RPSEA-0002-04 **GRI-04/0168**

GAS PRODUCTION/STORAGE SHUTTLE FEASIBILITY STUDY:

ULTRA-DEEPWATER GAS FIELD DEVELOPMENT

FINAL REPORT

(November 2003 – July 2004)

Prepared by:

Charles N. White and Paul Britton, EnerSea Transport LLC

Luis Bensimon and Tim Dean, Kerr-McGee Corporation

Contractor:
EnerSea Transport L.L.C.
3555 Timmons, Suite 650
Houston, TX 77027

Prepared for:

RESEARCH PARTNERSHIP TO SECURE ENERGY FOR AMERICA
Subcontract No. R-514

RPSEA Project Manager
Robert W. Siegfried
Vice-President, Unconventional Gas Technology

July 2004

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
July 2004

3. REPORT TYPE AND DATES COVERED
Final
November 2003 – July 2004

4. TITLE AND SUBTITLE
Gas Production/Storage Shuttle Feasibility Study: Ultra-Deepwater Gas Field Development

5. FUNDING NUMBERS
RPSEA Subcontract R-514
GRI Contract 8693

6. AUTHOR(S)
Charles N. White, Paul Britton, Luis Bensimon and Tim Dean

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
EnerSea Transport L.L.C.
3555 Timmons, Suite 650
Houston, TX 77027

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING ORGANIZATION NAME AND ADDRESS
Research Partnership to Secure Energy for America
One Fluor Daniel Drive
Sugar Land, TX 77478

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
RPSEA-0002-04

GRI-04/0168

11. SUPPLEMENTARY NOTES
The work documented in this RPSEA report was funded under GRI Contract 8693 with RPSEA, Technology Development for Unconventional and Ultra Deep Offshore Natural Gas Resources.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
The Gas Production/Storage Shuttle GPSS) Feasibility Study was performed for Kerr-McGee Oil and Gas Corporation to develop the conceptual design and assess the technical and commercial feasibility of a gas production system for a generic ultra-deep gas reservoir in 8,000 feet of water approximately 150 miles off the Louisiana coast. The concept allows raw reservoir fluids to be produced directly onto the GPSS, which process and stores separate gas and condensate streams, then transports and unloads the gas into a Gulf of Mexico gas trunk-line system at a site approximately 120 miles from the hypothetical field location. Two GPSS vessels, each able to transport 220mmscf of gas, are used to enable continuous production from the reservoir in this pioneering field development scenario. The feasibility study scope included efforts to address regulatory approval matters and the potential for U.S. fabrication of the GPSS system. Meetings were held with the relevant regulatory agencies to discuss the permitting process and issues on a conceptual level. The team also met with ship and fabrication yards to assess means for fabrication, construction, and commissioning of the GPSS vessels in the United States.

14. SUBJECT TERMS

15. NUMBER OF PAGES
261

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

1. EXECUTIVE SUMMARY

The Gas Production/Storage Shuttle (GPSS) Feasibility Study was performed for Kerr-McGee Oil and Gas Corporation to develop the conceptual design and assess the technical and commercial feasibility of a gas production system for a generic ultra-deep gas reservoir in 8,000 feet of water approximately 150 miles off the Louisiana coast. The concept allows raw reservoir fluids to be produced directly onto the GPSS, which processes and stores separate gas and condensate streams, then transports and unloads the gas into a Gulf of Mexico gas trunk-line system at a site approximately 120 miles from the hypothetical field location. Two GPSS vessels, each able to transport 220mmscf of gas, are used to enable continuous production from the reservoir in this pioneering field development scenario, as shown in Figure 1. Industry-proven technology is used for all of the production and gas handling equipment. The study concludes that the novel GPSS system is technically feasible as a production and transportation solution for deepwater gas field developments. Based on the results of this study, EnerSea Transport has determined that transport and production services for such an offtake development could be provided for a commercially competitive all-inclusive tariff over a 20-year project life based on a production and transport rate of 100mmscf per day. Detailed commercial terms can be established on a project specific basis.

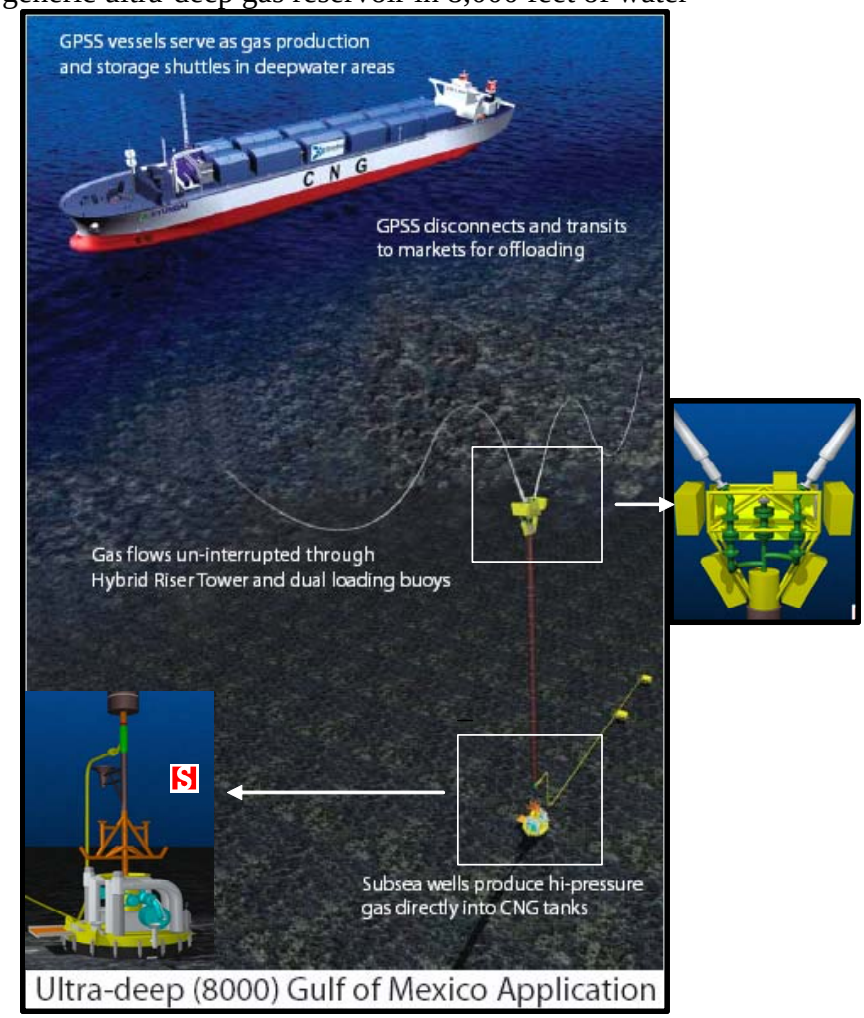

Figure 1 GPSS Development Scenario

The feasibility study scope included efforts to address regulatory approval matters and the potential for U.S. fabrication of the GPSS system. Meetings were held with the relevant regulatory agencies to discuss the permitting process and issues on a conceptual level. The team also met with ship and fabrication yards to assess means for fabrication, construction, and commissioning of the GPSS vessels in the United States.

At Field Facilities (Subsea Systems)

Preliminary flow assurance studies confirmed that Kerr-McGee's standard subsea architecture coupled with the GPSS production control is a feasible development scenario. The two-well

subsea production development uses Kerr-McGee's standard deepwater wellhead assemblies, which are connected by jumper segments to an 8-inch carbon steel subsea flowline.

The flowline connects to the bottom of the Hybrid Riser Tower (HRT) which rises 7,000 feet to within 1000 feet of the water surface to a pair of 6-inch flexible jumpers leading out to the two Submerged Turret Production (STP) buoys supplied by APL (Advanced Production and Loading). Each of the STP turrets are moored to the seafloor using a taut-leg mooring system anchored by suction anchors. The HRT technology is deployed today at Total's Girassol field in Angola in approximately 6,000 feet water-depth and may be extended up to 8,000 foot water depth. This concept is illustrated in Figure 2.

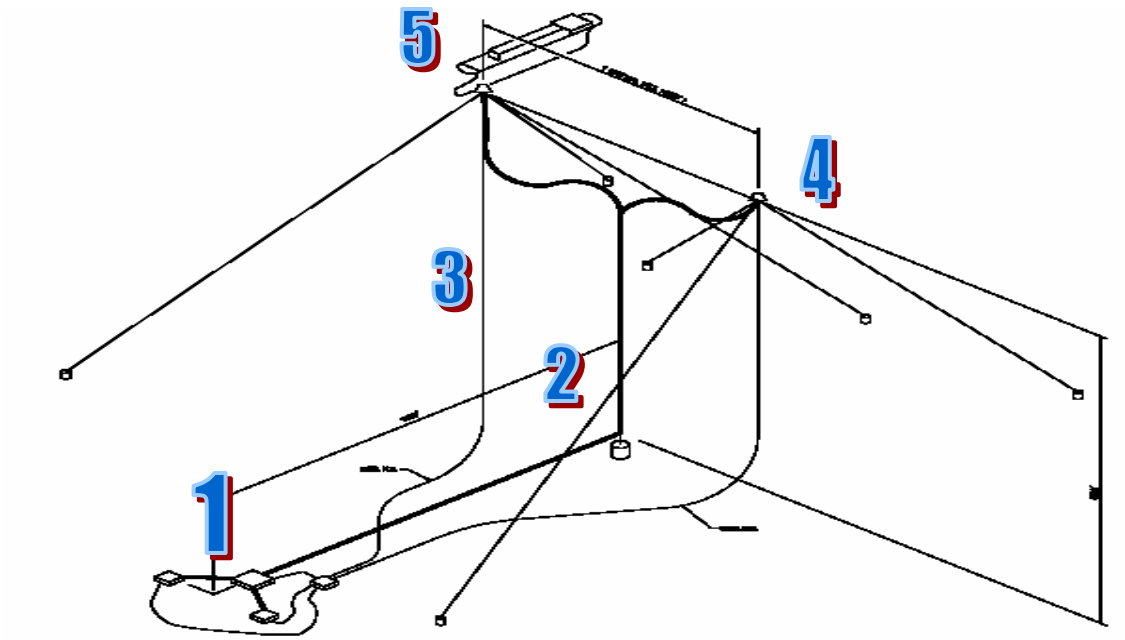

Figure 2: Ultra-deep HRT and Riser System

[**KEY to Figure 2**: 1=subsea well center; 2=subsea flowline & hybrid riser; 3=control umbilical; 4= Submerged Turret Production (STP) buoy with 3 mooring legs; 5=GPSShuttle vessel]

Control, monitoring and chemical injection of the subsea equipment is performed through a typical multi-conductor umbilical connecting the subsea equipment through the turret connected to the GPSS vessel. Control of the gas production is to be provided by the GPSS whenever it is connected to the turret. The two STP units allow continuous production from the gas field with a staged handover of control when switching from one GPSS to the other.

The GPSS Vessel and Operations

Two (2) US flag ships (per Jones Act requirements) are required for the GPSS service, as shown in Figure 3. The 645-foot long ships are dynamically-positioned, twin-screw vessels with diesel-electric propulsion. Diesel-electric propulsion allows convenient load sharing with the gas handling

facilities onboard. Each GPSS is equipped with a forward compartment to enable connection to the STP and STL buoys. The deck and hull spaces adjacent to the turret compartment support the production and gas handling equipment and bulks. The cargo block amidships is comprised of 4 insulated holds that are tightly enclosed to maintain a cold, nitrogen-inerted storage environment. The helm, accommodations, and gas handling facilities main control stations are located aft.

Typical gas field production facilities suited for subsea well applications are located on each GPSS, including methanol, condensate and water separation and handling facilities. Methanol injection at the wellheads is used to prevent hydrate formation. As the produced fluids arrive on the GPSS, separation equipment recovers the methanol and separates the gas and condensate flow stream. The flow streams is cooled down to the storage temperature of -20°F and the pressure throttled and controlled to the initial loading pressure of 1685 psig as it is injected into the gas containment system at the design production rate of 100 mmscfd (note - final storage pressure is 1720psig). The gas containment system on each GPSS consists of 1296 vertical 42" API5L X80 pipe cylinders, each 80 feet long, and segregated into CNG modules of 36 cylinders each with 9 modules placed into each of 4 holds aft.

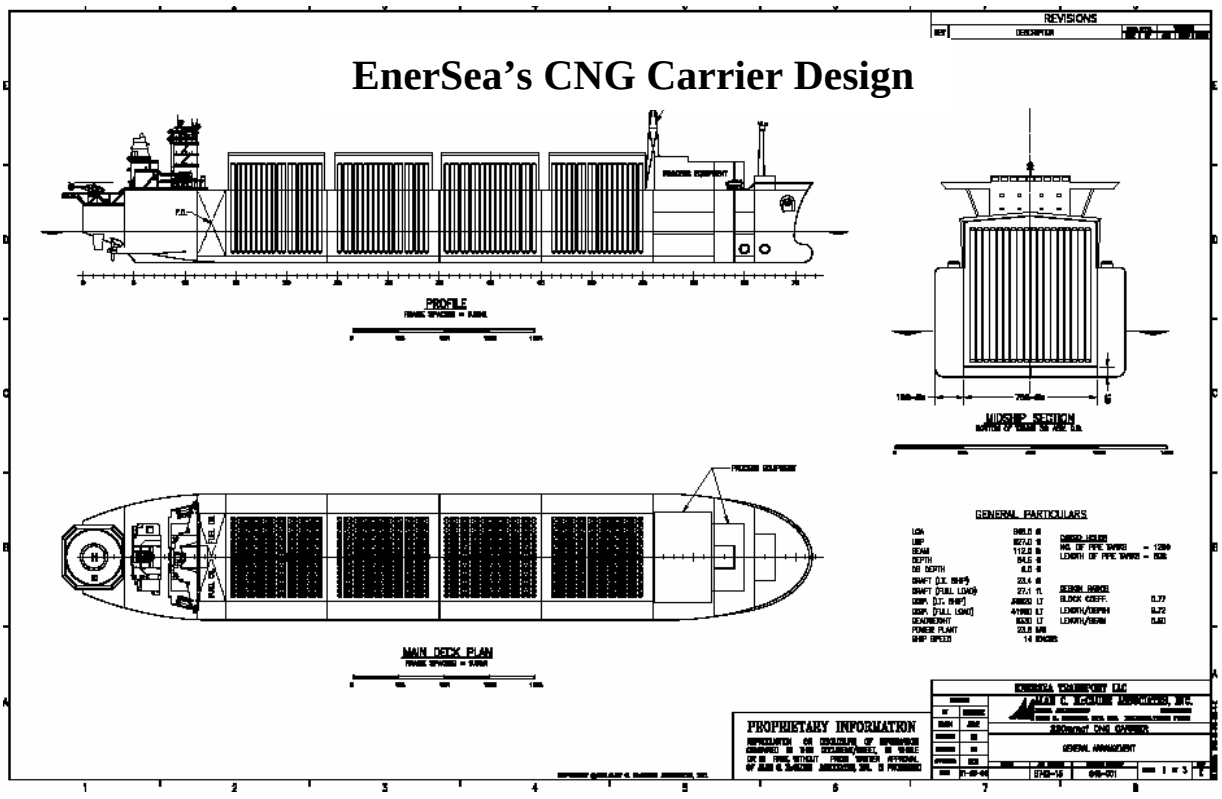

Figure 3 GPSS Vessel General Arrangement

As one GPSS is filled to near capacity, the other, now empty (after unloading) GPSS connects to the unoccupied STP buoy. Control and production flow are switched over to the second vessel in a phased manner to ensure continuous control and production.

The completely loaded GPSS isolates all gas containment facilities and de-pressures all gas handling piping and production vessels prior to disconnecting from the STP buoy. The GPSS then

transits to the unloading buoy, which takes approximately 10 hours at 14 knots. During transit from the field to the delivery point, the cargo handling facilities are idle other than refrigeration used to maintain the cargo temperature at -20°F.

The GPSS connects to a single unloading STL (Submerged Turret Loading) buoy to discharge its cargo into a nominated and commercially qualified pipeline system through an offloading facility at an appropriate Gulf Shelf location at a rate of 220 mmscfd. The unloading time is approximately 24 hours. The product is offloaded at the pipeline pressure and a minimum of 40° F. It is assumed that the temperature of the gas will rise to the minimum trunk-line inlet temperature during transit through the flowline to the tie-in point. After the GPSS is fully unloaded, the gas handling piping and equipment are de-pressurized prior to STL disconnect and transit back to the production field.

Fabrication and Construction

According to Jones Act regulations, the ships must be constructed in U.S. shipyards. To limit uncertainty and risk for the shipyard, the project construction strategy requires segregation of the ship construction and cargo system construction and integration. The GPSS hull and ship systems only, referred to herein as a multi-purpose cargo ship is fabricated and delivered by a U.S. shipyard and transported to a fabrication yard on the Gulf Coast for the installation and overall integration of the cargo containment and handling facilities. The riser tower is fabricated at fabrication site near the shore and towed out for up-righting at the field. The STP/STL buoys and mooring components are fabricated by the suppliers at competitive fabricators.

Regulatory & Permits

The permitting process was discussed with the MMS and Coast Guard on a conceptual level. The novel GPSS process requires permits for a floating production system and a CNG transport vessel. The MMS and Coast Guard would jointly execute a Memorandum of Understanding (MOU) to deal with the dual functionality and oversight roles that they have to play.

The MMS staff responsible for environmental impact assessments has indicated that existing documentation from studies undertaken for the introduction of FPSOs to the Gulf of Mexico provides a suitable basis for “tiering off” environmental approvals of GPSS projects. As such, the MMS has stated that a 6 month Environmental Assessment process is required as opposed to a full Environmental Impact Study, which could take up to two years to complete.

The Coast Guard has confirmed its leadership role in approval of the offloading terminal. The offloading terminal should pose very few permitting problems as the DOT recently approved a similar STL buoy system for an offshore gas port for the El Paso (now Excelerate) Energy Bridge application. The Energy Bridge buoy is projected to be installed and in operation in 2005, which will pave the way for the permitting process of the GPSS system.

Regulatory approvals are likely to be a dominant feature of both the pathway to project sanction and first gas. The codes and interactions between the oversight bodies still need some definition, but project development plans should not be overly conservative about the lead times and activities required to gain the necessary approvals. The regulators are motivated to help resolve the nation’s energy supply challenges and issues around ultra-deepwater gas transportation.

Schedule and Path to Commercialization

The project schedule for introduction of this new technology requires greater lead time than is seen in projects recently undertaken by Kerr-McGee. The lead time to project sanction depends on the level of regulatory approval required prior to commitment of project funding. The schedule for first gas depends on the degree to which long lead items can be defined and committed prior to final project sanction. At present, EnerSea has estimated that with FEED starting in the fall of 2004, project sanction could be achieved by August 2005 and first gas produced (with both shuttles in service) by March 2009.

Conclusions

The Gas Production/Storage Shuttle is a viable concept using a combination of industry-proven technology and the EnerSea VOTRANS (Volume-Optimized TRANsport and Storage) CNG technology, which has received Approval-in-Principle from ABS. There were no technical roadblocks identified that would prohibit the successful permitting, design, construction, and operation of the GPSS as described herein.

The GPSS system, including subsea facilities, risers and buoys are designed to be re-deployable and as such could be used to produce multiple reservoirs in deepwater areas in the GOM and worldwide. These small reservoirs would otherwise not justify development for many years until sufficient reserves are proven in surrounding blocks to justify a "HUB" development. Due to its re-deployable nature, the GPSS system can in essence, be considered as a "virtual hub", providing a gas exploitation solution for multiple fields. The U.S. is projected to be a net importer of gas and therefore needs to develop additional domestic gas reserves to satisfy its increasing gas demand.

The GPSS production and transport service can be offered economically - even for such minimal reserve sizes. It is also assumed that extraordinary royalty relief may also be obtained for fields of this size. Given a gas sales price at Henry Hub of $4.50 per MMbtu (10-year strip as of December 3, 2003), an experienced ultra-deepwater operator such as Kerr-McGee might be able to realize netbacks approaching $1.50 per MMbtu (excluding well costs). Further, at current prices, the available netback to producers should be substantially increased.

Further opportunity and upside exists by increasing the scope of service by adding a third GPSS vessel to support development and operations at a second field after the first field starts its decline, which may result in additional value creation and lower rates for the comprehensive service.

Recommendations

EnerSea recommends that additional work be performed related to the GPSS development, primarily in the following areas:

1. *Project Costs and Schedules – These are the primary project drivers. Substantial investigations related to U.S. ship-building have taken place over the past several years with discussions focused on oil shuttles from FPSO and fixed installations. Alabama*

Shipyard worked closely with Conoco and Samsung to develop a cost-efficient shuttle tanker hull design. It is recommended that additional engineering work and specification of the ship design be performed and direct discussions with Alabama Shipyard take place to develop a more cost-effective and schedule-driven GPSS hull design.

2. *Financing – MARAD provides financing for vessels to be built and operated under U.S. flag under Title 11. This low interest loan and government guarantees could lower the overall financing cost and result in lower tariffs. Additional investigation may be performed to better understand the requirements of Title 11 financing.*
3. *Cost Reduction Options - It is recommended that the cost reduction options as detailed in Section 10, are evaluated relative to their cost impact and doability and selected options be further investigated. In particular, the scenario with a GPSO buoy and a single shuttle, which appears to offer approximately 10% CAPEX reduction, should be further explored.*
4. *Long Term Tariff Reduction Opportunities - It is possible for production to start at a second (smaller) field by adding just one new GPSS ship and subsea field facilities, and sharing the fleet optimally between both fields. New fields could then be added sequentially every few years by re-deploying the riser, buoy, and fleet without adding any new ships. Further, by optimizing fleet service, it should be possible to support additional field developments while expanding the regional fleet by only one ship per field. A new ship could be delivered into this service every year if justified, but the total fleet size operating in the Gulf would be unlikely to ever need to exceed 5 or 6 ships.*
5. *Additional Government Funding – Additional funding for Development Projects such as this, with potential to unlock otherwise stranded gas reserves, may be available for further investigations. Moreover, under pending "Energy Bill" legislation, substantial funding may be made available to support unconventional gas development options. Such funding may be used to offset a significant fraction of the cost to bring the first GPSS solution into service.*
6. *Technology Validation – EnerSea will commence Phase 2 of its Prototype Test Program in the summer of 2004 to complete the testing required to confirm the efficiency of the gas handling system and to confirm the structural integrity of the containment system. Kerr-McGee participated in Phase 1 of this program and is now considering EnerSea's recommendation to continue its participation in Phase 2 of this test program.*
7. *Finally, the regulatory approval process will be expedited if one or more operators begin working proactively with the MMS as EnerSea works to resolve Concept Approval with the USCG. Appropriate action could initiate a "new technology review" by the agency and stimulate MMS and USCG to resolve and issue their MOU for FPSO's (and by extension or addendum cover the GPSS concept).*