

API RP 17B to supplement the pipe specification and incorporate new technological developments.

OTC 8181

New Standards in Flexible Pipe Technology Including API Spec 17j

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Abstract

Recent and future developments in the offshore industry will see the use of flexible pipes in more severe applications than previously. Included in this is its use in deep water, high temperature, high pressure and sour service applications. There is therefore a requirement in the industry for the development of consistent standards for the specification, design, materials, manufacturing and testing of flexible pipes.

A Joint Industry Project (JIP) commenced early in 1994 to develop these new industry wide standards for unbonded flexible pipe. The 20 participants to the JIP included twelve oil companies, three manufacturers, three regulatory authorities and three contractors. The first phase of the project involved the development of a standard specification for flexible pipe, with a second phase, presently ongoing, to develop a new recommended practice for flexible pipe.

The initial development of the industry standard specification was completed in May of 1995 and the document was subsequently submitted to API for technical review. This was completed by December 1995. The specification was updated accordingly in cooperation between API and the JIP, and subsequently released in January 1996 for API balloting. The specification is expected to be adopted and published as API Spec 17J by the middle of 1996. The specification will also be incorporated during 1996 into the new ISO series of standards for subsea equipment. The recommended practice will update

This paper discusses the scope, including new developments, addressed by API Spec 17J and also describes significant aspects in the updating of the recommended practice. This development of new standards within the flexible pipe industry is in line with the objectives of initiatives such as CRINE and NORSOK.

Introduction

Since being first used in the 1970s, flexible pipe applications have progressed enormously. Recent and future developments in the offshore industry will see the use of flexible pipes in more severe applications than previously. These include deep water, high temperature, high pressure and sour service applications. In addition, the pipe designs are continually evolving, with major changes such as the use of different shaped armour wires and different materials (e.g. composites).

Because of the complexity of flexible pipes and the severity of the applications, the development of design standards has been an important part of the technological advancements in the industry. Developments in this area have included API [1], Bureau Veritas [2] and Veritec [3] documents. These documents have in general concentrated largely on flexible pipe systems and tend only to give guidelines and recommendations. All of these documents were written in the 1980s and there is a need for updating to address the changes that have occurred in flexible pipe technology since then. A more recent publication in 1994 by DnV [4] addresses their certification requirements for flexible pipes.

In addition until the development of this specification, there has been no industry standard for the specification of flexible pipes, in particular relating to the design, materials and manufacturing requirements for the pipe itself. This has resulted in the use of project-specific and company specifications,

leading to inconsistencies which have increased supplier costs in recent years.

Project Overview

In line with the objectives of initiatives such as CRINE and NORSOK, the flexible pipe industry perceived a need for the development of consistent standards for the specification, design, materials, manufacturing and testing of flexible pipes.

To address this, MCS in cooperation with Shell Internationale Petroleum set up a Joint Industry Project (JIP) in early 1994 to develop worldwide standards for flexible pipes. An indication of the importance attached to this development can be seen from the number and global spread of participants to the project. The participants are listed in Table 1 and include twelve oil companies, three regulatory authorities, three manufacturers and two contractors. A major achievement of this project has been to obtain the cooperation (and major input) of all manufacturers in the project and this has been a significant factor in the successful development of the new standards.

The overall project was divided into two main phases as follows:

- Phase I - Development of a specification.
- Phase II - Development of an updated recommended practice (RP).

Phase I was initially completed in mid-1995 with the finalisation of the specification and the submission of the document to API for technical review. There was significant interaction between the API and JIP committees on the technical review, which was completed in December 1995. The specification [5] was released by API in January 1996 for balloting and it is expected to be adopted and published as API Spec 17J by the middle of 1996. The specification will also be incorporated during 1996 into the new ISO series of standards for subsea equipment.

Phase II of the JIP, development of the RP, is presently ongoing. A second draft of the document [6] was reviewed by the JIP Steering Committee at the end of 1995 and was being updated subsequent to this. It is intended that this document will be finalised and submitted to API by the middle of 1996.

One of the most important aspects of this JIP is that it has focused only on flexible pipes of unbonded construction, to the exclusion of bonded pipes. It was generally considered within the committee that the two types of flexible pipe should be addressed separately, due to the substantial differences between them in terms of design, materials, manufacture and use. Therefore, this JIP is developing standards for unbonded pipes, while a separate committee (being set up by a number of bonded pipe manufacturers) will address standards for bonded pipes.

Note that API RP 17B addressed both bonded and unbonded pipes.

Description of New Standards

As discussed in the previous section, this industry wide JIP will result in the development of two standards, namely a specification and a recommended practice. The specification will

be known as API Spec 17J (an ISO designation has not yet been assigned). A designation for the recommended practice is also to be decided. It is possible that the recommended practice will replace API RP 17B or alternatively be given a new designation.

It is important to distinguish between a specification and an RP as defined by API, which is as follows:

Specification - A specification defines the technical requirements for safe, dimensionally and functionally interchangeable products, that are designed and manufactured to uniform standards and criteria.

RP - An RP gives guidelines and recommendations based on current best practice in a particular area of technology.

Specifications have typically been developed for particular components, which subsequently can be monogrammed by API. This is the process whereby API will audit a company to a particular specification and allow the company to use the API monogram on the product if the company passes the audit. API will also audit the company to API Spec Q1, which is the equivalent to ISO 9000, and also performs regular re-audits.

RP's have generally been written to describe best practice in a particular area of technology or to address an evolving technology. For example, API RP 17B [1] for flexible pipe was written in 1988 to address flexible pipe technology as it was current at that stage.

In general, specifications and RP's have been mutually exclusive, in that it has not previously been considered necessary to have both an RP and a specification for one particular area of technology. This is therefore a unique development and represents what is considered to be the optimum solution to meet the needs of the offshore industry.

In summary, the specification defines the minimum requirements for the supply of flexible pipes, while the RP gives guidelines and recommendations for flexible pipe systems. In addition the RP provides supporting information for the specification, which by its nature is a contractual document. A further distinction is that the specification addresses settled technology, while the RP considers evolving technologies.

API Spec 17J

API Spec 17J specifies minimum requirements for the design, material selection, manufacture, testing, marking and packaging of unbonded flexible pipes. The main sections in the document are listed in Table 1. Important issues addressed by the document include the following:

- Definition of functional requirements.
- Requirements of the design methodology.
- Pipe layer design criteria.
- Sour service.

These issues are discussed further in the subsequent paragraphs. However, it should also be noted that the specification represents a significant advance in standardisation in the following areas of flexible pipe technology:

- Polymer materials tests.
- End fitting requirements.
- Manufacturing requirements.
- Documentation standardisation.
- Factory acceptance tests.
- Quality assurance and control.

Also note that due to the criticality of bend stiffeners and bend restrictors in flexible pipe systems, they have been addressed in an appendix to the API Spec 17J, rather than being left to the RP. However, appendices to the specification are not considered to be obligatory requirements and are only intended as guidelines or for information purposes.

As noted above a major effort was expended in the definition of functional requirements, i.e. how the application needs to be specified by the purchaser. It was considered very important that they completely define all the functional requirements of the pipe, so that the pipe design would account for all relevant parameters. This area is covered by Section 4 of the specification, which defines the functional requirements, and Appendix A (Purchasing Guidelines), which gives a detailed listing of information to be supplied to the manufacturer. An example of the purchasing guidelines appendix is given in Table 2.

All three major manufacturers design their pipe cross-sections using in-house proprietary software. The specification defines requirements for this software, in particular that it is to be verified by an independent third party. The requirements of this third party verification are identified in detail and will improve the level of confidence in the results from the design methodologies of the manufacturers. The methodology for this verification, which is intended to provide a consistent background of documentation for API monogramming of standard products, is also consistent with the ISO standards approach to product quality assurance.

Much of the discussions within the JIP forum in the development of the specification centred on the definition of design criteria for the pipe layers. This was mainly due to significant variations in the criteria and basis for the criteria

between manufacturers themselves and between end users. After many revisions it was finally agreed to use permissible utilisation factors for the steel layers and to use strain and creep criteria for the polymer sheaths. The design criteria table from API Spec 17J is reproduced as Table 3. Note that one of the major agreements has been on design criteria which are less conservative than previous, e.g. note that the safety factors on carcass collapse are formulated to allow optimised designs in deeper water.

In the period during the main preparation of the specification a large effort has gone into research on the use of flexible pipes for sour service applications, in particular by Shell, Coflexip Stena

Offshore and Wellstream. The results of this research effort have been used to define the requirements for sour service applications. These requirements are based on NACE qualification tests, though it is to be noted that the steel wires used in flexible pipe dynamic applications have been shown to be sensitive to levels of H₂S which are lower than the NACE definition for sour service.

Recommended Practice

At the time of writing, phase two of the JIP is currently ongoing, with the preparation of a recommended practice for unbonded flexible pipes. A second draft of the document has been reviewed and discussed by the JIP Steering Committee. The main contents in this draft are listed in Table 4. Subsequent to the review meeting for Rev. 2, subcommittees were organised to revise each of the individual sections. The work of the subcommittees was expected to be completed by the end of March with a release of Rev. 3 of the RP at that stage. It is expected that the document will be completed by the middle of 1996 and released to API for review and adoption as an API standard by the end of the year.

The major objectives of the recommended practice are as follows:

- (i) Give guidelines and recommendations in all areas of flexible pipe systems, from design to installation.
- (ii) Provide information backup to the specification.
- (iii) Address evolving areas of technology.

The recommended practice commences with a detailed overview of all aspects of flexible pipe technology and directs the reader to the appropriate sections of the specification and RP for each topic.

The following flexible pipe system issues are considered within the RP:

- System definition.
- Critical issues including interfaces.

- System design.
- Analysis considerations.
- Handling, transportation and installation.

In the objective of providing supporting information and backup for the specification, the RP addresses the following aspects of flexible pipe technology:

- (i) It elaborates on pipe design criteria given in the specification and presents additional criteria for torsion, collapse during installation and effective compression.
- (ii) Possible failure modes for flexible pipes are identified and the consequences and causes of the failure modes are described.
- (iii) Materials commonly used in flexible pipe applications are listed and the agreed ranges of application for these materials are presented.
- (iv) The RP gives detailed guidelines on requirements for prototype tests and presents standardised test procedures.

Finally in the area of evolving flexible pipe technology the recommended practice will give guidelines and recommendations on the following issues:

- Composite materials.
- Material (polymer and steel) test procedures.
- Retrieval and reuse of flexible pipes.
- Integrity and condition monitoring.

Conclusions

The main conclusions from this paper are as follows:

- (i) A draft international standard specification (ISO/API) for unbonded flexible pipes has been submitted for acceptance.
- (ii) This ISO/API specification (draft) is written as a functional standard and meets the objectives of industry initiatives such as CRINE and NORSOK. This industry-wide standardisation will result in significant technical and cost benefits to both suppliers and users.
- (iii) The JIP is currently developing an updated recommended practice for unbonded flexible pipes, which will address all aspects of flexible pipe technology from design to installation and use. This RP will address new evolving areas of technology, including pipe reuse and integrity and condition monitoring.
- (iv) The JIP described in this paper is developing, in collaboration between manufacturers and users, worldwide standards for unbonded flexible pipe, which address all aspects of the technology including, design, materials,

manufacture, test requirements, installation, use, monitoring, etc..

Acknowledgements

The authors would like to acknowledge the contributions of all of the JIP participants to the development of the specification and RP. The participants are listed in Table 1. Numerous other people and companies have contributed to this project and they are also acknowledged.

References

1. API RP 17B, "Recommended Practice for Flexible Pipe", 1988.
2. Bureau Veritas, "Non-Bonded Flexible Steel Pipes used as Flow-Lines".
3. Veritec, "Guidelines for Flexible Pipes", 1987.
4. Det Norske Veritas, "Rules for Certification of Flexible Risers and Pipes", 1994.
5. MCS International, "Specification for Unbonded Flexible Pipe", JIP Doc. No: 5-4-012/SP01, Rev. 5, January, 1996.
6. MCS International, "Recommended Practice for Unbonded Flexible Pipe", JIP Doc. No: 5-4-029/RP01, Rev. 2, October, 1995.

Table 1 JIP Participants.

Amerada Hess, American Petroleum Institute, BHP Petroleum, BP Exploration, Coflexip International, Exxon Production Research, UK Health & Safety Executive, ISO, Kerr McGee Oil, Mobil Research and Development Corp., NKT Engineering, Norsk Hydro, Petrobras, Saga Petroleum, Single Buoy Moorings, Shell Internationale Petroleum, Statoil, Stena Offshore, Texaco Britain Ltd and Wellstream Corporation.

Table 2 API Spec 17J Contents List.

1. Scope
2. Referenced Standards
3. Definitions and abbreviations
4. Functional Requirements
5. Design Requirements
6. Materials
7. Manufacturing Requirements
8. Documentation
9. Factory Acceptance Tests
10. Marking and Packaging

Appendix A Purchasing Guidelines

Appendix B Bend Stiffeners and Bend Restrictors

Table 3 Sample Page From Appendix A

Table 4 Flexible Pipe Layer D

- Notes:
1. Abbreviations used are Environ. = Environmental, a
 2. For mechanical loads the permissible utilisation of pressure armours.
 3. D_{\max} is the maximum water depth including tidal a
 4. The design criteria for the pressure and tensile armo

**Table 5 Proposed Con
Recommender**