Vacuum insulated tubing used in BP's Marlin field

BP'S MARLIN FIELD in the Gulf of Mexico is the focus of a special session at the 2002 IADC/SPE Drilling Conference, 26-28 Feb in Dallas. Session chairmen are **M L Payne**, **BP plc** and **M R Plaisance**, **Diamond Offshore Drilling Inc**.

The Marlin Field is located in the Gulf of Mexico, Viosca Knoll Blocks 817/915, and was originally intended to be produced from a TLP via 5 dry tree penetrations. First production from the A-2 well began in November 1999.

Shortly thereafter, a minor but persistent tubing leak occurred. Between 7 Nov and 20 Nov, Well A-2 was alternately flowing and shut in, depending on shakedown of the surface equipment and availability of the pipeline.

On 20 Nov, the casing pressure jumped to shut-in tubing pressure, signifying a major tubing failure.

This first of 3 papers in the special section, IADC/SPE paper 74528, describes the actions of the incident investigation team formed to evaluate the Marlin A-2 failure. The paper, "Marlin Failure Analysis and Redesign—Part 1, Description of Failure," was prepared by **D W Bradford**, **D G Fritchie**, **D H Givson**, **S W Gosch**, **P D Pattillo**, **J Sharp** and **C E Taylor**, BP plc.

Among the possible tubing failure modes investigated by the team were:

• Helical buckling of the production tubing, with or without the combined loss of a tubing centralizer;

• Crushing of the tubing by ratcheting displacement from a failed centralizer;

• Lateral deflection of the subsea wellhead;

• Collapse of the production (and/or intermediate) casing onto the tubing due to one or a combination of causes;

• Inadequate performance of the tubing or casing, either due to an incorrectly run or inadequately manufactured joint.

Collapse of the production and/or intermediate casing onto the tubing could have been caused by hydrate migration outside the intermediate casing from a shallow hydrocarbon zone, with subsequent dissolution during initial production; or non-uniform loading of the production casing due to the geometry of the sub-mudline pack-off tubing hanger. A leak in the production casing connection could also have been the cause.

Collapse could also have resulted from annular fluid expansion; formation of a heat pipe in the production tubing annulus; or casing wear on the intermediate casing. Finally, excessive initial pressure resulting from setting the casing hanger seal assembly in the subsea wellhead could have been the cause.

FAILURE ANALYSIS

IADC/SPE paper 74529, "Marlin Failure Analysis and Redesign—Part 2, Redesign," was prepared for the Conference by D G Fritchie, **D H Gibson**, S W Gosch and P D Pattillo, BP plc.

The fact that all 5 of the initial Marlin penetrations were predrilled up to the completion stage has the following consequences:

• The remaining wells can be expected to be exposed to the same loads as the failed A-2 well;

• The remaining wells have the same vulnerability as the failed well;

• Apart from the redrill option, one does not have complete freedom in devising solutions for the remaining completions.

Within the limitations posed by predrilling, well design concepts were screened using agreed risk acceptance criteria for health/safety/environment, do-ability and operability.

Based on the risk profile and cost associated with each option, a Vacuum Insulated Tubing (VIT)/Fiber Optic completion concept was selected. Then an extensive assurance plan was initiated which involved the physical testing and analysis of every component.

VIT/FIBER OPTIC

Implementation of VIT required a number of computational and experimental innovations. Provision had to be made for insulating the tubing couplings, the source of 90% of VIT heat loss. And detailed flow loop temperature profiles using both axial probes and radial probes traversing the annulus outside the VIT were created.

> **"...(The use of) vacuum insulated tubing (VIT) and fiber optic/software monitoring system (provides a) means of both controlling and observing well thermal behavior."**
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> **IADC/SPE paper 74530**

IADC/SPE paper 74530, "Marlin Failure Analysis and Redesign—Part 3, VIT Completion with Real Time Monitoring," focuses on the value of the combined VIT and fiber/software monitoring system as a means of both controlling and observing well thermal behavior.

The paper was prepared for the session by **R K Ellis**, **Consultant**; S W Gosch, **D J Horne** and P D Pattillo, BP plc; **P C Shah**, **Landmark Graphics Corp**; and **J Sharp**, BP plc.

As well survival depends on proper VIT performance, a distributed temperature monitoring system was developed and evaluated during full scale testing. On the TLP, fiber optic is run in each well along the length of the VIT to continuously monitor the production annulus temperature profile.

A software system was also developed to take binary fiber data and feed an integrated thermal simulator-casing design software package that calculates safety factors for the B and C annuli. These real time safety factors feed the platform alarm system and are continually monitored by operators.

If a low safety factor is calculated, a well will be shut in. In addition to feeding the platform alarm system, the software system provides data to a web based plotting program. If a single joint of VIT loses its insulating properties, this specific joint can be identified.

Finally, the monitoring system has also proved to be a valuable quality assurance measure for special annular gels used to minimize natural convection in the production annulus, the authors report. ■