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Development of Local Competence on Product Qualification in Support to Risk Management

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ABSTRACT

This article aims to provide an overview on the development of local competence for product certification within NOV Flexibles. A review on state-of-the-art knowledge about product qualification describes the current knowledge on product qualification and its relationship to risk management practice, along with the reasons and the mechanisms for knowledge transfer. The longitudinal study spans the period from the onset of the local organization until recent time, carried out by action research, document analysis and interviews. Then the results firstly include the description of how the qualification framework was carried out, which is followed by discussing the variety of tests that were performed to consolidate the Type Approval Certificate of the NOV factory in the Açu port, Brazil. The study proceeds to exploring the relations between local staff and overseas engineers, and the process to performing the tests and verifying their results for certification. Finally, the article concludes with addressing future directions in the company to evolve the field of certification for the assurance of good practice in certification and risk management.

KEYWORDS

Product certification, risk management, local competence.

INTRODUCTION

To say that a product is qualified does not only mean that it has been successfully tested to a given condition. Bringing oil & gas from wells under the seabed to an offshore platform is the most common use of flexible pipe; when a flexible pipe is qualified, it means is proven to work under all operating conditions within the boundary test conditions. This proof is made through drawing the basis for the integrity assurance requirements, alongside a variety of tests that is intended to verify and validate that the product meets them. Moreover, this places requirement to the ability of a supplier to procure and employ resources that will enable it to guarantee its product to be fit for purpose by design. Using the experience from NOV Flexibles in establishing the production of flexible pipe in Porto do Açu, this paper aims to demonstrate the role of product qualification regarding product risk management, and the value of developing local competence to enable successful product qualification. With focus on the development of activities to support qualification of flexible pipe, this paper is intended as a reference displaying how risk management principles are embedded in product qualification practice.

BACKGROUND

To anticipate operational and strategic uncertainties, businesses need to harness principles of operational sustainability and risk management as drivers into their practice. The increase of complexity in the offshore oil&gas operations requires industry to exceed current regulations and adapt its culture to the needs of the time.

In this environment, risk mitigation technology and practices require an ever-developing workforce, which is empowered with technical judgment and work ethic to do the right thing [1]. The application of risk management principles in the technology development process becomes an essential foundation for evolution and improvement in business practice for the oil&gas industry. This requires organisations to be equipped to investigate, scrutinise, and make evident that technologies and processes are sure to work under their intended use circumstances. Product qualification is one of the areas where these traits are needed the most, as companies need to make evident that their development activities comply to the values that they stand for, demonstrate a record of respect towards managing the uncertainty through developing new products, and ensure their workforce is equipped to face this challenge.

Qualification on the offshore industry

The uncertainties and hazards involved in the operation of offshore activities require that technologies for this market undergo scrutiny on their performance before they shall be produced to operate in the field. This scrutiny is especially important for companies to enable the commercialisation of novel technologies and/or manufacturing processes, because failure to mitigate their uncertainties may bear consequences to environment, society, and the market. This motivates the need for qualifying technologies before making them available for business; this means selling the product accompanied by evidence that its technology functions within specified operational limits and with acceptable confidence [2].

In this context, risk management becomes a matter of anticipating how the product carrying given technology or process will operate. Yet offshore operations bring a twofold challenge to risk management by technology suppliers. On the one hand, offshore oil & gas cannot afford uniformity of application, nor can provide affordable access and monitoring within their operations; the population of specimens of a given product is also quite small in comparison to products from other industries such automotive and aerospace [2]. On the other hand, most products/technologies in this sector are associated with significant hazards due to its nature or intended use. In conformance to directives by international certification bodies – the API RP17B [3] in specific for our case – manufacturers are required to enlist the support of third-party organisations to analyse evidence from the R&D activity. The role of these organisations is to attest that they have witnessed the test protocols and reviewed the results, in such way that their authentication works as proof that qualification requirements are met [4].

Qualification practice as risk management

Under the context of offshore operations, technology qualification works as to uncover risks influencing the development and operation of certain technology. The basic process aims at raising the factors that may influence the fulfilment of the intended solutions, on the following aspects: (1) goals and requirements; (2) novelty and obstacles (3) failure modes and risks; (4) evidence-raising methods; (5) collection of evidence; and, (6) verification of compliance. In this last step, evidences make proof that the technology complies with its stated requirements [2].

Regarding flexible pipe, most aspects of its design as a product are regulated. On prototype testing, for instance, different classes are defined following the complexity of product tests; as from its recommended practice, API sees the following types of tests: Class I tests include standard prototype test protocols with low complexity, Class II comprises specific tests with more complex execution and analysis protocols, and Class III tests are intended for verifying specific properties of pipe structures. Novel pipe designs are required testing in case modifications are intended for commercial production [4].

The prescription of test protocols by API is set per the type of modification in the structure, and per the kind of failure mode the pipe will be tested against. Approaching this practice with a risk management mindset means improving the confidence on testing so that the test results do reflect the actual performance of the product with proven confidence. Obtaining a population of test results under varied conditions, which consistently performs above the integrity criteria, should be the aim for the qualification phase so that this reflects confidence that the product will perform within the area of acceptable operation that is found through qualification testing [6].

The API testing framework can be augmented through a technology qualification approach by: (1) considering a range of requirements and specifications through design documents (design premise + design report), alongside a definition of the qualification basis; (2) assessing new challenges and uncertainties through the participation of stakeholders and the elicitation of expert judgment; (3) identifying and ranking failure modes through expert judgment against the qualification basis; (4) executing and analysing tests to evaluate the arising failure modes; and, (5) performing follow-up during production [7].

Qualification in product development

Qualification work is an essential part of the process to develop and commercialise a new product for the offshore oil & gas market. NOV Flexibles' expertise comprises both the qualification of novel structures and materials for flexible pipe. The work starts with defining a design basis that supports the selection and execution of test protocols. Standard test protocols shall be performed following the prescriptions in appropriate standards. Other design requirements shall be assessed with predictive calculations, intended to support further testing. Specific tests are based on the information from predictive calculations, that help defining the loading protocol and the results to be expected. All test protocols selected for qualification testing are witnessed and analysed by third-party, to ensure the integrity of the test and analysis protocols prove compliance with requirements.

In the case of a deep water dynamic riser, dynamic tests comprised in-plane bending and rotary bending tests that were with the aim of certifying the fitness-to-purpose of the design as well as calibrating predictive fatigue models. The rotary bending test was carried out based on the application setting with a lazy-wave configuration, where the sag bend may involve rotation (bending the pipe to a given radius and then applying cycled torsion) – the pipe was tested, and maintained its integrity to 3.3 million cycles. Thus, the design was seen to follow the results from the numerical fatigue analysis [8].

Based on the understanding of essential requirements to any material to be used as pressure sheath, Flexibles has carried out a qualification programme to demonstrate the suitability of IR-cured Cross-linked Polyethylene (XLPE). Besides the tests required by acknowledged material standards, Flexibles has identified specific design requirements that motivated the in-house development of specific test protocols to prove the suitability of the material to the application environment. For the sealing requirement, samples of the material were demonstrated to maintain leak-tightness well above the requirement from industry standard [9].

Knowledge transfer between organisations

The success of knowledge transfer in R&D is mainly linked to the commonality of knowledge based in between the source and the receiving organisation, besides the understanding of what is understood as source knowledge. Then, knowledge transfer is implemented through making source knowledge accessible and enabling learning protocols at the recipient organisation to help implement the transferred knowledge. The factors with most relevance seem to be the degree to which knowledge is recorded and coded, the closeness between source and recipient teams, and the degree to which norms and culture are shared across source and recipient [10].

The globalisation of R&D activities reflects the diffusion of design and development activities through competence hubs distributed across distant locations, whereas past R&D activities were mostly executed in facilities closely located to global management. Global companies had been through a process of distributing and delegating R&D and engineering work to competence hubs located farther from the global administration and closer to local talent and markets. This is seen mostly as result of a growing trend that started from the adaptation of global products to local market needs, and progressed to the consolidation of application and development knowledge in the markets they operate [11].

The experience of Brazilian development teams within multinational contexts is that the transfer of competence and assignments to local units hangs on the global strategy orienting the development efforts, if there are base competencies that enable understanding of more advanced knowledge or its generation in the local environment. Local development activity is normally jumpstarted by the previous acquisition of competencies under coordination of headquarters abroad, along with incentives coming from market characteristics, government support and available resources for project activities [12].

METHODOLOGY

This article aims to provide an overview on the development of local competence for product certification within NOV Flexibles. This is attained through a retrospective study on the experience by the Engineering department with developing the competences needed to ensure the provision of qualified flexible pipe for use in post-salt and pre-salt oil fields by the Brazilian coast. This retrospective study is carried out through document analysis and action research, the authors being committed to the qualification activities in the positions of Product Engineer and Engineering Manager. Yearly goal assignments in the later years are also considered. In our view, this activity works as a cornerstone to risk management through the verification and validation of design acceptance criteria by proving compliance of pipe structures and design methodology to standards, through authentication and verification of test results by independent third-party agent.

The study comprises testing and qualification activities for flexible pipe, carried out as result of incorporating the product engineering competence into the newly established Flexibles' organization in Brazil. As result of it, the development of local competence for product qualification took place within the following timeline as shown in Figure 1 below.

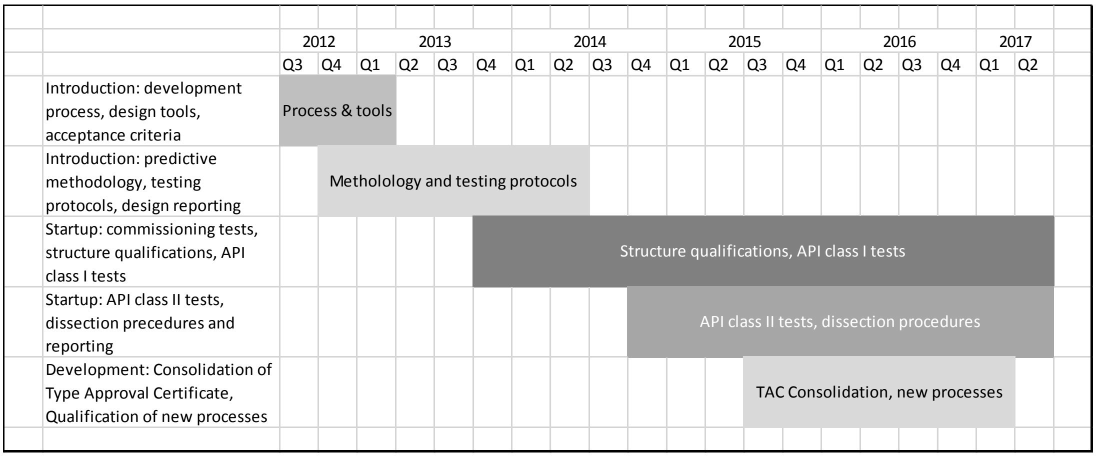

Figure 1 – Timeline of retrospective study.

Document analysis consists of skimming through internal records, gathering evidences and noting relevant information, whereas action research consists of insight gathered through one's own experience through the activities committed to. The work hereby described fits into a descriptive study [13], whose focus is to provide an overview about the process of developing local competence to product qualification. The methodology outline comprises the following aspects of the study: characteristics, document analyses, action research and interviews.

The case being diagnosed comprises project activity regarding the development and consolidation of the Type Approval Certificate for the Açu factory. Document analyses were performed on procedures and reports from tests and dissections, to evaluate the development of design parameters under consideration, and of the techniques in use to evaluate them. Action research consists of an evaluation of the experience gained through one's own commitments. Then interviews consist of a two-round discussion among the authors, to evaluate the development of competence to product qualification and its benefits to risk management.

Table 1 - Research approach for retrospective study.

Characteristics	Document analyses	Action research	Interviews
Case consists of actual project activity	Email records plus test and dissection reports;	Reflections on authors' own experience	Two-round interview between authors

RESULTS AND DISCUSSION

The study is carried out with support of criteria defined by API (17J/RP 17B) and DNV (RP-A203) standards to assess the evolution of competence to product qualification and risk management. The competence development to certification and support to risk management is described below, regarding the practical aspects of engineering work and the competence development transitions, in Table 2.

Table 2 – Results from retrospective study.

	Learning witness → Commitments	API Class I tests → API Class II tests	API Class II tests → TAC Consolidation
Organizational structure and relationships		Coordination and supervision of dialogue	Coordination and supervision of dialogue
Certification of structures and processes	Inclusion of local staff	Experience and methodology applied	Support to program planning and development
Discussion and way forward to engagement			Support to program planning and development

Inclusion of local staff: setting and coordination of test protocols

The acquisition of competence to prototype testing and certification began with a period under which newly hired local staff were involved onto witnessing/assisting prototype testing tasks. This period took place through an internship in the established test facility at Broendby, Denmark, and then following the first commissioning/qualification tests at the new factory along personnel from the mother company who oversaw the activities.

Through the incorporation of the local plant of Porto do Açu in Brazil, the manufacturing equipment was settled with mostly reproducing the equipment used in Flexibles' other plant in Kalundborg, Denmark. While the structure designs to be manufactured in Porto do Açu were already qualified through production in Kalundborg, the innermost layer that has the function of withstanding hydrostatic pressure was to be produced by whole new machines with higher process capability. Hence, the qualification program for the Porto do Açu plant focused the testing and certification of static pipe through Class I API tests. Collapse strength and burst tests (Figure 2) were carried out in Flexibles' own facility in Porto do Açu, and in cooperation with specialized test labs, respectively, with supervision by Flexibles' staff and witnessing from the third-party inspector.

Figure 2 – 6" flowline – burst test sample in test rig.

Following and assisting the test procedures for the collapse test and the burst test on the 6” flowline in loco enabled the inclusion of local staff into the testing of next prototypes to be started production, being the 8” and 4” flowline for commercial deliveries, through originating the test protocols. The requisite for this was to understand the purpose of their tests and the protocols used, and this was relevant to local staff being able to participate in the preparation of test protocols besides giving support to test coordination – such as implementation of work instructions and acquisition of test supplies.

The first phase of qualification testing was completed with testing all-layer samples, which required specific instructions to prepare the samples and test them. This test was coordinated and supervised by local staff with assistance of the mother company through checking the test protocols.

Experience and methodology applied: dissections and API Class II tests

The evolution of competence to prototype testing and certification continued through the hiring of new staff to support ongoing activities, which undertook the same witnessing routine through the ongoing tests in the Porto do Açu plant, with local supervision.

As result from the first tests on static pipe being successfully carried out, local competence was established about API Class I tests and the logical evolution was to have these types of tests fully performed by local staff. Training of newly hired engineers was carried out through the same learning-by-doing process to get them configuring the test protocols and helping carry out the test procedures. Further work involved the dissections after Class I testing of the static pipes, which enabled further learning of the local organization about cross-sectional properties of flexible pipe (Figure 3) and their properties.

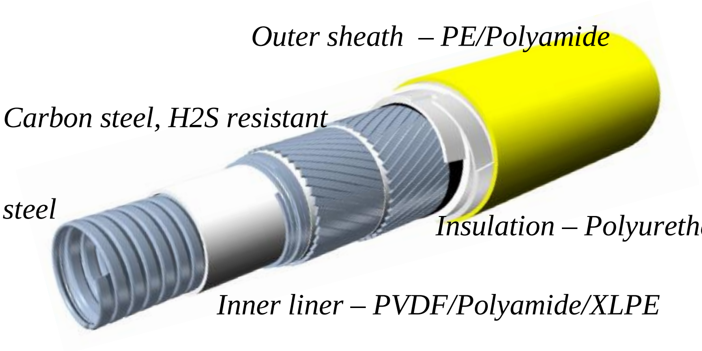

Figure 3 – Cross-section of flexible pipe

Besides these dissections, the qualification program for the Porto do Açu plant for manufacturing flexible pipe involved the dynamic testing of pipe for attesting the ability to manufacture flexible pipe for dynamic application (riser). To achieve this purpose, Flexibles set out an API Class II tension-tension test which was coordinated and supervised by local staff, with methodology support from the mother company.

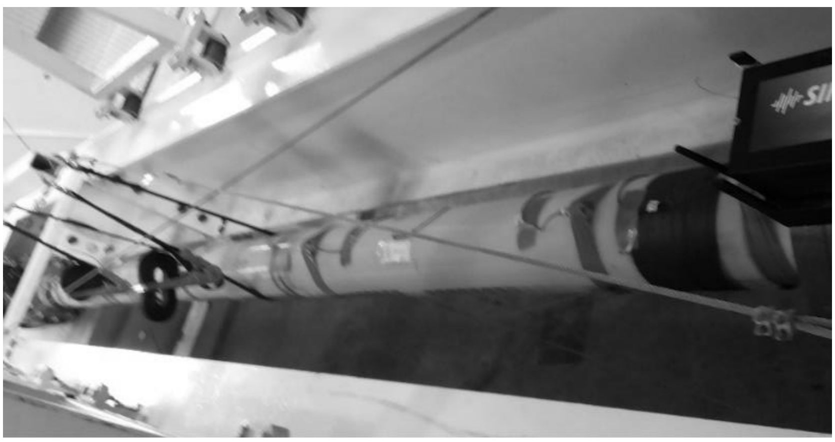

Figure 4 – 4” riser – tension-tension test rig

This test was done with a 4” pipe set up on a test rig structure with remote controls and interlocking safety protocols in place. The test plan was set in load batches to proceed onto the predicted fatigue damage, with leak tests being carried out in the beginning of the test and by the completion of each stage. Flexibles’ staff saw the knowledge of the witnessing phase come in handy when reviewing the installation of the test rig and its assembly of sensors and hardware. One essential competence was to walk the third-party inspector through the setup, regarding both physical equipment/connections and the logical/documental proof, for alignment on the readiness of the test setup.

Once having the test begun, then local staff took charge of supervising the progress of the test and supporting the operations needed for completion of the test. This included the handling of periodic status updates, the setting of non-destructive inspection and the communication of relevant test events towards the completion of the test.

Coordination and supervision of dialogue: review of reports and certification

After the test activities are carried out, these activities have their protocol, results and analyses communicated to the third-party agent for review and attestation that the products designed and manufactured by Flexibles meet the specifications set up during the engineering phase. The organizational arrangement involves two links: one link between Brazilian and overseas units, and other link between Flexibles and the third-party certification agent, as shown in Figure 5.

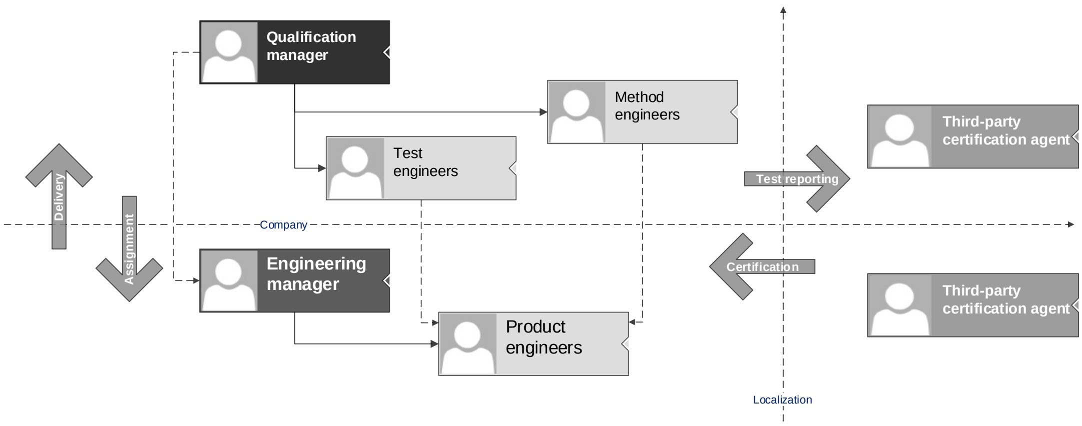

Figure 5 – Organizational description for product testing and certification

On the interaction with the third-party agent, the engineering manager coordinates and supervises this interface with support from staff who carry out periodic follow-up inquiries about ongoing reviews. For example, the qualification of an extrusion process with a new material grade was carried out with local staff coordinating production and third-party witnessing in the manufacturing shopfloor, and liaising with overseas engineers responsible for analysing the material test results. With completing the reviews, the test results – proven successful through the third-party review process – are to be certified into the Type Approval Certificate program. This is intended to generate a file of test performance records that authenticates the performance results of the pipe structures to be higher than their design specification ranges. The process of product certification is carried out in the following steps as in Figure 6.

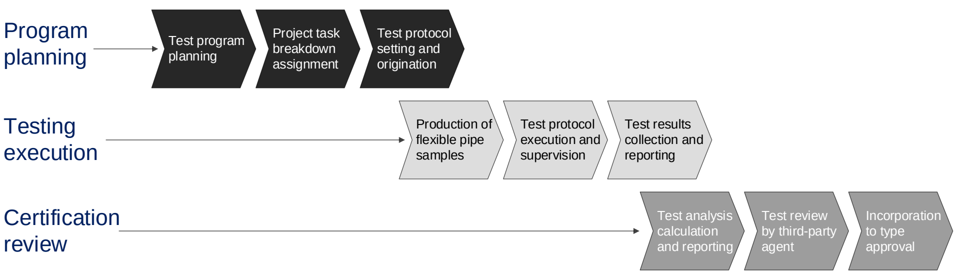

Figure 6 – Process for product certification

The main responsibilities of the local staff along the engineering manager are to ensure that test execution and certification review proceed as planned and within intended results. During this process, the manufactured sample is subject to a test protocol that is intended to test its limits. This principle is the same for all tests regardless of API Class involved. With the experience accrued through the startup and the consolidation of the Flexibles' Brazilian organization, local staff has evolved to taking responsibility over the phases of execution and review in coordination with overseas management.

Overall planning and coordination of testing activities is shared between managers of Flexibles' units and staff in the local unit in Brazil is responsible for liaising with suppliers/contractors, supervising and executing the documentation, the test protocols, and the reporting of test results to the third-party. Test analyses are carried out with control by the overseas engineers responsible for test protocols and for methodology calibration within coordination agreed by the qualification manager and the engineering manager.

Discussion and way forward: support to program planning and development

The achievements so far with the qualification program for the Type Approval Certificate of the Porto do Açu plant are quite positive about the development of local competence to handling product tests and certification. An overview on the results achieved so far through the qualification program of the Porto do Açu plant are shown below in Figure 7. The figure shows the qualification activities for the Porto do Açu plant that were executed in Brazilian territory with support progressing to supervision by local engineering staff.

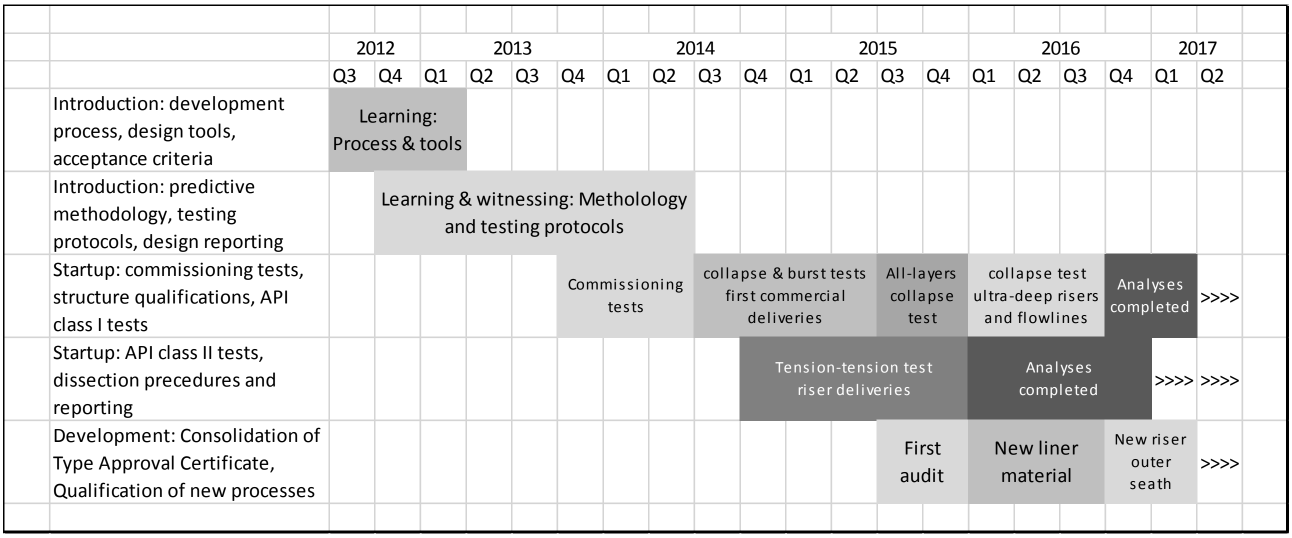

Figure 7 – Timeline of results from product qualification for the Açu plant

Future challenges require a keen eye to the parameters setting improvement and development requirements so that the current approach to qualification does greatly benefit from an overall testing/certification perspective with a risk management mindset. Specific factors to the oil fields by the Atlantic Coastline, such as water depth, aggressive bore environment and high bore pressure (especially on gas injection pipe) make for the opportunity of continued effort towards development, testing and certification of new products that are designed with these factors in mind.

Through Flexibles' own experience, proof of performance is seen better addressed in a qualification program perspective, with the inclusion of a technology qualification mindset. In this context, participation of local staff that are closer to the intended manufacturing facility and have better understanding of the aspects of local manufacturing processes makes the company better equipped to addressing the requirements of flexible pipe for deep waters of the Atlantic coastline.

To tackle this challenge, Flexibles aims to keep focus on its quality of execution while increasing teamwork capability. Table 3 shows the expected competences from local staff to support the execution of qualification activities.

Table 3 – Expected competences from ongoing development stage of qualification activities

Position	Program planning	Testing execution	Certification review
Engineering manager	Propose test scope and distribute test protocol assignments.	Approve testing, inspection, and certification contracts.	Approve reports and communications to third-party review.
Senior staff	Call for resources and do checklists about test assignments.	Check test protocols and follow up on ongoing assignments.	Author/check reports and communications to third-party review.
Engineering staff		Author test protocols and supervise ongoing assignments.	Author reports and communications to third-party review.

Three organizational levels have their competences defined following each phase of a product certification process: management, senior staff, and engineering staff. Management is to be responsible for distributing the test scope, setting the expectations to the team, and approving the production and sharing of evidences and knowledge by the manufacturing company to testing contractors and certification third-party; Senior staff works on a supervisory basis with ensuring that standards and proper test protocols are met, both working inside the manufacturing organization and liaising with testing and certification contractors; engineering staff works in owning individual test activities with regard to test protocols, execution, third-party notifications, and reports/communication for the third-party.

Risk management to technical product characteristics such as design options, materials and manufacturing processes is a part in the certification process to which local competence is required. On our understanding, the handling of dialogue through testing and certification is greatly supported by the deployment of risk management approaches onto testing and certification activities, meaning that question marks assess during the program planning level are properly considered in the execution and review phase. The test certification process is currently ongoing consolidation within the detailed engineering phase [2], regarding the tests of qualification planning, execution and performance assessment. Knowledge of specific requirements for the Atlantic coastline may open possibilities to local staff in participating of the basis and assessment tasks of the RP-A203 qualification process.

CONCLUSION

This paper displayed the framework under which NOV Flexibles developed its local competence for product qualification, in support to managing product risk in the development and commercialization of flexible pipe for the Brazilian offshore market. The background to performing qualification activities has been presented with focus on the use of qualification program in support to risk management, and on the framework of how such program is executed to provide proof of performance and reliability of flexible pipes in the perspective of NOV Flexibles.

The methodology of the paper presented the approach to unfolding how local competence evolved in support to the qualification program on flexible pipe from the Porto do Açu factory. The results and discussion presented the storyline to how the competence to performing qualification work has evolved starting from support to factory commissioning, through tests on several conditions in respect to recommended practice on flexible pipe, and in support to reporting and answering comments from the third party regarding issues on through the test protocols.

The conclusion of this paper summarizes the results achieved by the qualification program so far, with local staff being qualified and able to perform activities under a technology qualification program with an eye on further supporting technology qualification activities by the company.

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