Qualification of Flexible Fiber-Reinforced Pipe for 10,000-foot Water Depths

Research Objectives
The objective of this program was to develop a novel hybrid (composite/metal) unbonded flexible ultra-deepwater riser which met the following oil & gas industry requirements:

- 10,000 foot (3048m) water depth
- 10,000 psi (690 barg) design pressure
- 7 inch internal diameter
- 120 °C design temperature
- 25 year field life
- Sour gas capability

The top tension reduction offered by flexible fiber-reinforced pipe (FFRP®) enables light weight and small footprint installation vessels and production platforms. FFRP enables installation vessels and floating production systems which previously had water depth limits of 3300 - 6600 ft to be used in ultra-deepwater of up to 10,000 ft. This greatly expands the number of existing installation vessels and FPSO’s that can be used in ultra-deepwater, substantially reducing overall project cost and risk.

Approach
This project was to develop, qualify, and field-deploy FFRP for ultra-deepwater applications in the Gulf of Mexico. FFRP was unbonded flexible pipe with composite reinforcement layers which have the advantages of light weight, high flexibility, and corrosion resistance. Due to these advantages, a simple, low top tension riser configuration was enabled. The initial design basis, was a 7-inch ID, 10,000 psi design pressure, 120°C design temperature, 3,048 meter design water depth production riser application. The Phase 1 Engineering Study confirmed the FFRP riser and system design was to be employed in the subsequent phases. In Phase 2, a prototype pipe was manufactured and qualification testing was conducted in accordance with API RP 17B recommendations. With successful testing, and approval via a Phase 2 decision stage gate, Phase 3 was an actual field deployment of the riser system with 6 months of performance monitoring.

Accomplishments
Phase 1, the Engineering Study has been completed within budget and schedule, with the following reports documenting the work submitted to RPSEA: Design Premise, Design Report, Failure Mode Effects and Criticality Analysis (FMECA), Manufacturing, Qualification, and Field Development Plans. During the first part of Phase 2, layer material and structure characterization tests were conducted. In addition, a pre-prototype pipe including the structural layers that resist internal pressure and tension loads was manufactured, followed by successful burst and failure tension tests.

Significant Findings
In Phase 1, a feasible FFRP design which meets the project design premise requirements has been developed. A comprehensive FMECA and qualification plan was completed to define a clear qualification path which addresses all known potential failure modes and mechanisms. The governing standards API 17J, API 17B, DNV OS-C501 were applied in the design phase, and DNV RP-A203 and API 17B qualification testing guidelines were utilized to develop the qualification plan. The investigations so far in Phase 2 have demonstrated the new technologies and has facilitated the calibration of the models generated during Phase 1. The test results to date indicate that the pipe structure, end fitting design and selected materials meet expectations for the Phase 1 design premise conditions.

Future Plans
The remainder of Phase 2, included the overall pipe structure manufacture at the new DeepFlex manufacturing facility under construction in Pensacola, Florida, followed by qualification testing in accordance with the plan developed in Phase 1. After successful qualification tests, the pipe length required for field deployment of the riser system was manufactured in Phase 3. Project has been completed.