5. CONCLUSIONS

Elgin Franklin wells have been designed with a very robust architecture, with state-of-the art equipment, able to cope with the 1100 bar and 200◦C conditions of the Fulmar reservoir. Since start-up, the Operating Philosophy has been based on the strength of the tubulars to manage the abnormal pressures of the annuli through the use of the Annulus Management System.

Communication between the Hod and the G4 A annulus was observed three years after start up in 2004. The gas ingress was coming through leaks in the casing set across the Chalk formation, as indicated by temperature surveys carried out during summer 2007. The suspected cause of these leaks is the failure of pipe connections.

The G4 well also developed abnormal pressure in the B annulus in 2005. The feeding mechanism of the B annulus is understood to be caused by micro-annuli channels in the cement sheath behind the production casing. The channels were probably initiated during completion operations and exacerbated in the life of the well.

Studies made at design stage of these HP/HT wells recognised the requirement to manage pressure arising from fluid expansion and contraction of the annuli generated by the thermal cycles (of more than 100°C) during production start up and shutdown. A permanent Annulus Management System, incorporating the capability to top up the annulus with nitrogen, was installed for the A annulus as part of the deliverables of the Elgin Franklin project. Systems were also subsequently installed for the B and C annuli which had become active particularly after summer shutdowns.

Maximum Allowable Pressures (MAPs) were defined for each annulus on every well, based on casing properties and taking into account actual well conditions. Operating windows (MOPs) were also defined in order to operate the wells safely within the actual design limits provided by the revised MAPs when it became necessary.

The G4 A annulus activity dropped after summer 2007 but started to increase sharply after the 2009 summer shutdown.

In January 2011, the G4 well lost its production due to a collapse of the 7" liner across the Kimmeridge clay, the cap rock above the Fulmar reservoir. The Fulmar reservoir was isolated in February 2011 with a wire line plug set below packer, while waiting for a permanent plug and abandon operation.

During summer 2011, the A annulus had to be bled off frequently to remain within its operating window (300 to 380 bar(g)). It was therefore decided in October 2011 to allow the pressure to build-up in an attempt to balance the pore pressure at Hod level (~800 bar at 4240m). The pressure increased sharply during the first weeks and then exhibited a steady 11 bar(g)/month rise from November 2011 to February 2012. On 25 February 2012, with 563 bar(g) in the A annulus, a sudden pressure drop occurred (down to 440 bar(g)) while the B annulus pressure climbed from 33 to 266 bar(g). This event indicated a deep communication between the A and B annuli, which has now been proven to have occurred at 2217m at a connection of the 10¾" casing. Six hours later a communication between the B and C annuli occurred indicating a failure of the 13⅜" casing. The G4 well has an MLS system for the 13⅜" casing which is suspected as the point of failure for this annulus.

The well situation was recognised as being serious. A task force was set up within the Well Construction and Maintenance Department and information was forwarded to management and all stakeholders. The decision to intervene was made immediately and the operation was given high priority with significant resources being allocated.

The Rowan Viking suspended P&A work on the G8y to allow skidding-in of the cantilever in order to provide access to the G4 slot for wire line work. The main steps of the intervention involved punching the tubing above the packer and killing the well through a circulation down the tubing with returns up the A annulus. The programme called for a first circulation to brine to flush hydrocarbons out of the A annulus followed by 2.05 sg mud, while managing the pressure of the B and C annuli within their operating windows.

Several risk analysis sessions were conducted during the preparation for the G4 intervention including a Risk Assessment, a HAZID and two HAZOPs for different phases of the well intervention operation.

Circulation operations were delayed due to the suspension operations of the G8y and operational difficulties in wire-line work. A first circulation to brine was conducted on 15 March and succeeded in displacing hydrocarbons from the A annulus. However the subsequent circulation to mud did not achieve the killing of the well. The requirement to bleed the B and C annuli very frequently due to the limited operating windows resulted in the inability to maintain a bottom hole pressure above the Hod pore pressure, leading to gas influxes. This was aggravated by the difficulty in continuously circulating the mud, and by a time factor resulting from delays in the wireline activities.

In addition the operation was impaired by unexpected changes in the activity of the well resulting from the following factors:

- Job designed initially for Tubing to A annulus circulation only;
- Escalation of the frequency of bleed offs to manage the B and C annuli within their operating windows;
- Difficulty in circulating mud continuously;
- Difficulty in managing the returns;
- Uncertainties arising from the complex U tube configuration.

It finally became impossible to bleed the B and C annuli due to topsides constraints which led to a pressure surge in the C annulus, and eventually a failure below design of the 20" casing or MLS at approximately 125 bar. The gas was released from the C to the D annulus, and then through the wellhead ports to atmosphere at the platform lower deck.

Drilling of the relief well and a dynamic kill operation were launched simultaneously at the end of March. The well was successfully killed by 15 May and the gas release stopped. The drilling of the relief well was stopped and the rig was released when the well was secured with one cement plug. As at the date of the report the well securing operation was fully complete following the setting of five cement plugs.

A detailed analysis of the causes of the failures below design has not yet been possible, however:

- the 10¾" casing has been retrieved on 5 October, showing a major failure in a connector at 2217m MD/RT Rowan Viking. A detailed failure analysis is now in progress;

- For the 13⅜" casing, the most likely location of failure based on data recorded during the event is at a depth of approximately 160m MD/RT Rowan Viking which corresponds a measured restriction in the Mud Line Suspension area;
- For the 20" casing there has been no opportunity to gather evidence for the failure.

The conclusion of the Root Cause Analysis, supported by all other information available, is that the main causes of the incident are the following:

- Gas flow from an overlying Chalk formation entering the A and B annuli;
- Failure below design of the 10¾" casing and the sequential failure of other casings below design;
- The well intervention programme was unable to kill the well before over-pressurisation of the C annulus occurred.

The G4 Elgin Incident was ranked as a high potential event. However, due to the systems and controls in place there was no injury to personnel, minimum environmental impact and, apart from the damage to the G4 well, only superficial impact on the platform equipment. Nevertheless, production has been shut down since 25 March.

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