Guidance for life extension of unbonded flexible pipe systems

GUIDANCE FOR LIFE EXTENSION OF UNBONDED FLEXIBLE PIPE SYSTEMS

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CONTENTS

LIST OF FIGURES AND TABLES

Page

Figures

Tables

FOREWORD

The intention of this publication is to provide guidance for life extension of unbonded flexible pipe in the offshore oil and gas industry, to facilitate good practice throughout the industry.

Unbonded flexible pipe represents a subset of the global pipeline and riser inventory, and is a specialised and relatively complex product when compared to traditional rigid (steel) pipe systems. Flexible pipe is an enabling technology in many cases for deepwater and floating production developments, though experience is less mature compared to the operational experience of rigid (steel) pipeline systems; commercialisation of flexible pipe systems in their current form initiated in the early 1970s.

Various integrity lessons have been learned through operational experience, and are shared in a number of industry standards and guidance documents, with flexible pipe industry guidance and good practice delivered through the Sureflex joint industry project (JIP) publication *Flexible pipe integrity management guidance and good practice* in 2017. This guidance builds on the JIP, and provides specific guidance relating to the life extension phase of flexible pipe system life cycle.

Although it is anticipated that following this publication will assist those involved in the life extension of unbonded flexible pipe, 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.

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1 INTRODUCTION

Unbonded flexible pipe represents a subset of the global pipeline and riser inventory, and is a specialised and relatively complex product when compared to traditional rigid (steel) pipe systems. Whilst flexible pipe is an enabling technology in many cases for floating production developments, industry experience is less mature (being commercialised in its current form in the early 1970s) compared to the operational experience of rigid (steel) pipeline systems.

As the technology has evolved to meet the industry challenges of higher temperature, higher pressure, larger diameter pipes, and deeper water developments, a number of failure mechanisms have been identified and managed by the industry. Lessons have been learned through this operational experience, and have been shared in a number of industry standards and guidance documents, with flexible pipe industry guidance and good practice delivered through the (publicly available) Sureflex JIP report *Flexible pipe integrity management guidance and good practice*. Key findings of the JIP are further summarised and shared in the Society of Petroleum Engineers (SPE) technical publication *The latest flexible pipe operational experience and integrity management guidance*. In addition, Annex A of this guidance provides a brief overview of the JIP contents.

This guidance builds on the Sureflex JIP, and provides specific guidance relating to the life extension phase of flexible pipe system life cycle. Whilst it is assumed that no handling or recovery of a pipe system shall be performed, the guidance may also be used to support re-use applications where applicable.

1.1 SCOPE

This guidance provides a structured approach to life extension. Whilst it is aligned with the routine risk and integrity management approach, which should be central to the life cycle operations, it takes on board the specific requirements of flexible pipe and its corresponding ancillary equipment.

The scope focuses on conventional flexible pipe products with metallic armour layers, but also takes into account the various ancillary components that form a flexible pipe system.

This guidance is not intended to provide an overview or introduction to flexible pipe technology, but rather assumes that individuals reading the report have a general knowledge of the design, manufacture, and operational aspects of flexible pipe, e.g.:

- API Specification 17J *Specification for unbonded flexible pipe*, and Recommended Practice 17B *Recommended practice for flexible pipe*, for flexible pipe.
- API Specification 17L1 *Specification for flexible pipe ancillary equipment*, and Recommended Practice 17L2 *Recommended practice for flexible pipe ancillary equipment*, for flexible pipe ancillary equipment.
- Sureflex JIP *Flexible pipe integrity management guidance and good practice*, detailing industry guidance and good practice relating to flexible pipe integrity management, including:
  - global industry experience of use, degradation, damage, and failure of flexible pipe;

- review of flexible pipe inspection and monitoring technology, and
- life cycle integrity management guidance, and operator experience.

Nonetheless, the guidance is intended to be standalone, with supporting references, to assist the life extension assessment of flexible pipe systems. The guidance is not intended to specify a minimum standard, as most flexible pipe systems have their unique challenges with specific integrity issues to be addressed. However, it does provide a framework for life extension, consistent with a risk-based approach to integrity management, which can be utilised to consider system-specific threats to life extension.

1.2 DETAILS OF FLEXIBLE PIPE SYSTEMS

Flexible pipe is an enabling technology for floating production systems in harsh dynamic environments. Industry experience shows that flexible pipe products are also utilised in more benign environments, where they may be deployed in static flowline applications over conventional rigid flowlines, due to installation considerations. The range of applications can be summarised as follows, based on information from *Flexible pipe integrity management guidance and good practice*:

- Over 17 500 supplied flexible pipe sections, with a cumulative supplied length of ~ 16 000 km:
  - risers (typically dynamic), account for ~30 % of supplied pipes (~20 % length);
  - flowlines (typically static), account for ~50 % of supplied pipes (~75 % length), and
  - jumpers (typically static), account for ~20 % of supplied pipes (~5 % length).
- Design water depths down to ~3 000 m, though with over 50 % of pipes with a depth rating of less than 500 m.
- Pipe diameters up to 20 inch interior diameter (ID), though over 90 % of pipes with an ID less than 10 inch.
- Product of design pressure times inner diameter (PxID) currently up to ~85 ksi-inch (~5 900 bar-inch), though over 80 % of supplied pipes with more benign pressure capacities below 35 ksi-inch (~2 400 bar-inch).

In addition, the oldest flexible pipes were supplied in the early 1970s, and were supplied in comparatively low numbers. Whilst the proportion of flexible pipes that were manufactured over 35 years ago is small, there is industry experience of some flexible pipes operating into late life with no significant issues.

The generic definitions applied to unbonded flexible pipe layers throughout this report are shown in Figure 1. These are aligned with the industry terminology used in API RP 17B *Recommended practice for flexible pipe*.

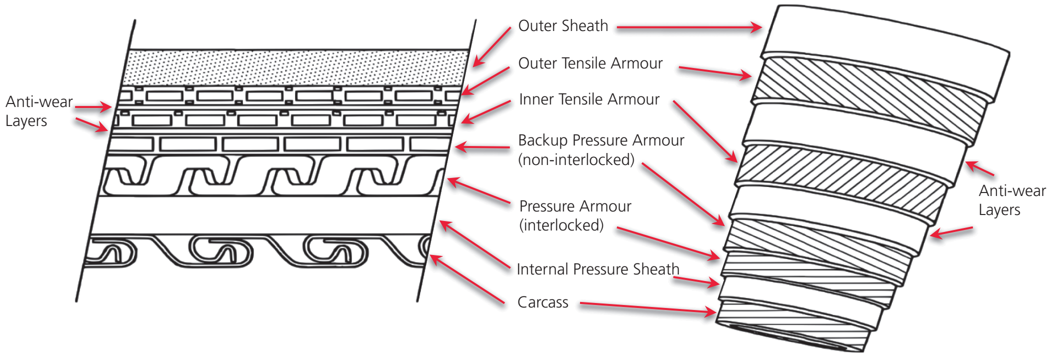

Figure 1: Unbonded flexible pipe cross-section, API RP 17B *Recommended practice for flexible pipe*

1.3 LIFE EXTENSION ASSESSMENT TRIGGERS

This guidance expects users of flexible pipe to build on a routine risk-based integrity management approach through the full life cycle into the life extension phase. It is recommended that operational threats, based on actual industry experience (e.g. via *Flexible pipe integrity management guidance and good practice*), are considered through every stage of the flexible pipe life, including through life extension. For flexible pipe applications close to the edge of industry capabilities, where operational experience is limited, life extension assessment may involve a higher degree of qualitative judgement based on operating history, and it is recommended that expert industry guidance is engaged in these cases.

It is expected that operators regularly consider the condition of the flexible pipes they operate, and assess the impact on the original predicted design lives and the potential for life extension, e.g. defects, anomalies, accidents/incidents, and changes of use/service/ownership.

The original predicted design life of a flexible pipe should be documented in the design, and the drivers for the stated design life understood. It is worth noting also that the stated design life is often a result of the operator's stated aspiration for planned field life at the initial development phase, and is rarely reflective of specific design limits on the supplied pipe. This factor should be assessed through review of the flexible pipe design documentation.

The stated design life should be documented and operational experience tracked against this figure. It is recommended that a formal life extension assessment is performed well in advance of the pipe reaching the original design life. Industry good practice is for assessments to be completed at least three years in advance of the original design life being reached. Whilst there may be additional regulatory requirements to perform a formal assessment at a minimum specified time in advance of the original design life being expended under certain jurisdictions, it is also good engineering practice for operators to understand the threats to life extension in advance, so that any replacement/modifications can be planned in good time.

1.4 APPROACH – ROUTINE INTEGRITY MANAGEMENT VS LIFE EXTENSION

The approach taken to both 'routine' integrity management and life extension of flexible pipes should be similar. The key differentiator for life extension is that there should be stated confidence that future integrity threats/risks do not restrict the required operational envelope for the duration of the lifetime extension. The management of data, risk and integrity should be central to every stage through the life cycle, as illustrated in Figure 2. Issues relating to the 'early life' stages of a pipe (e.g. manufacture, installation, commissioning and handovers) have the potential to impact operations into life extension. Data relating to operations and the management of change (e.g. change of use/application) through these operating phases are an essential requirement to support future life extension assessments. Equally, emergent issues/challenges (see further details in 3.4.3.1) need to be addressed, and this reinforces the requirement for integrity management and risk analysis on a continuing life cycle basis.

In recent years, there has been a growing trend of changing ownership/duty holders for operating assets as oil and gas basins mature, with some assets having had multiple changes of ownership/duty holder through their life cycle. During these transitional phases, there is a real potential for loss of data which could be significant in a subsequent life extension assessment. The processes around such transitions, specifically the transfer of all data relating to all stages of flexible pipe life cycle stages, should be carefully managed to ensure the potential for life extension at a later time is maximised.

In addition, the lessons learned through the life cycle of any project should ideally be captured and taken into account in the next generation concept design. Periodic updates to the codes and standards (e.g. API Spec 17J *Specification for unbonded flexible pipe* and RP17B *Recommended practice for flexible pipe*) and shared industry data relating to operational degradation and failure (e.g. *Flexible pipe integrity management guidance and good practice*) form key routes to capture these industry trends.

The strong guidance herein recommends that operators have a continued focus on risk management/assessment and integrity management through the life cycle, in a robustly documented format, to support the potential for life extension.

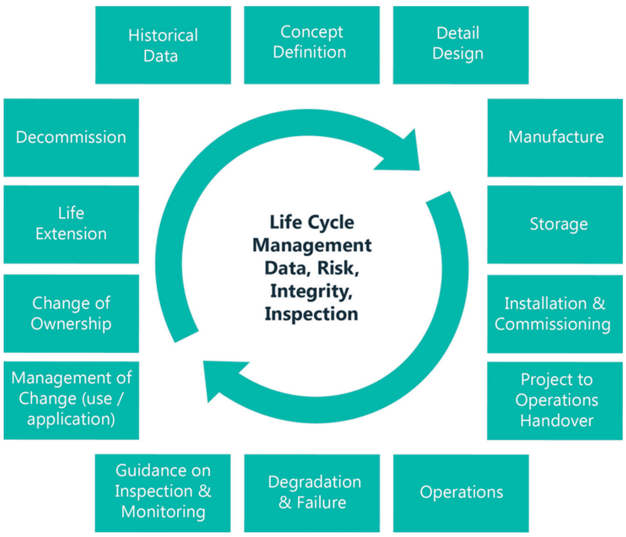

Figure 2: Life cycle integrity management

1.5 ABBREVIATIONS

ALECOM	Ageing and Life Extension Committee
API	American Petroleum Institute
CP	cathodic protection
EI	Energy Institute
ESDV	emergency shutdown valve
FAT	factory acceptance testing
FEA	finite element analysis
FLIP	flow induced pulsation
FPU	floating production unit
GVI	general visual inspection
HIC	hydrogen-induced cracking
ID	inner diameter
ILI	in-line inspection
JIP	joint industry project
LCM	load case matrix
MAH	major accident hazard
MAPD	major accident prevention document
MBR	minimum bending radius
MWA	mid-water arch
OEM	original equipment manufacturer
PA	polyamide
PRV	pressure relief valve
PSR	Pipeline Safety Regulations
PU	polyurethane
PVDF	polyvinylidene difluoride
RAO	response amplitude operator
ROV	remotely operated vehicle
SSC	stress corrosion cracking
STAC	Scientific and Technical Advisory Committee
TRL	technology readiness level
UT	ultrasonic testing
WI	water injection