-1 Flameproof enclosure	'd'
IEC/EN 60079-7 Increased safety	'e'
IEC/EN 60079-11 Intrinsic safety	'i'
IEC/EN 60079-15 Type of protection	'n'