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Chapter 1 Appraisal of Flexible Pipe Systems

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Chapter 1 Appraisal of Flexible Pipe Systems

- Section 1

Introduction

1.1 General

1.1.1 Flexible pipe systems are complex technologies which have allowed the development of oil and gas fields that are difficult to reach. These products are increasingly being used to transport hazardous products in deeper water and harsher environmental conditions. It is therefore becoming increasingly important for Owners and manufacturers of these systems to be able to demonstrate that their assets/products are compliant with the relevant specifications and standards, and are reliable and safe for use.

1.1.2 Given the complexity of flexible pipe structures, the methods of manufacture and the confidential nature of the technology, it is challenging for manufacturers and Owners to demonstrate that each manufactured flexible pipe design is compliant with the relevant specifications and standards on a case-by-case basis. Therefore, manufacturers may seek Type Approval for their products (or a specific range of their products) in order to demonstrate that they have the capability to design and manufacture pipes within a certain envelope of sizes and operating conditions.

1.1.3 It is acknowledged that flexible pipe structures vary in levels of complexity, from just a few simple layers of polymers and metals, to many layers of polymers and metals with complex profiles. It is therefore necessary to provide a framework for the appraisal of flexible pipes that enables manufacturers to seek assurance as required, either on a case-by-case basis, or wider assurance such as Type Approval.

1.1.4 It is acknowledged that verification and certification bodies, such as Lloyd's Register (LR), have developed different regimes to provide assurance to manufacturers and Owners of the compliance of their flexible pipe products. These Guidance Notes describe LR's approach to independent appraisal services of flexible pipe systems.

1.2 Purpose

1.2.1 These Guidance Notes describe the application of LR's independent appraisal services, which are documented individually, addressing flexible pipe systems, in order to provide a common scheme for appraisal methodology.

1.2.2 The document provides guidance to manufacturers, Owners, Operators and other stakeholders with an interest in different types of appraisal.

1.3 Scope

1.3.1 These Guidance Notes cover appraisal of bonded and unbonded flexible pipes (risers, flowlines and jumpers), and associated ancillary equipment during product development, project design, manufacture, installation, commissioning, and operations including life extension, for offshore and onshore applications.

1.3.2 Reuse of flexible pipes is outside the scope of these Guidance Notes.

1.3.3 Umbilical, hose, choke and kill line systems are outside the scope of these Guidance Notes.

1.4 Applicable appraisal services

1.4.1 This document addresses appraisal according to the following LR services, which can be provided in isolation or as complementary appraisals:

- Type Approval – appraisal to confirm compliance of general design and manufacture with recognised codes or standards, including consideration of the production controls in place at the manufacturing location. A continual process which includes mandatory inspections to confirm the continued conformity of the product during the validity period of the Type Approval certificate.

- Certification – appraisal to confirm compliance with recognised codes or standards; can cover design, manufacture, installation, commissioning or operation (including fitness for service and life extension).
Where there is a statutory requirement for certification, such as offshore Canada, reference should be made to the applicable statutory regulations rather than this document.

- **Verification** – appraisal to confirm the suitability of the components/system in accordance with defined requirements, not necessarily limited to recognised codes or standards; can cover design, manufacture, installation, pre-commissioning or operation (including fitness for service and life extension). Where there is a statutory requirement for verification, such as on the UKCS, reference should be made to the applicable statutory regulations rather than this document.

- **Approval in Principle** – appraisal of the key aspects of a design confirming that the design principles are sufficiently defined/mature to progress to detailed design; normally applied during the early stages of product design, as an intermediate appraisal towards certification, verification or Type Approval.

- **Technology Qualification** – a process for assessing novel flexible pipe system technologies and managing their qualification; typically applied during the early stages of a product development, may contribute to subsequent appraisals as part of certification, verification or Type Approval.

1.4.2 These services, and their typical interrelationships, are shown in Figure 1.1.1 LR services for flexible pipe systems covered by these Guidance Notes, and are discussed in more detail in Ch 1, 4 Certification to Ch 1, 7 Technology Qualification of this document.

![Figure 1.1.1 LR services for flexible pipe systems covered by these Guidance Notes](image-url)
Section 2
Abbreviations and definitions

2.1 Abbreviations

The following abbreviations are applicable to these Guidance Notes unless otherwise stated.

<table>
<thead>
<tr>
<th>Abbreviation</th>
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<tr>
<td>AIP</td>
<td>Approval in Principle</td>
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<tr>
<td>CRS</td>
<td>Comment Response Sheet</td>
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<tr>
<td>DAD</td>
<td>Design Appraisal Document</td>
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<td>FAT</td>
<td>Factory Acceptance Test</td>
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<td>FLIP</td>
<td>Flow-induced Pulsation</td>
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<tr>
<td>FMECA</td>
<td>Failure Mode, Effects and Criticality Analysis</td>
</tr>
<tr>
<td>IRN</td>
<td>Inspection Release Note</td>
</tr>
<tr>
<td>ITP</td>
<td>Inspection and Test Plans</td>
</tr>
<tr>
<td>IVA</td>
<td>Independent Verification Agent</td>
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<tr>
<td>LR</td>
<td>Lloyd’s Register</td>
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<tr>
<td>NCR</td>
<td>Non-conformance Report</td>
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<tr>
<td>NDE</td>
<td>Non-destructive Examination</td>
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<tr>
<td>PQA</td>
<td>Production Quality Assurance</td>
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<tr>
<td>SCA</td>
<td>Software Conformity Assessment</td>
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<tr>
<td>SECE</td>
<td>Safety and Environmental Critical Element</td>
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<td>TA</td>
<td>Type Approval</td>
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<td>VWI</td>
<td>Verification Work Instruction</td>
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2.2 Definitions

The following definitions are applicable to these Guidance Notes.

2.2.1 **Company** – Owner, Operator, designer, consultant or contractor.

2.2.2 **Flexible pipe** – An assembly of a pipe body and two end fittings (including integral flanges) where the pipe body consists of a combination of multiple layers of helically wound metallic strips, composite materials, tapes and extruded thermoplastics, forming a pressure-containing conduit, and the pipe structure allows large deflections. Unbonded flexible pipe, as opposed to bonded flexible pipe, allows for relative movement between layers.

2.2.3 **Flexible pipe system** – A flexible pipe from flange to flange and associated ancillary equipment attached to it, directly or indirectly. For the purposes of this document, a flexible pipe system implies static/dynamic riser, static flowline or static/dynamic jumper system.

2.2.4 **Ancillary equipment** – Ancillary equipment including, but not limited to, pull-in head, l-tube/J-tube seal, bend stiffener, bend stiffener connector, bend restrictor, bend limiter, bellmouth, buoyancy module, ballast module, buoy, tether/chain system (tether element, shackle and/or hook), tether clamp, tether base, riser clamp, riser base, anode, connector, hub connection clamp, impact protection and fire protection.

2.2.5 **Interfaces** – Depending on the location of installation sub-sea or on-land, flexible pipe systems interface with wide range of features and structures. These include, but are not limited to, floating structure, hang-off structure, clashing with other risers or subsea structures, hold-down/hold-back systems, seabed, tie-in structures, conduit system (for pipe-in-pipe system), end termination systems, etc.
2.2.7 **Appraisal** – The process of assessing a system's compliance with stated requirements, for the purpose of independently providing confidence to an Owner, Operator or other interested party. It comprises desktop review and/or physical surveillance activities.
Section 3
Type Approval

3.1 General

3.1.1 Type Approval (TA) represents the culmination of an impartial evaluation exercise, based upon an LR-approved methodology, to ensure that products certified are built in strict conformity to recognised standards or LR Rules they claim to meet. Products seeking TA should undergo assessments as described in LR’s TA system procedure TA14. The process applies to TA of new products as well as the renewal of previous TA certification. The fundamental elements of this process normally involve an appropriate design appraisal (sometimes referred to as design review), formal type testing, and Production Quality Assurance (PQA), conducted at the place of manufacture. The purpose of this Section is to provide further clarification on the requirements of TA14 in relation to flexible pipe products, and in particular to API Specifications 17J and 17K. This Section should be read in conjunction with TA14. In case of any conflict in TA requirements, TA14 will be the governing document.

3.1.2 Any manufacturer wishing to market a product in a regulated environment would ordinarily require that each product be independently verified and subsequently certified to recognised standards. The costs associated with such an exercise can be prohibitively high. Hence TA offers an efficient alternative to certifying identical products, saving time and reducing cost. Apart from the above, upon achieving this certification, a manufacturer can subsequently claim that their product meets specific recognised standards or LR Rules, and can be used for any application within the limits defined on the associated TA certificate. Possessing such certification may well enhance competitiveness, affording a distinct business advantage during any bidding or marketing endeavour.

3.1.3 Having stated the above, some products require enhanced levels of testing or more extensive design reviews beyond what would ordinarily be required for TA of most other products. This usually applies to products where a standard TA process is insufficient to endorse the products seeking TA certification. A flexible pipe product is one such product. Specifically, this is due to the following reasons:

(a) Flexible pipe systems are typically exposed to additional loading or stress beyond the categories stated on a standard TA certificate. These can include environmental loads, interference loads from other entities, and accidental or further functional loads not tested for as part of an ordinary certification process. For this reason, each flexible pipe is tailored to specific requirements for a particular application, resulting in a unique pipe cross-section.

(b) Due to the extensive requirements of API Specifications, e.g. 17J/17K, a design review for a flexible pipe system is a considerably detailed process and can be uneconomical.

3.1.4 To overcome the issues stated in Ch 1, 3.1 General 3.1.3, the process of examination is broken down into two stages:

- Examination of the general design – This is conducted independently of any application-specific requirements during the product development phase and is usually considered to be part of the regular TA process. See Ch 1, 3.4 General design for details.

- Examination with respect to application-specific design – This is conducted at the project design phase and not covered by TA. See Ch 1, 4 Certification and Ch 1, 5 Verification for details.

3.1.5 TA of flexible pipe products is therefore defined as general approval of a product type which comprises review of general design, formal type testing, a PQA, and a review of the Quality Management System conducted at the place of manufacture, as shown in Figure 1.3.1 Components of TA certification.

3.1.6 When it comes to appraisal of the product for a specific application, TA not only removes the necessity for re-examination of product general design and testing, it benefits manufacturers as the underlying product technology only requires to be shared with the TA body.
3.1.7 TA of ancillary equipment is covered by standard TA processes in TA14.

3.2 Scope

3.2.1 In accordance with LR’s TA system procedure TA14, the scope for TA certification for a flexible pipe product is to certify compliance with API Specification 17J (for unbonded flexible pipe), API Specification 17K (for bonded flexible pipe), and/or other relevant recognised industry standards. Elements such as design methodologies, manufacturing methodologies and criteria, welding procedure qualification, material qualification, and prototype performance should be reviewed in the course of the process.

3.3 Limitations

3.3.1 When a type approved product is to be provided for a specific application, an additional appraisal assessment is required to ensure the product conforms to requirements specific to their application and the environment of deployment (e.g. functional, environmental, interference and accidental). Ch 1, 4 Certification and Ch 1, 5 Verification offer guidance on different routes of application-specific appraisal.

3.3.2 Additionally, the TA process for flexible pipe products does not preclude the requirement for further inspection or survey required by the API Specification 17J, API Specification 17K, and other relevant codes and regulations.

3.4 General design

3.4.1 In terms of TA certification of flexible pipes, general design of flexible pipe products can be categorised into the following components:

- design methodologies;
- material qualification;
- manufacturing methodologies; and
- design guidelines.

3.4.2 As a minimum, the following aspects should be examined for assessment of the general design of a flexible pipe product: failure mode, effects and criticality analysis (FMECA), design methodologies, material qualification and manufacturing methodologies. As API Specifications 17J and 17K do not specifically require
examination of design guidelines by the certification body, approval of design guidelines is not a prerequisite for TA, but can be included upon manufacturers’ request.

3.4.3 Design methodologies

(a) As a consistent approach to the design of a component of system, design methodologies represent a collection of the calculation methods and analysis procedures along with the models and assumptions they employ. Examples of design methodologies are calculation methodologies, formulae, finite element and/or analytical models, modelling assumptions and simplifications, validity of mesh size for ranges of applicability of a finite element model, modelling options and parameters for the ranges of applicability of the model, and calibration factors established through validation of methodologies against type tests.

(b) Manufacturers, as a minimum, should cover all design aspects specified by API Specification 17J/17K. At the time of publication of these Guidance Notes, API Specification 17J/17K does not provide design methodologies. Hence, the manufacturer should establish in-house design methodologies using best engineering practice.

(c) Manufacturers should propose ranges of applicability for each design methodology for examination. These may include, but are not limited to, onshore/offshore, shallow/deep-water, static/dynamic, sweet/sour application, etc. For each design aspect, a design methodology or a collection of design methodologies should cover the entire range of TA ratings.

(d) During the assessment of design methodologies, a validation envelope for each model should be established. These may include, but are not limited to, internal diameter, design pressure, design temperature, water depth, H2S level, pH level, chloride level, CO2 level, etc. If these are not considered, the TA certificate will carry exclusions/limitations for the ratings that were not assessed.

(e) Validation of models against type tests should cover the entire range of their applicability. Extrapolation of validation envelopes in the absence of type tests may be acceptable if parameters are independent, or the level of confidence in the predictive capability of the model is high, sufficient safety margin is considered, and the argument is supported by a risk assessment.

(f) In addition to the validated envelopes, manufacturers may present maxima capability envelopes of manufacture that may exceed the validated envelopes. If these are proposed for examination for inclusion in TA, they should be accompanied by a similarity assessment, refer to Ch 1, 3.5 Type testing 3.5.10 for more details.

(g) Software conformity

• Once design methodologies relating to manufacturer’s in-house software tools have been examined, the conformity of software tools can be performed by software conformity assessment (SCA). Through this process, it is established that a manufacturer has satisfactory controls in place for the design development, verification testing of software tool’s performance and functionality, graphical user interface (GUI), version control, configuration management, and maintenance to provide confidence in the software tools.

• Conformity of software by the certification body is an optional requirement of API Specification 17J/17K and hence is not typically included in TA scope by default.

3.4.4 Material qualification

(a) As flexible pipes are usually bespoke products, manufacturers normally qualify a wide range of material types and grades, each suitable for a range of applications. Examination of manufacturer’s material qualification entails assessment of manufacturer’s favoured/most-used material types and grades.

(b) During assessment, the following aspects are reviewed:

• Material specification, characteristics, behaviour and compatibility;
• Material qualification test plans;
• Material testing; Ch 1, 3.5 Type testing applies;
• Fatigue curves and associated curve generation methodology.

(c) For commodity components such as those used in end fittings, manufacturer's qualification procedure for selection of suppliers is reviewed instead of material qualification tests.

(d) Ranges of applicability for each material grade should be proposed by manufacturer and examined. These may include, but are not limited to, pipe layer/end fitting component, static/dynamic application, sweet/sour service, non-cyclic/cyclic application, high temperature/pressure application, etc.

(e) Material suitability for exposure to expected environments, e.g. H₂S, CO₂, CH₄, H₂O etc., should be examined and envelopes of suitability, qualified by testing, established. Qualification envelope may include these parameters, but is not limited to, H₂S level, pH level, chloride level, CO₂ level, CH₄ level, min/max temperature, max pressure (for polymers), etc.

(f) Manufacturers may have multiple suppliers. In this case, certificates associated with material supplied by all suppliers are examined to ensure conformance with manufacturer's material specifications. Certificates should be based upon an approved qualification scheme to ensure consistency of the materials being supplied.

(g) Manufacturers may change suppliers through the course of the validity period of TA certification, provided that the new supplier is accepted by LR and meets manufacturer's material specification.

3.4.5 Manufacturing methodologies and criteria

(a) As part of TA assessment, manufacturing processes should be reviewed. These processes will later form part of the PQA audit (refer to Ch 1, 3.6 Production Quality Assurance) to ensure process variables are adequately controlled such that the design requirements (e.g. allowable manufacturing tolerances, acceptance criteria for acceptable anomalies, etc.) are met within the range of applicability of the design methodology. Processes requiring assessment, as a minimum, are as follows:

• Manufacture and repair procedures for metallic layers;
• Manufacture and repair procedures for polymer layers;
• Field repair procedure for outer sheath (if unbonded)/cover (if bonded);
• Assembly procedures for end terminations;
• Qualifications of end fitters;
• Welding procedure specifications;
• Procedures for qualification of welding procedures;
• Qualifications of welders;
• Procedures for heat treatment and coating;
• Non-conformance procedure;
• Procedure for destructive and non-destructive examination (NDE);
• Qualifications of NDE Operators; and
• Procedures for FAT.

(b) If a part of the manufacture is sub-contracted and certified by a third party, LR reserves the right to request manufacturer's qualification procedure of the sub-contractor and sub-contractor's certification procedures. This is to ensure that the final product assembled is built using components secured from sub-contractors that have an approved quality management and production processes in place.

3.4.6 Design guidelines

(a) Assuming that design for a specific application is performed by the manufacturer, design guidelines refer to the manufacturer's procedures for determining inputs for design methodologies, 'how-to' procedures for selection of methodologies and materials, and any acceptance criteria in excess of, or in addition to, codes
and regulatory requirements. Examples of design guidelines include, but are not limited to, selection of layer dimension and thickness, wire profile dimensions, tolerances (manufacture, installation, etc.), load factors, material selection, application-specific empirical coefficients, such as coefficients of friction, means of selecting any of the above, procedure for selection of load cases/failure modes, manufacturer's acceptance criteria.

(b) Examination of manufacturer's design guidelines is not required by API Specification 17J/17K. The manner in which the manufacturer conducts a design, e.g. how they select materials or methodologies for design, is deemed as the manufacturer's internal matter not affecting the safety of personnel or the environment. However, whether the materials and methodologies selected in design for a specific application are appropriate and do not jeopardise the safety at a field, whether load cases, layer dimensions, wire thicknesses, material derating, load factors, empirical coefficients are appropriate for a specific application, and whether manufacture and installation meet design tolerances and requirements, should be examined by certifier/verifier during application-specific design phase, refer to Ch 1, 4 Certification and Ch 1, 5 Verification.

3.5 Type testing

3.5.1 With respect to flexible pipe products, the scale of type testing depends upon what elements need to be tested and to what extent. The tests are generally categorised into three levels:

(a) Full scale – This involves the entire pipe construction with its end fittings;
(b) Medium scale – This involves only the layers of a pipe that require to be tested with or without its end fittings;
(c) Small scale – This refers to raw/formed material or specific layers that require to be tested.

3.5.2 Type tests are generally conducted for one or more of the following reasons:

(a) To verify that the material or pipe component meets the specified requirement in API Specification 17J/17K;
(b) To establish or verify principal performance characteristics for a particular pipe design, which may be a new or established design;
(c) To validate a manufacturer's general design methodology;
(d) To validate a manufacturer's repair procedures;
(e) To establish material data, characteristics and behaviour;
(f) To comply with any new requirements of API Specification 17J/17K where there is a new revision;
(g) To verify product general design where there has been an improvement in the product due to identification of a new failure mode.

3.5.3 It should be noted that if a product or component fails a type test, it is deemed to be a design failure and not a sample/component failure. Merely substituting one component for another and attempting to re-run a type test is not considered acceptable. An investigation shall be conducted to understand why the test failed and what changes in design will be required to ensure the component meets the test criteria for a subsequent type test.

3.5.4 Sample selection

(a) Samples for inspection and testing should be selected in accordance with API Specification 17J/17K, API Recommended Practice 17B, and other relevant standards. The selected samples should be representative of the entire range of products to be type approved. When applicable, the sample should include welds or repaired sections or process variations.

(b) The manufacturer should provide a statement defining how the samples selected are representative of the product seeking certification. In case the test standard(s) does not indicate specific requirements for the selection of samples for a range of products, the range of samples needs to be agreed between the manufacturer and LR.
3.5.5 Sample manufacture

(a) Full-scale pipe samples produced using the same methods and tools established during a production run, should be truly representative of the products. Manufacture of pipe and the assembly of end fittings for full-scale pipe samples produced to undergo type testing, should be witnessed by LR.

(b) Once the processes of manufacture for the flexible pipe and its related components have been assessed and approved by LR, they should not be modified. Any modifications made without written consent of the TA body will automatically invalidate the TA certificate.

(c) There are no TA requirements on manufacture of medium scale and small scale samples beyond those stated in API Specification 17J/17K and Recommended Practice 17B.

3.5.6 Type Test Plan

(a) A type test plan is usually written by the manufacturer and subsequently reviewed and marked-up by LR prior to the start of testing. The plan should contain the full scope, sequence of the type tests (e.g. load cases) to be conducted, acceptance criteria and witness points. It should also include all tests linked to the product ratings that will be written on the TA certificate.

(b) The approved type test plan should be presented to attending Surveyor prior to testing.

3.5.7 Type Test

(a) A type test must be undertaken in accordance with an approved type test plan at a laboratory or at the manufacturer's premises where authorised by LR. All test and measuring equipment should be correctly calibrated and be of proven accuracy. Where appropriate, calibration certificates for test equipment may be requested prior to the commencement of any test involving them.

(b) During a type test, the role of the attending Surveyor is to act as a witness and not a participant in the test. Results obtained during the course of the test, are required to be recorded by the manufacturer. The attending Surveyor witnessing the tests may endorse the findings, as appropriate. Type tests may be conducted at accredited laboratories/test facilities or non-accredited ones.

(c) Tests conducted at an accredited facility:

- If a manufacturer wishes a type test to be conducted at an accredited laboratory/facility, the accreditation status of the test facility, the scope of test facility accreditation, and copies of the calibration certificates of the test equipment that will be used should be made available to LR prior to the commencement of the type tests. If endorsed, a type test may be conducted in accordance with an accepted type test plan at such a facility without the requirement of a LR Surveyor to witness the tests.

- It remains the responsibility of the manufacturer to ensure all type test elements listed on the type test plan are conducted. If any elements of a type test are omitted, the final TA certificate will carry exclusions/limitations for elements of the test plan that have been omitted.

(d) Tests conducted at a non-accredited facility or manufacturer’s premises:

- If a type test is conducted in accordance with an accepted test plan at a non-accredited laboratory/facility, only an LR Surveyor can witness and endorse it. The type tests conducted should not exclude any elements from the approved type test plan. If any elements of a type test are omitted, the final TA certificate will carry exclusions/limitations for elements of the test plan that have been omitted.

- Prior to the commencement of a test, the following items should be made available to the attending Surveyor for sample audit:
  - calibration certificates for the test equipment to be used;
  - relevant training records of personnel undertaking the testing;
  - records of environmental control of laboratory;
  - recording and storage of test data; and
- retention plan of test samples.

- Witness certificates or visit reports from third-party Surveyors witnessing any type tests at non-accredited facilities are not acceptable for the purposes of a TA certification unless in exceptional circumstances for which additional requirements will apply. These include, but are not limited to, review of third-party certification procedures to ensure these are accepted by LR and potentially some repeat tests may be required.

3.5.8 Post type test reports

(a) Upon completion of each type test, a report shall be issued by the manufacturer or test facility, which accurately, clearly and unambiguously presents the test results along with relevant supplementary information. The test report should be signed by the test personnel involved as well as the test facility supervisor (if an accredited facility is used). These will be affixed to the LR Surveyor attendance report. These results should be made available to the LR attending Surveyor during the PQA site visit, see Ch 1, 3.6 Production Quality Assurance.

3.5.9 Review of test results

(a) Following the receipt of test results, they will be examined by the TA body. If any recommendations are to be made, these will be communicated to the manufacturer in writing stating the precise nature of the findings. Where necessary, the manufacturer should act on the recommendations accordingly and demonstrate these have been addressed.

3.5.10 Similarity assessment

(a) The qualification of a new pipe design by adopting a similarity assessment, instead of type testing, may be acceptable, subject to examination of objective evidence supported by a risk assessment by FMECA. Refer to API Recommended Practice 17B for further guidance.

3.5.11 Qualification programme

(a) The TA process is flexible in that it accepts prior product certification received for products that seek TA. While such evidence will require to be re-assessed during the general design review phase, it is possible to take credit for previously held independent evaluations. Nevertheless, the product will still need to undergo formal type test(s) in accordance with an approved type test plan as stated in Ch 1, 3.5 Type testing 3.5.7.

(b) After attainment of the TA certificate, the manufacturer may continue to further develop the product and qualify new aspects of the product. In such cases and where the manufacturer intends to type approve the new pipe design, the product will need to undergo a formal type test(s) in accordance with an approved type test plan(s) as stated in Ch 1, 3.5 Type testing 3.5.7 (type tests conditions and requirements of Ch 1, 3.5 Type testing 3.5.7 apply). In any case, an upgraded product based upon further development or refinement cannot be linked to a TA certificate issued for a lower version of the same product presented during the TA certification process. Any requirement to link a TA certificate to an upgraded product will require an application for a modified TA certificate to be made.

3.6 Production Quality Assurance

3.6.1 This involves a visit to each place of manufacture intended to be listed on the TA certificate to ensure that the manufactured products (implementation of controls) are built to acceptable quality standards. These are related to design methodologies, manufacturing methodologies, welding procedures, material qualification, etc. The assessment consists of a review of the technical aspects of product realisation as well as related processes from the procurement of materials to handling and storage of finished products; refer to TA14 for full procedure. Additionally, each place of manufacture should also hold an appropriate quality management certificate. See Ch 1, 3.7 Quality Management System for more details.

3.6.2 Following the receipt of the PQA report from the attending LR Surveyor, it will be examined by LR. If any recommendations are required, these will be communicated to the manufacturer in writing stating the precise nature of the findings. Where necessary, the manufacturer should act on the recommendations accordingly and demonstrate these have been addressed.
3.6.3 In order to retain the validity of a TA certificate and in keeping with the LR approved process TA14, a secondary PQA assessment exercise should be arranged to be conducted at every place of manufacture listed around thirty months (with a grace period of three months) from the date of issue of the final certificate. It remains the manufacturer’s responsibility to arrange these visits well in advance to ensure the availability of a Surveyor. The purpose of these visits is to ensure that there have been no significant changes to the manufacturing process controls or supporting processes since the issuance of the certificate. During such a visit, if it is discovered that there have been significant changes and LR were not informed of these, LR in keeping with its approved TA process, TA14, reserve the right to withdraw the TA certificate for all products affected by the changes. If Surveyors from LR are frequently present at a place of manufacture, this secondary PQA exercise can be combined with one of these visits.

3.6.4 Multiple places of production

Where products are manufactured at multiple locations, separate PQA assessment exercises are required to be conducted at each of them. Manufacturers should arrange for these visits well in advance of a planned date, by establishing a notification process and audit schedule, to ensure the availability of a Surveyor.

3.7 Quality Management System

3.7.1 As part of the TA process, the manufacturer is required to hold a current quality certificate (e.g. ISO 9001 or equivalent) covering each place of production. Additionally, although not prescribed by the TA system procedure TA14, it is advisable to hold supplementary certificates required by local law (e.g. environmental assessment certificates, waste disposal certificates, etc.) to ensure that the places of production and production quality are not disturbed by local authorities subsequent to the issuance of a TA certificate.

3.8 Deliverables

3.8.1 Through the TA exercise there are the following deliverables:

(a) Interim Deliverables:

- Comment response sheets (CRS) to document comments and responses regarding individual review activities.
- Design Appraisal Documents (DAD) relating to individual design methodologies, manufacturing methodologies, and testing.
- Material qualification certificates for individual material qualifications may be delivered if requested by the manufacturer.
- TA progress report may be delivered if requested by the manufacturer.

(b) Final Deliverables:

- TA certificate and TA DAD listing type approved product, places of production, ratings, and ranges of applicability.
- General Design Review DAD which lists all the technologies reviewed and accepted through the TA process.
- TA assessment summary report (known as an independent verification authority report in API Specification 17J/17K) may also be delivered if requested by the manufacturer.

3.8.2 A TA certificate issued at the end of TA certification exercise usually has a five year validity period, after which it will need to be renewed. As mentioned in Ch 1, 3.6 Production Quality Assurance 3.6.3, half way through its validity period, a secondary PQA exercise will be required in order to retain the TA validity for that period.

3.8.3 Once a certificate is issued, the contents of that certificate are entered onto a publically available database referred to as the LR ‘List of Approved Products’. Access to this database is available through the URL: www.lr.org/en/services/type-approval. Products that have been certified may then carry a TA mark, as illustrated in Figure 1.3.2 Type Approval mark.
3.9 Manufacturers’ responsibility

3.9.1 Following the issuance of a TA certificate, the manufacturer remains responsible for ensuring that the certified products continue to be manufactured in accordance with recognised standards and processes approved at the time of the certification exercise. Further details on this are available in the TA system procedure TA14. Additionally, in relation to the manufacture of flexible pipe products, the manufacturer is also responsible for the following:

(a) Declaring any non-type approved design aspects during application-specific appraisal, for an independent review by an Independent Verification Agent (IVA);
(b) Declaring any non-type test during application-specific appraisal, for an independent review by an IVA;
(c) Providing any NCR of pipe manufacture or repair to LR for examination during application-specific appraisal;
(d) Notifying LR to review type test plans prior to type tests;
(e) Notifying LR to witness the manufacture of the pipe body and its assembly of end fitting for pipe samples produced for type testing;
(f) Notifying LR to witness type tests;
(g) Notifying LR of any failure of any aspect of a flexible pipe during type tests;
(h) Notifying LR of the secondary PQA assessment (see Ch 1, 3.6 Production Quality Assurance 3.6.3) if there is no regime in place for frequent site visits of manufacture by LR Surveyors; and
(i) Advising LR of any changes made to the product design or construction for each place of production, including introduction of any new technologies or novel designs, modification to design methodologies, manufacturing methodologies, material qualification, welding qualification, etc.

3.9.2 A regular dialogue with LR is encouraged to facilitate efficient accomplishment of the above-mentioned items.
Section 4
Certification

4.1 General

4.1.1 The purpose of certification is to undertake an agreed scope of review for confirming compliance of new construction, replacement, or repair assets, with standard(s) as specified by the company or manufacturer. The standard(s) may be stipulated by application-specific requirements, or established based on discussion and agreement with certification body (known as an Independent Verification Agent (IVA) in API Specifications 17J and 17K). The scope of certification can be as narrow or as wide as the company or manufacturer specifies; as small as design or manufacture of one component or as wide as design and manufacture of an entire flexible pipe system. Exclusions from or additions to the design codes or standards can be agreed by LR on a case-by-case basis.

4.2 Scope

4.2.1 The scope for certification for a flexible pipe system is to appraise its compliance with the specified standard(s) for design and/or manufacture for the flexible pipe and/or any ancillary equipment.

4.2.2 The main industry standards applicable for assurance of flexible pipe system are API Specification 17J (for unbonded flexible pipe), API Specification 17K (for bonded flexible pipe), and API Specification 17L1 for the associated ancillary equipment. Where certain performance criteria are not specifically covered by the above-mentioned API specifications, other recognised standards may be applicable.

4.3 Overview

4.3.1 Certification can be performed for flexible pipes with or without TA certification. It should be recognised that use of a type approved flexible pipe product in a system does not automatically constitute certification of the flexible pipe or the system for a specific application (refer to Ch 1, 3.3 Limitations 3.3.1).

4.3.2 Certification assessment is performed through desktop review of design and/or physical surveillance of pipe body manufacture, end fittings manufacture, and assembly and manufacture of ancillary equipment.

4.3.3 A sampling approach is permitted for both desktop review and physical surveillance activities. The level of involvement and frequency of sampling requires professional judgement, and depends on the criticality of the subject component, novelty of its application, degree of similarity in design, experience of designer, etc., and should be agreed with certification body at the outset, and if necessary, adjusted over the length of the certification process based on findings. If flaws are identified during the process, the company or manufacturer should be informed and an increased sample size and/or frequency should be agreed.

4.3.4 For certification of type approved flexible pipes where proposed ratings remain inside the envelope of existing type approved ratings, the process starts with a review of the product specification against the TA certificate and associated appendices to confirm the validity and limitations of TA certification and applicability of TA ratings to company specifications and conditions. Assessment should include design and manufacture aspects which are not covered by TA certification for the specified company requirements, i.e. functional, environmental, interference, accidental loads, design guidelines (refer to Ch 1, 3.4 General design 3.4.6), and inspection and test plans (ITP).

4.3.5 For certification of type approved flexible pipes where proposed ratings fall outside the envelope of existing type approved ratings, the manufacturer should seek approval from the associated TA body well in advance of the certification process, and propose and conduct a qualification programme. The qualification programme should address any new technologies introduced in the product and any additional testing requirements. If applicable, Production Quality Assurance (PQA) may be required by the TA body for new/modified manufacturing facilities. Upon approval of the new technologies by the TA body, a certificate from the TA body is then required as supporting evidence as part of the certification process.

4.4 Design assessment

4.4.1 Assessment of design is performed through desktop review of one or more of the following aspects, depending on the system setup and application.
(a) Static flowline:
- The following aspects:
  o design basis;
  o material selection and fluid compatibility;
  o pressure containment;
  o cross-section design;
  o static stress analysis;
  o end fitting design;
  o crushing analysis;
  o dropped object and pipe impact resistance;
  o crazing analysis;
  o free span analysis;
  o crossing analysis;
  o service life assessment;
  o gas diffusion;
  o gas venting system;
  o slug flow analysis;
  o erosion analysis;
  o corrosion analysis and cathodic protection design;
  o fracture analysis;
  o on bottom stability;
  o as installed tie in analysis;
  o flange/hub interface;
  o hub connection clamp;
  o studs, nuts and gaskets;
  o installation head strength;
  o bend restrictor strength and corrosion;
  o concrete mattress impact resistance and stability; and
  o ITP including Factory Acceptance Test (FAT) and leak test.
- For unbonded flexible pipe, bird-caging and in-place buckling analysis, gap span analysis, and flow-induced pulsation analysis (FLIP) should also be considered.
- For bonded flexible pipe, free span analysis should address fatigue due to VIV.

(b) Static riser
- All aspects included in (a) static flowline, plus:
  o riser fatigue analysis and corrosion-fatigue for hanging section outside I-tube/J-tube;
  o hang-off assembly strength and corrosion; and
  o I-tube/J-tube seal system strength and corrosion.
- For bonded flexible pipe, fatigue analysis should address fatigue due to VIV.

(c) Dynamic riser
- All aspects included in (b) static riser, plus:
  o riser hydrodynamics;
  o fluid-structure interaction analysis;
- riser global dynamic analysis;
- clashing/interference analysis;
- disconnect sequence and disconnected analysis;
- hang-off latching mechanism (or diver-less bend stiffener connector) strength, fatigue and corrosion;
- bend stiffeners strength, fatigue and corrosion;
- ballast modules strength and corrosion;
- buoyancy module strength and corrosion;
- mid-water arch system strength and corrosion;
- riser clamp strength and corrosion;
- hold-down/hold-back tether system strength, fatigue and corrosion; and
- pile/gravity anchor base strength, corrosion and stability.

4.4.2 For design certification of flexible pipes without a TA, assessment should also cover review of application-specific aspects of general design, described in Ch 1, 3.4 General design.

4.5 Manufacturing assessment

4.5.1 Assessment of manufacture is performed through attendance during one or more of the following activities, making a number of random or agreed visits for surveillance and monitoring. Surveillance may be partial, at pre-agreed intervals, or if specified by company, a full-time attendance.

- Manufacture of pipe body;
- Manufacture of end fitting forged components;
- Assembly of end fittings;
- Manufacture of ancillary equipment; and
- Flexible pipe FATs.

4.5.2 All metallic materials used in the manufacture, as a minimum, should have a 3.1 certificate according to EN 10204, and end fitting forged components should have a 3.2 certificate. When 3.2 certification does not cover machining, heat treatment, cladding, welding, etc., these should be inspected. When the flexible pipe system is intended for high-performance application (e.g. high pressure, ultra-deep water depth, supercritical CO2, highly sour service), all metallic materials used in the manufacture are recommended to have 3.2 certification. The procedure used by a third-party certifier for certification should be reviewed to ensure the certification is adequate.

4.5.3 Where deviation from product quality standards occurs during manufacture, the manufacturer should provide a non-conformance report (NCR) and photographic records to the TA body (if applicable) or certifier, with the proposed corrective action, accepted by purchaser, for assessment and approval of corrective actions. Records of approval should be reviewed for certification.

4.5.4 Repair during manufacture should be monitored and records reviewed to ensure that the process is carried out in accordance with the manufacturer's repair procedure.

4.5.5 For certification of flexible pipes without a TA, assessment of manufacture includes the requirements of Ch 1, 3.4 General design 3.4.5 and review of the following quality items:

- Inspection and test plans (ITP);
- Material certificates; and
- Repair records.
4.6 Deliverables

4.6.1 Deliverables should reflect the activities performed by the certification body based on the scope specified by company/manufacturer and agreed with the certification body.

4.6.2 Depending on the scope of certification the form of deliverable varies. Typical deliverables are as follows:

- Comment response sheet (CRS) or company/manufacturer preferred comment response system;
- Design Appraisal Document (DAD);
- Visit Report;
- Inspection Release Note (IRN); and
- Certificate.

Other forms of deliverables may be agreed and delivered based on client's requirements.
Section 5
Verification

5.1 General

5.1.1 Independent verification provides the Owner of an asset with assurance on lifecycle hazard management, safeguarding personnel on an installation and the associated environment. Verification confirms the suitability of the components/system in accordance with the requirements defined by the Owner. It involves agreement between the verifier and the Owner throughout the entire process, typically in a goal-setting form.

5.1.2 Depending on the country and state where an asset is located, verification can be regulated or not driven by legislation. In legislative frameworks where verification is regulated, the intent and scope of verification is driven by the underlying legislation. An example of such legislative framework is Directive 2013/30/EU on the Safety of Offshore Oil and Gas Operations, where, through the verification process, Safety and Environmental Critical Elements (SECE) are established and each examined for suitability for the intended purpose.

5.1.3 Where a flexible pipe system is identified as a SECE or is otherwise identified as requiring verification, the associated ancillary equipment should be screened. The ancillary equipment which provides a role in maintaining the integrity of the flexible pipe system, from just after installation up to decommissioning, is a SECE and should be included in the scope of verification.

5.1.4 Under the European Safety Directive, a verification scheme requires formation of performance criteria for each SECE, known as performance standards. Performance standards define essential requirements that flexible pipe system must meet. These performance requirements can include functionality, availability, reliability, survivability, integration, interactions, and dependencies requirements. With regards to the two latter performance requirements, i.e. interactions and dependencies, the performance of a flexible pipe system should be assessed in relation to interfaces stated in Ch 1, 2.2 Definitions 2.2.6.

5.1.5 In the verification scheme, verification tasks should be defined by the Owner and LR based on the legislation, specifying the nature and frequency of examinations, i.e. an instruction to the verifier, known as Verification Work Instruction (VWI), on how to verify the suitability of the SECE.

5.2 Scope

5.2.1 The scope for verification for a flexible pipe system is to confirm the suitability in accordance with defined performance criteria, not necessarily limited to recognised codes or standards, e.g. those stated in Ch 1, 4.2 Scope 4.2.2.

5.2.2 Verification covers design and manufacture, and can be extended to cover installation, commissioning, and continued suitability, i.e. fitness for service and life extension.

5.3 Overview

5.3.1 Verification assessment, depending on the requirements of the performance standards, is achieved through a combination of desktop review and physical surveillance activities.

5.3.2 For new construction, verification is performed through desktop review of design and installation, and physical surveillance of manufacture of pipe body, manufacture and assembly of end fittings, manufacture of ancillary equipment, installation and commissioning including field hydrostatic pressure test, and for unbonded flexible pipes, annulus vacuum test and whether annulus monitoring is available and operational.

5.3.3 For continued suitability of aged components/system, verification is performed through desktop review of fitness for service assessment or life extension analysis, and physical surveillance of pipe body, end fittings and ancillary equipment.

5.3.4 A sampling approach is permitted for both desktop review and physical surveillance activities, in accordance with Ch 1, 4.3 Overview 4.3.3.

5.3.5 Guidance notes from Ch 1, 4.3 Overview 4.3.1, Ch 1, 4.3 Overview 4.3.4 and Ch 1, 4.3 Overview 4.3.5 apply.
5.4 Design assessment

5.4.1 Guidance notes from Ch 1, 4.4 Design assessment apply.

5.5 Manufacture assessment

5.5.1 Guidance notes from Ch 1, 4.5 Manufacture assessment apply.

5.6 Installation and as-built assessment

5.6.1 Assessments of installation and as-built are performed through a combination of desktop review and physical surveillance activities.

5.6.2 Desktop review is performed through the following activities:

- Review of installation analysis;
- Review of installation procedure(s) to confirm that the Owner’s assurance process ensures that they contain sufficient test parameters, instructions, procedures etc. to allow the components to be installed and tested in accordance with the SECE performance criteria;
- Review of field leak test;
- Confirm by review that the as-built configuration reflects the as-designed configuration;
- Confirm by review of the master punch list, and/or sample review of the system’s commissioning records, that all major punch list items or those that affect performance standard compliance have been closed out;
- For unbonded flexible pipes, confirm by review of annulus vacuum test after installation that the outer sheath layer is intact and the annulus is at dry condition.

5.6.3 Physical surveillance should be performed to ensure that the installation activities are in accordance with manufacturer and Owner installation recommendations and the accepted specifications and procedures. General visual examination should be performed to confirm that gas venting system is operational and satisfactory (i.e. that vent paths are clear). For unbonded flexible pipe, this includes examination of annulus monitoring system.

5.7 Fitness for service/Life extension assessment

5.7.1 Assessment of fitness for service/ life extension is performed through a combination of desktop review and physical surveillance activities.

5.7.2 For fitness for service of a flexible pipe system prior to expiry of design life, desktop review is performed through review of the following aspects:

- Operational procedures;
- Operational history, e.g. flexible pipe bore and annulus history data (if unbonded), shutdown/startup cycles, depressurisation periods, and any instances of exceedance of environmental design conditions;
- History of modifications, damage, integrity assessment, and repairs/replacements;
- Condition assessment; and
- Integrity assessment and adequacy of proposed repairs/replacements.

5.7.3 For life extension, desktop review is performed through review of the following aspects:

- Risk assessment by FMECA;
- Operational procedures;
- Operational history e.g. flexible pipe bore and annulus history data (if unbonded), shutdown/startup cycles, depressurisation periods, and environmental loads including any instances of exceedance of environmental design conditions;
- History of inspection, maintenance and in-place testing, e.g. general visual inspection, NDE, detailed visual inspection, corrosion reports, cathodic protection surveys, anomaly reports and gas venting testing;
• History of modifications, damage, integrity assessment and repairs/replacements;
• Condition assessment;
• Integrity assessment and adequacy of proposed repairs/replacements;
• Re-visit relevant aspects of design described in Ch 1, 4.4 Design assessment for the extended life; and
• Inspection and maintenance plan.

5.7.4 Physical examination is performed through surveillance of pipe body, end fittings and ancillary equipment for defects, damage and tests including post-repair tests.

5.7.5 As stress analysis methodology, fatigue SN curves and polymer ageing data are typically proprietary information, stress, fatigue and ageing evaluation reassessment are recommended to be performed by the original manufacturer.

5.7.6 Due to immaturity of NDE techniques and failure mechanisms for flexible pipe products, condition and integrity of layers and components cannot be reliably measured and verified. At the time of publication of these Guidance Notes, life extension of static or dynamic flexible riser systems is currently not recommended.

5.7.7 If recognised codes or standards are used for life extension, it is a good engineering practise to use the most up-to-date revision of these even if the original design of the system had been to an older revision.

5.8 Deliverables

5.8.1 Deliverables should reflect the activities performed by the verifier based on the scope specified by asset Owner.

5.8.2 The deliverables would be as follows:

• CRS or Owner's preferred comment response system;
• Signed-off VWI;
• Visit report; and
• Verification statement.

Other forms of deliverables may be agreed and delivered based on client's requirements.
Section 6
Approval in Principle

6.1 General

6.1.1 Approval in Principle (AiP) is designed to provide manufacturers and users of flexible pipe and ancillary equipment with early confidence, by assessing the key aspects of the product concept without conducting a full, detailed, appraisal. An AiP confirms that the product is capable of being appraised, and is likely to be certified, verified or Type Approved by LR and accepted by other stakeholders (where applicable), provided that the principles reviewed are applied during further development, and that the correct amount of risk assessment, product engineering and type testing is undertaken.

6.1.2 AiP helps the company to obtain early confidence that there are no major obstacles to further progress in application-specific design, and can help a manufacturer to understand the path to achieve TA. It also provides an early opportunity for LR to identify areas requiring attention as the design or product evolves. It can support manufacturers and the company in securing project finance, insurance, or partner approvals, prior to committing to the next phases of the development.

6.1.3 In TA, AiP can also support on-going product evolvement by providing an early confidence for new aspects of the product general design prior to conducting a full, detailed appraisal. It can provide a roadmap for manufacturers willing to obtain TA for a product.

6.2 Scope

6.2.1 The scope for an AiP for a flexible pipe system is to assess the concept design in accordance with the client's requirements, e.g. for compliance of design principles with API Specification 17J (for unbonded flexible pipe), API Specification 17K (for bonded flexible pipe), API Specification 17L1 (for ancillary equipment), and/or other relevant recognised standards for associated technologies.

6.3 Limitations

6.3.1 AiP does not constitute regulatory approval.

6.3.2 AiP does not constitute appraisal of detailed design. To obtain appraisal of detailed design, all of the necessary code requirements will have to be met, or equivalency demonstrated, examined and accepted.

6.4 Assessment

6.4.1 AiP assessment entails review of the following principles, adjusted as applicable to the type of appraisal:

- Specified codes and standards, and/or other criteria or terms of reference;
- Basis of design or philosophies, including the principal parts of the design methodology and overall plan for full appraisal of the product;
- Material specification/selection for critical systems or components;
- Critical design calculations; and
- Adequacy of field-specific parameters.

6.5 Deliverables

6.5.1 The deliverables would be as follows:

- Comment response sheet (CRS) or company/manufacturer preferred comment response system; and
- Approval in Principle Statement.

6.5.2 Approval in Principle statement comprises:

(a) High-level statement indicating:

- The principle design basis that has been used, e.g. API Specification 17J/17K, etc.
- Given good engineering design practice, there are no conceptual issues related to the design with regard to the appropriate standard(s) which should prevent the design gaining the necessary approvals.
• Brief detail of the equipment/concept/technology;
• Operational location/restrictions; and
• Any further limitations which may apply.

(b) A list of documentation that the AiP is based on.
Section 7
Technology Qualification

7.1 General

7.1.1 Manufacturers of flexible pipe systems who intend to use a novel technology in the methodology, material or manufacture of their products, can benefit from Technology Qualification. Novel technologies are usually not covered by recognised standards. Technology Qualification enables manufacturers to quantify the risks brought in by novel technologies. It can support manufacturers in securing project finance and insurance, or partner approvals during TA or certification processes.

7.1.2 Technology Qualification is a risk-based process that uses the readiness level framework, a total system perspective and lifecycle approach to qualify new technologies, unconventional designs or innovative processes of applying existing technology. For flexible pipe system products, this can be qualifying new materials, new pipe layers, new end fitting designs, new valve concepts, or other new technologies. For further guidance, refer to LR Guidance Notes for Technology Qualification available on www.lr.org.

7.1.3 This qualification process is separate to, and often a forerunner of, certification, verification or TA processes. It is most suited to new products with lower readiness levels that would benefit from support in building evidence of the technology’s suitability and from a formal assessment by a recognised independent body. Once the product has developed a specified level of maturity, it can be provided with a technology qualification certificate. It can subsequently progress towards certification, verification or TA, provided a recognised code or standard is developed for the technology, or if suitable performance standards are agreed for verification.
### Section 8

#### References

8.1 References in support of flexible pipes

8.1.1 A number of recognised standards and other documents have been published that relate to or support, flexible pipes. The list below provides an overview of some of those used most prominently throughout industry:

- API SPEC 17J – Specification for unbonded flexible pipe;
- API SPEC 17K – Specification for bonded flexible pipe;
- API RP 17B – Recommended practice for flexible pipe;
- API SPEC 17L1 – Specification for flexible pipe ancillary equipment;
- API RP 17L2 - Recommended practice for flexible pipe ancillary equipment;
- LR TA14 - Type approval system procedure; and
- LR Guidance Notes – Guidance notes for technology qualification.