Incident description

Hydrocarbon gas was detected on the main deck. A loose gas tube inside a shell and tube heat exchanger had rubbed against adjacent tubes until its wall thickness had become so thin that it began to leak. This leak developed into a ductile final fracture which opened the tube to a 131mm flange.

The hydrocarbon gas followed the seawater down through the seawater caisson to the outlet, where it spread to the riser module and main deck. Pressure blowdown and automatic deluge were activated in these areas. The leak rate was assessed as 2kg/s.

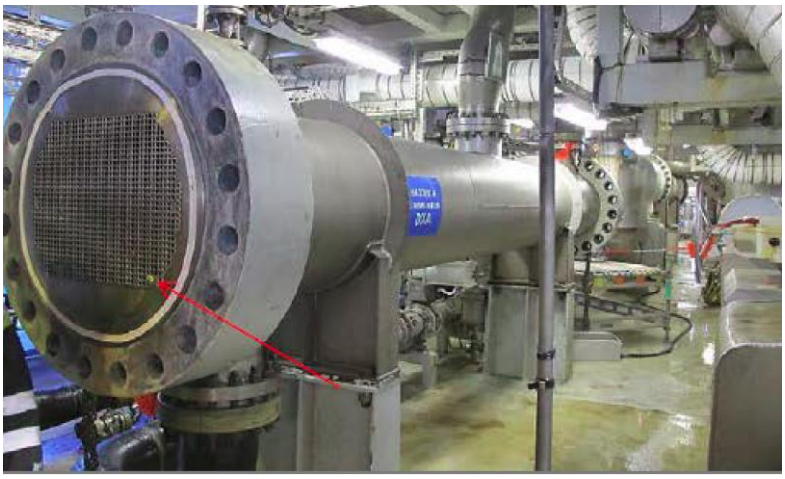

Figure 1: Gas cooler. The leaking tube is identified with an arrow.

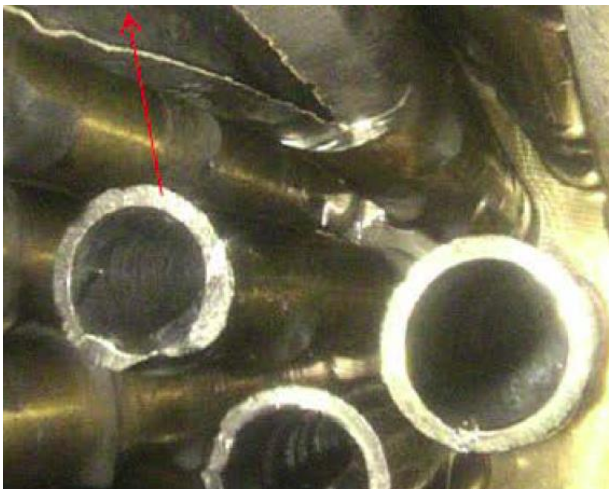

Figure 2: Video inspection after the incident. The leak site is marked with an arrow. Seen towards the cylinder plate.

Causes

Direct causes

- The gas tube in the heat exchanger had rubbed against adjacent tubes until its wall thickness had become so thin that the tube began to leak and subsequently fractured.
- The aspirator system with detection functioned poorly and gave a low alarm (clogged by moisture and salts in the conductor).
- The gas detector was circumvented (disconnected) and failed to activate ESD.
- The rupture disc did not burst.

Underlying causes

- Weakened integrity of the heat exchanger owing to rubbing between baffle plate and gas tube.
- The heat exchanger could have been exposed to seawater rates above its design level over a long period since start-up.
- Excessive capacity selected to the valve in connection with design.
- Recommendations from the supplier indicated that it was acceptable to exceed the heat exchanger's design load.
- Flow-induced vibration (high seawater rate through the heat exchanger).
- Unfortunate optimisation of the gas train at maximum gas export.
- Method selected for repair had caused damage to the heat exchanger
    - puncturing method was not adequately risk assessed
    - condition after puncturing was not verified.
- External experts are used for heat-exchanger repair, which means that insufficient leading-edge expertise on such repairs was available internally in the organisation.
- Insufficient expertise on the puncturing method for heat-exchanger gas tubes was available internally on the installation.
- The design was sub-optimal, with 8mm tubing 10-12m from the seawater outlet in the caisson to the aspirator cabinet and gas detector.
- The central control room regarded repeated alarms from the rotameter and gas activation of the gas detector in the caisson as a "disruptive element".
- The detector was old, and difficult to source spare parts for.
- Inadequate system/risk understanding.
- HC gas emerged in vent lines which lacked gas detection.
- The seawater system was not overpressured.

Lessons and recommendations

- A suitable method must be developed for repairing titanium tubes in heat exchangers.
- The design of aspiration and detection of HC gas in the seawater system must be improved.
- HC gas must be prevented from passing via vent lines to the bypass line.
- A good overview of safety systems which have been rendered non-functional must be ensured.