1. EXECUTIVE SUMMARY

This report on the G4 Gas Release Incident is based on the analysis of documents and a detailed Root Cause Analysis established with the participation of key personnel from TEP UK who have detailed knowledge of the incident and the operations.

This interim report is based on the best information available. Further forensic tests have still to be carried out on the casing. Future investigations, tests and simulations may shed new light on mechanisms of failure and the vulnerability, or otherwise, of equipment and systems.

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.

The Elgin Field was developed in the years 1997-2001 and its development was at the leading edge of technology using equipment which was state-of-the-art at that time. The production reservoir, the Fulmar, at a depth of around 5500m, is an HP/HT reservoir with an initial reservoir temperature of 200°C and a pressure of 1100 bar(g).

To reach the reservoir the wells are drilled through a hydrocarbon-bearing Chalk formation (at approximately 3500-5000m) with low matrix permeability. During the G4 drilling operations this interval did not raise any concern, since the gas was not mobile owing to the very low petro-physical characteristics of the formation.

The G4 well was a pre-drilled well which required a tie-back operation to re-connect the 30" conductor and the 20" and 13⅜" casings. The 20" and 13⅜" MLS re-connections were made with a stab-in thread. All pressure-containing envelopes were tested satisfactorily and the well was put on stream in March 2001.

Due to the high temperature variations (more than 100°C at mud line and up to 180°C flowing temperature at tree level) during well production operations, an Annulus Management System was provided in the original design to manage the A annulus pressure. Studies conducted at that time defined the Maximum Allowable Pressure (MAP) for each annulus on every well taking into account as-built conditions. MAP's are based on complex casing design calculations including thermal simulations. The MAP's of the A annuli for all the Elgin wells were initially limited by the value of the triaxial safety factor at the top of the cement of the production casing (around 3100m for G4). Later, the limiting factor became the differential pressure across the production packer due to very severe depletion of the Fulmar. Consequently in December 2009 the MAP for the G4 A annulus was reduced from 885 to 731 bar(g), which still provided a significant margin above operating window for the management of annulus pressure.

In 2004 there was a first indication that the G4 A annulus was pressurised by gas which was different from the gas coming from the Fulmar reservoir.

After the 2005 summer shutdown it was noticed that the B annulus exhibited an abnormal behaviour which was interpreted as being due to a potential communication with the Chalk formation through a micro-annulus behind the production casing.

In 2007 a temperature log was run inside the tubing and confirmed that the leaks feeding the A annulus were located at the level of the Chalk formation.

Over time the Annulus Management Systems were enhanced on the Elgin and Franklin Well Head platforms to manage the B and C annuli pressure which had become active, particularly after each summer shutdown.

In 2011, due to the Hod activity in Franklin, an action was initiated to test flow potential from the Hod formation, and a bleed off of short duration of the A annulus was performed in May 2011 on Franklin well F2. This was followed by a longer duration bleed off in December 2011 / January 2012 on the well F3.

In January 2011, G4 experienced loss of production due to the collapse of the 7" liner. It was decided to isolate the Fulmar reservoir with a deep set plug, which was installed in February 2011. Despite stopping production, the pressures in the annuli continued to require management. Full abandonment of the well was incorporated into the 2012 well programme.

In October 2011 the bleeding frequency of the G4 A annulus increased and a decision was taken to let the pressure rise, within the limit of the MAP, in order to balance the pressure in the Chalk formation at the leak depth.

From October 2011 to 25 February 2012 the pressure rose steadily in the A annulus from 300 bar(g) to more than 560 bar(g).

On 25 February 2012 the 10¾" production casing failed at 563 bar(g) (well below its MAP of 731 bar(g)) and the A annulus pressure dropped suddenly to 440 bar(g), while the B annulus pressure rose simultaneously to 263 bar(g). About 6 hours later the 13⅜" casing failed, again below design, allowing a clear connection between the B and the C annuli.

It was still possible to manage the annuli pressures within their defined operating limits and the behaviour of the well started to stabilise. The situation was a significant concern and TEP UK decided to immediately intervene on G4 and set up a task force within the Well Construction and Maintenance department to deal with the situation. Significant resources were redirected to the intervention. The G8y work–over which was in progress, was immediately suspended to allow the rig cantilever to be skidded in order to allow access to the G4 slot for wire line work.

The well intervention team reacted quickly to the situation in issuing the intervention programme for G4. Several risk analysis sessions were conducted for the intervention (two HAZOP's, one HAZID and a Risk Assessment). In preparing the well intervention programme, the level of actual information available on the depths and the extent of the communications, and the complexity of the transient flows between the different annuli was limited.

The Rowan Viking rig commenced work on the G4 intervention on 05 March. At the start of the intervention operation the G4 well behaved as expected. In the course of the programme, rising pressures led to the requirement to bleed the B and C annuli more frequently than expected in order to maintain the pressures within the defined operating windows. This exacerbated the gas influx which was aggravated by the inability to circulate the mud continuously and by operational delays in perforating the tubing. Finally it became impossible to bleed the B and C annuli, due to diverse surface constraints, which led to a pressure surge in the C annulus and a failure of the 20" casing.

On 25 March at 12:29 the gas flowed out of the C annulus to the D annulus (30" conductor x 20" casing), and then escaped through the wellhead ports at surface at the lower deck of the platform. It is considered most likely that the 20" casing failed at MLS level (below test pressure).

Following the gas release, the platform safety systems functioned correctly and the Rig and the Platform were evacuated in an orderly fashion, supported by the early establishment of the Emergency Response Room and Crisis Management Team.

Following the incident all planned pollution response measures were quickly put in place to the satisfaction of UK Government bodies. In addition, comprehensive modelling, sampling, analyses and surveying programmes were conducted to enable monitoring and environmental assessment of the incident. An Elgin Gas Leak Government Industry Group was set up by DECC and subsequently two reports have been issued, stating that environmental impact from the incident is minimal.

Drilling of a relief well and a dynamic kill operation were launched simultaneously at the end of March 2012. 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. G4 is now fully sealed 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 was retrieved on 5 October, and appears to have sustained 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 to 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.

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