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FULL SCALE QUALIFICATION TRIALS AND CERTIFICATION OF THE AMPLITUDE-LNG LOADING SYSTEM

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1. ABSTRACT

The Amplitude-LNG Loading System (ALLS) has been conceived and developed through a series of phased developments by a consortium of companies, consisting of Technip, Eurodim, KSB and Gaz de France. All development phases, from 1999 to 2006, have been sponsored through JIPs involving major Oil & Gas companies, LNG operators and engineering companies, and the ALLS consortium.

The aim is to provide the LNG Industry with a family of compliant methods of transferring LNG, which can be used in nearshore and offshore environments. By separating the mooring and transfer operations, and using non-dedicated LNG carriers whenever possible, system architectures are kept simple and light, and the operability of the whole LNG chain is optimized. The use of cryogenic flexibles and their integration into a harmonised system will reduce weather down time to an absolute minimum whilst considerably improving safety aspects of marine operations. The methods used are based on the well proven principles of R&D development through small scale and full scale testing, followed at all stages by recognised certification authorities. LNG Industry standards such as OCIMF and EN1474 have been used as the basis of development for the connection assembly, which comprises of a hydraulic QCDC, ERS and guidance system for all connection, disconnection and emergency situations.

The paper examines in detail the full scope of the trials, which are taking place in the Gaz de France Montoir LNG import terminal on the French west coast in 2006. The trials are split into 2 parts. The first part is to install a complete ALLS including a 50m long, 16" ID cryogenic flexible on a dynamic test bench, 70m overall length and 23m high, with a dynamic arm to simulate a significant wave height of 5.5m, and acceleration of $4 m/s^2$. When all components have been verified, "live" LNG from the terminal will be circulated through the complete system and all operations as for LNG carrier transfer operations will be tested. The ALLS will then be installed on the LNG terminal jetty, and offloading from an LNG carrier, through the ALLS with the cryogenic flexible will take place.

All of these operations have been previously validated by a full FEED study, and DNV has carried out Hazid and Risk Assessments and issued a Statement of Feasibility. Through DNV, who is an active partner in this development, this equipment will be certified using their RP-A203 "Qualification Procedures for new Technology" with the final aim of issuing a Statement of Fitness for Service. This will finally qualify the ALLS for both ship-to-ship (side-by-side and tandem configurations) and ship-to-shore architectures. By using compliant transfer systems the safety aspect of LNG transfer operations can be improved by increasing the distance between the LNG carrier and the LNG facilities, whether they are fixed or floating, liquefaction or regasification.

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2. INTRODUCTION

The transfer of LNG has traditionally been carried out using rigid loading arms with the LNG carriers (LNG-C) moored alongside well-sheltered berths with very little influence from wind or wave induced motions. Indeed any positional variation has come from the tidal effects with dynamic movement being limited to a few centimeters in most cases.

With the advent of offshore LNG and the requirement to ensure maximum availability of the transfer facilities in full marine environments, new systems are being evolved and the need for cryogenic flexibles to integrate into a large number of architectures has become prevalent.

The LNG industry has always been, and continues to be, a safety conscious industry, and this has proven to be the only path to follow to maintain an excellent track record and reduce risk to an absolute minimum.

This therefore means that any new systems or equipment must be fully developed, tested, qualified and certified before being offered to the Industry as a whole.

This paper will present the long and methodical period of development of the Amplitude-LNG Loading System (ALLS) and its qualification and certification process. These developments and trials were partly funded through a series of Joint Industry Projects (JIPs) involving a group of major Operators, LNG shipping companies and engineering companies.

3. DESIGN BASIS

A modern LNG transfer station has traditionally been composed of the following main components:

- 3 x 16" internal diameter rigid loading arms for liquid gas
- 1 x 16" internal diameter rigid loading arm for gas return
- 1 x 16" internal diameter rigid loading arm as a spare line

Each loading arm is equipped with a complete safety system, comprising an Emergency Release System (ERS) and a Quick Connect – Disconnect Coupler. In addition a position monitoring system is required to constantly monitor the position of each loading arm extremity. All of this equipment is completed by a complex control system incorporating all electrical, hydraulic and electronic functions.

The design basis of the ALLS was therefore to reproduce the same operational functions but to replace the rigid arms with cryogenic flexibles.

3.1 Operating Conditions

Each liquid gas cryogenic flexible should be designed for:

10,000 cubic meters per hour flow rate of liquid natural gas
Design pressure of 10 bars
Normal transfer pressure of 3 to 5 bars
Operating temperature range from plus 40℃ down to minus 163℃
Design temperature from plus 40℃ down to minus 193 ℃.

Each gas return cryogenic flexible should be designed for:

30,000 cubic meters per hour flow rate of gas
Design pressure of 0.5 bars
Normal transfer pressure of 0.15 bars
Operating temperature range from plus 40℃ down to minus 140℃
Design temperature from plus 40℃ down to minus 163 ℃.

However all flexibles are identical and therefore interchangeable.

3.2 Additional design features

Additional design features for the ALLS were defined as being:

50 thermal cycles per year
Minimum service life of 5 years
No ice formation allowable on the exterior of the flexible itself
Flexible good for aerial service, but able to withstand temporary immersion in seawater.
All materials used to be compatible with LNG
Compliance with existing OCIMF and EN 1474 regulations when applicable

4. COMPONENT DESIGN AND TESTING

Prior to planning a full system test and qualification, the major components were built, tested and certified separately.

4.1 Cryogenic flexible

Due to the temperature and inner diameter constraints, the use of standard plastics in a non-bonded flexible structure is not acceptable.
The flexible structure is therefore composed of (starting from the inner layer):

- A stainless steel bellows to ensure leakproofness, fluid compatibility and flexibility

- Polyester armours and spiral layer to sustain any axial loading and provide an initial thermal barrier
- Thermal insulation tapes to keep the LNG at cryogenic temperature and prevent ice build-up on the outside surface of the flexible
- Intermediate leakproof sheath to contain any internal fluid leak
- External leakproof sheath to prevent any water or humidity ingress and provide mechanical protection for the inner layers.

The construction of a prototype, 16” ID and 17m long, was completed in 2000, and was subjected to a comprehensive test programme throughout 2000 and 2001. This included extensive fatigue testing at cryogenic and ambient temperatures (up to 2 million cycles) and a burst test. In addition small scale testing (8”) was carried out on the internal bellows, as well as tensile tests on the armours also at cryogenic temperature. Bureau Veritas witnessed this series of tests, and a full report issued to them.

This test programme culminated in the issuance of a B.V. Concept Approval Certificate in 2003, reference E&P/10591A 03-001. Full Type Approval certification is to be issued upon completion of full manufacturing procedure documentation and results of a full manufacturing process using a dedicated bench.

4.2 Multi function connection system

This comprises a complete Emergency Release System (ERS) and a Quick Connect Disconnect Coupler (QCDC). In addition, due to the requirement for connection and disconnection in dynamic mode, a mechanical guidance system was also built, integrated and tested. This assembly, known as Connectis™, and developed by KSB and Eurodim, is the second key component of the ALLS.

The main elements are as follows:

- Quick Connect Disconnect Coupler – to ensure ease of connection and disconnection to the LNG-C manifolds, with 6 double locking hydraulic clamps
- Emergency Release System – to allow emergency release under safe conditions. This incorporates double Danaïs offset butterfly valves and actuators, and an emergency release collar.
- Guiding and Alignment Device (funnel, pin, guide fork, cable, winch)

All of these elements (except the Guiding device) were tested separately and assembled, at ambient and cryogenic temperatures, using OCIMF and EN1474 specifications. Bureau Veritas also witnessed these tests and a B.V. Type Approval Certificate was issued in 2004, reference 13031/A0 BV. The full-scale Guiding system was also tested, whilst subjected to heavy vertical and horizontal loads, on a test bench simulating dynamic movement of the LNG carrier manifold.

5. PREPARATION OF A FULL SCALE OPERATIONAL SYSTEM TEST – F.E.E.D.

The requirement to carry out full-scale dynamic testing, with circulation of LNG, was deemed necessary by the ALLS team as well as the group of sponsors. However as no offshore LNG plants exist it was decided, thanks to a proposal by Gaz de France, to study the possibility of carrying out a full-scale test programme in the Gaz de France LNG import and regasification terminal in Montoir, on the West coast of France. Due to the sensitive nature of all such terminals, a complete FEED had to be carried out prior to any final go-ahead being given.

During the execution of this FEED the following objectives for the full-scale test programme were defined:

- ❑ To demonstrate the viability of the ALLS through the qualification of all of the operating procedures and functionalities relative to both sheltered and harsh environment facilities

- ❑ To check and confirm the behaviour and performances of the system on real cryogenic fluid transfer conditions (thermal, hydraulic, vibration etc)

- ❑ To demonstrate in real offloading conditions the performance and compliance of an integrated LNG transfer facility (including a Position Monitoring System) using the ALLS as an alternative to the rigid arms system

- ❑ To prove that the ALLS complies with the needs and requirements of all relevant Authorities and actors involved in traditional terminals

- ❑ To engage Det Norske Veritas (DNV) to manage the qualification of the ALLS, through to issuance of a "Fitness for Service" Statement, using the DNV RP A-203: Certification of New Technology.

The FEED deliverables were further defined as being:

a) General:

- Project Execution Plan (for the Operational trials phase)
- Full test programme
- Planning for Operational phase
- Cost Estimate

b) Qualification:

- Qualification Basis
- Technology qualification Plan
- DNV Statement of Endorsement

c) Test Benches

- Design & General Arrangements
- Flexible pipe configurations
- Procedures and equipment lists

d) LNG carrier

- General arrangement for offloading
- Scantling of loads

e) Loading system

- Cryogenic flexible pipe specifications
- General arrangements (flexible, connecting system, hydraulics, instrumentation, control, position monitoring system)

f) Process and Instrumentation

- Process Flow diagrams
- Piping & Instrumentation Diagrams
- Process description

g) Risk Assessment

- HAZOP study
- HAZID study
- Safety Study

The conclusions of the FEED were that the full-scale trials (known as the Montoir Operational Pilot Unit – Montoir OPU) were feasible, in spite of the added difficulties of working in an operational terminal, in an ATEX (Explosive Atmosphere) environment, and the need for local governmental approval and authorisation. In addition DNV issued a Statement of Endorsement, which stated that the ALLS technology can be proven Fit for Service by successfully carrying out the remaining planned qualification activities, certificate reference SOE 2004/001.

6. MONTOIR OPERATIONAL PILOT UNIT

6.1 Definition

The Montoir Operational Pilot Unit (OPU) consists of a full Engineering, Procurement, Fabrication, Construction, Installation, Commissioning, Testing and Operation of a complete Amplitude-LNG Loading System.

To carry out the project, a full Project Execution Plan (PEP) has been elaborated. There are a large number of interfaces at different levels of interaction to be considered in order to properly organise the OPU.

The PEP had therefore to initially take the following into account:

- Results from the FEED Phase
- Baseline management, Studies and Functional Analysis
- Validation of the FEED prior to OPU realisation phase start-up
- Definition of test programme and authorisations
- Manufacturing of ALLS equipment (FATs, Certification, delivery)
- Installation on-site and hook-up
- Operation of test programme
- Decommissioning
- Certification and final Statement of System Operability

The overall mission statement was defined as being:

To complete the Validation and Qualification of the Amplitude-LNG Loading system by giving factual terms of reference for this new solution of LNG transfer, in terms of –

- Overall performance
- Safety
- Efficiency and user friendliness
- Investment, cost
- Construction time
- Operation / maintenance costs
- Compliance to applicable standards
- System adaptability

and specifically for Montoir, Administrative and LNG Terminal requirements.

6.2 Trials programme

The OPU trials programme was split into 2 distinct parts.

The first part was to perform dynamic trials on a test bench, simulating ship-to-ship operating conditions in open sea. By qualifying to the more “extreme” tandem, or bow to stern, offloading conditions with aerial flexibles, more benign configurations such as side-by-side configurations, were also qualified. The specificities of each configuration were fully examined and treated by DNV. In addition these dynamic trials were to be conducted with flow of LNG, either from the adjacent LNG storage tanks, or from an LNG carrier during discharging mode. This flexibility allowed varying flow rates to be used and measured.

The second part was to install the ALLS, in its supports on the LNG berth, and to offload “live” LNG from a carrier, in parallel with the existing rigid offloading arms, by connecting to one of the midships manifold flanges.

The dynamic trials were to fully demonstrate the SYSTEM OPERABILITY for all required operations in working mode, i.e. at ambient temperature………

Handling, connection, disconnection, emergency disconnection & storage

…….. and then in full operational mode:

Handling
Connection
Cool-down
Transfer of LNG
End of LNG transfer
Purge
Disconnection
Storage

This sequence of trials was to be repeated with LNG flow, both in static and dynamic conditions. In addition an emergency disconnection under cold conditions will be carried out.

The LNG berth offloading also included a complete set of operational procedures prior to LNG transfer. This final phase of the OPU was to fully demonstrate in real LNG offloading conditions, the performance of an LNG transfer using the ALLS, and to prove that this new system complies with the needs and requirements of all relevant actors and Authorities, including LNG terminal supervisor and LNG carrier captain.

6.3 Equipment package

The ALLS consists of 4 distinct packages, these being the cryogenic flexible, the Connectis™ assembly, the support architecture and the Control package.

Prior to the OPU, both the flexible and the Connectis™ have undergone extensive full-scale prototype testing, both at cryogenic and ambient temperatures. This led to Bureau Veritas certification for both components, with Type Approval for the Connectis™ (QCDC / ERS) based on compliance to OCIMF & EN1474 standards, and Concept Approval for the flexible. Full Type Approval for the flexible will be issued by B.V. upon completion of the manufacturing process for the OPU flexible (50m of 16” I.D. structure) and presentation of the full dossier.

The support architecture, as it will be specific to each project, and is in any case part of the dynamic test bench for the OPU, cannot individually certified. However it’s design and acceptance will be required to match the relevant certifying authorities requirements on each project.

The Control package consists of all electrical, hydraulic, instrumentation, control panels, Positioning Management System and information transfer material. This equipment must meet OCIMF and EN 1474 requirements as a minimum. In addition for the OPU package all of the instrumentation sensors required for the trials results must be included. These include sensors for measurement of temperature, flow rate, vibration, pressure drop, angular movement, gas detectors, video cameras, strain gauges, hydraulic pressure etc, etc. In all an impressive 251 measurements will be controlled for the OPU trials.

6.4 Qualification and Certification Process

The reference document for the ALLS trials at Montoir is “DNV – RP - A203: Qualification Procedures for New Technology. This document has the objective of providing a systematic approach to the qualification of new technology, ensuring that the technology functions reliably within specified limits. Its scope is applicable for components, equipment and assemblies, which can be defined as new technology within the hydrocarbon offshore arena.

During the FEED phase a complete 4-day HAZID workshop was carried out on the ALLS, with the identification of 52 activities, 13 of which were considered High Risk, linked to 7 failure modes, on the Risk Classification matrix. The end of the OPU programme will close all of these activities, mostly by presentation of completed reports and documentation, of which 39 will issue from the OPU results themselves.

These failure modes were identified as being:

1. Shut down valves no longer operable
2. Failure of Position Management System
3. Inability to perform purge and drainage
4. LNG Carrier drift / drive off
5. LNG release (emergency disconnection)
6. Pull-in winch fails to connect
7. Mechanical damage to end connector.

It can be readily seen that these 7 failure modes, whilst needing to be fully addressed and resolved, are applicable to any LNG transfer system. By issuance of the Statement of Endorsement, DNV has found that the ALLS technology can be proven fit for service, through the remaining planned qualification activities. In other words, to correctly execute the Montoir Operational Pilot Unit trials.

The awarding of Type Approval, by B.V., for the cryogenic flexible, requires that all manufacturing processes are fully documented and controlled. This is in conformity with standard flexible manufacturing procedures, which B.V. has been carrying out since 1990 through a Guidance Note N1364. This details the qualification and certification process from issuance of Type Approval, through Independent Design Review and Certificate of Conformity. This procedure, through correlation with prototype work, also includes all manufacturing processes, raw material supply and factory acceptance tests, and ensures that, for each type of flexible, repeatability and conformity for repeated orders can be obtained, controlled and guaranteed.

7. RESULTS

Whilst the full results of the trials will not be available until later in 2006, it is worthwhile considering all of the preliminary and preparatory work that has been carried out. This work, which nevertheless consist of many intermediate results, is significant in that no show stoppers have been identified, thus proving that our development period and previous test programmes are leading us to a technically acceptable system, which can be operated in a consistent, repeatable and reliable manner.

These intermediate results include:

- Elaboration of full operational procedures
- Load and configuration analysis of the system in up to 6.5m significant wave height
- Dynamic simulation
- Definition of Control & Hydraulic systems
- Manufacturing of the worlds first single length 50m x 16” cryogenic flexible
- Elaboration of architectures and connection / disconnection equipment & procedures
- Design and manufacturing of LNG carrier spool piece
- Definition of extra loading on LNG carrier midships manifold area
- LNG carrier deck supports
- Qualification and Certification

8. CONCLUSIONS

The aim of this long and detailed development period, which started in 1999, has always been to provide the nascent offshore LNG Industry with a range of compliant transfer systems, which can be used in a safe and efficient manner in all nearshore and marine configurations. By complying with existing standards such as OCIMF and EN1474, especially in the context of operational practices, including emergency procedures, it has been possible to extend the working envelope of LNG transfer systems in dynamic modes. Side-by-side and tandem LNG transfer systems, in marine dynamic environments are now fully available, and the Industry can be assured that they are based on solid qualification methods.

Ease of connection and repeatability of marine operations is a must for all LNG carrier Captains and crew, and by including all architectural design and installation as part of the overall package, all project specific issues are taken into account.

By designing and qualifying new equipment, rather than attempting to modify existing land-based systems, all essential criteria have been analysed and included. The use of cryogenic flexibles enables custom-built solutions that allow the LNG carriers to remain at safe distances from the LNG facilities, whether these are fixed or floating, and liquefaction or regasification.

However the ALLS developments continue and detail design work is already in progress for Marine LNG terminals, incorporating floating flexibles and a fixed or floating single point mooring system. This indeed will be the mirror image of Crude Oil marine terminals and have a major impact on the reduction of environmental impact on coastlines.

The LNG Industry will doubtless continue an exponential expansion throughout the coming decades as natural gas progressively replaces crude oil. By opening up a family of new solutions for safe LNG transfer in marine conditions, this worldwide requirement for more and more LNG terminals can be met in the most effective manner possible.