Prior to H2S production, the most significant issue had been performance during adverse weather conditions. During periods of fog or snow, many detectors would report a blocked beam fault condition and, depending on the situation, some would falsely detect gas. As a result, Suncor would frequently be forced to assign technicians to clean the lenses and return the units to service.

The assessment team involved personnel from safety, risk analysis, operations, instrumentation and controls engineering. Based on the need to upgrade the gas detection system to detect H2S and the LOS detector performance issues, several projects were initiated.

The first initiative was to build a gas dispersion model for the Terra Nova FPSO and use this analysis to complete a comprehensive gas detection evaluation and optimisation study. In parallel, Suncor began to investigate and trial various gas detection technologies that could address the problems with the existing system and detect both flammable and toxic gas releases.

**Evaluation of the Gas Detection System**

Detailed analysis based on computational fluid dynamics (CFD) modelling was performed for the Terra Nova FPSO by GexCon. The overall objective of the analysis was to test and optimise system performance and suggest improvements for the existing system and detector layout.

The CFD model FLACS was chosen in the present study because it allows the simulation of the relevant toxic and flammable gaseous releases, the modelling of the detailed geometry within the facility, the simulation of both natural and forced ventilation within the facility, the evaluation of gas concentration measured by line and point detectors, the evaluation of danger potential for the dispersion cloud, and the ability to perform parametric sensitivity and optimisation studies. The geometry of the Terra Nova FPSO was based on a computer-aided design (CAD) model.

The quantitative evaluation of the GDS in the process modules was based on testing the performance for a large set of realistic gas leak scenarios. The ventilation conditions were determined by the wind speed and direction, the heading of the FPSO, large-scale effects from modules and buildings upwind and downwind of the area of interest, as well as smaller-scale effects from buildings, walls, equipment and piping inside the area of interest itself. In aggregate, over 1,400 gas leak scenarios were simulated and used in the evaluation, detector selection process, optimisation and overall design of the upgrade to the gas detection system.

**Selecting the Right Gas Detector Technology**

Since it commenced operation in 2002, the Terra Nova FPSO has relied primarily on LOS detection. Therefore, Suncor’s preferred option was to determine if LOS technology existed that could replace its existing detectors and provide coverage for both flammable and toxic gas leaks. This would minimise structural modifications required to mount new units, avoid having to run new cables and trays, thereby minimising construction time and cost. An extensive search eventually led the Suncor team to lab test, field trial and ultimately select the Enhanced Laser Diode Spectroscopy (ELED™) technology. This technology, developed by Senscient, had the capability of combining toxic and flammable gas detection in a single LOS detector whilst significantly improving the performance and reliability of the FPSO’s overall gas detection system.
In February 2011, a trial ELDS™ unit was acquired and subjected to qualification testing at the Terra Nova onshore distributed control system (DCS) simulator. Over a period of two weeks, stringent performance tests were conducted on the device, under four conditions that were known to generate problems for the existing IR detectors: simulated fog using water mist, direct water spray on the device lenses, plastic of various types placed in the beam path, and snow placed over the lens (approximately 2.5 cm thick). The test results showed no issue with performance for all four conditions.

Using a transmitter-receiver configuration, ELDS™ systems detect and measure gas concentrations at specific target gas absorption wavelengths over distances of up to 200 metres. One of the key techniques that enables ELDS™ to detect small fractional absorbances and eliminate false alarms is Harmonic Fingerprinting. A Harmonic Fingerprint is a specific set of harmonic components introduced by target gas absorption where the relative amplitudes and phases of the components are known and specific to the target gas absorption line that is being scanned.

**Implementation of the Retrofit and Upgrade**

Once onshore testing was completed, a dual Methane-HS ELDS™ detector was installed on the Terra Nova FPSO, in May 2011, in place of an existing IR LOS device that was known to cause issues in the past. The distance between the transmitter (Tx) and receiver (Rx) for this installation was approximately 34 metres. During a trial period that lasted approximately 24 months, the ELDS™ detector performed very well, with zero spurious trips. The only issue identified was a loose mounting bracket that resulted in misalignment, a problem that was easy to identify and resolve. Following the successful offshore trial, a decision was made by Suncor to replace all existing IR LOS gas detectors on the Terra Nova FPSO with the ELDS™ technology. In aggregate, 141 IR LOS detectors were slated for replacement. A recommendation from the study by GeCon added another 17 ELDS™ detectors to provide for additional coverage. Therefore, the overall retrofit and upgrade plan called for the decommissioning or 141 IR LOS and the installation of 158 ELDS™ detectors.

Retrofitting the FPSO while it was on location, in full operation, required significant planning. A thorough work package was developed which provided a plan for the decommissioning of the existing IR detectors, installation of the new ELDS™ detectors and training of personnel. Change out of the LOS detectors commenced in 2013, and is scheduled to be completed in 2015.

**Impact on Safety Performance**

The performance of the upgraded system has been exceptional. Prior to the upgrade, the Terra Nova FPSO experienced 3-5 plant trips, more than 200,000 fault indications and 20-25 unrevealed failures per year. Data from the Terra Nova data historian, maintenance management system and lost production tracking register was analysed to quantify this performance.

A review of the maintenance management system showed that there was an average of 21 unrevealed gas detector failures per year from 2009 to 2013. The signal these IR devices were sending to the control system indicated full health, however, they failed to respond to a function check. The ELDS™ detectors address this problem by completing a daily diagnostic check and signalling a fault if there is an issue. As of December 31, 2014, Terra Nova had not recorded a single unrevealed failure with the laser-based gas detectors. Startup and shutdown of a facility introduce risks that are not present when a plant is in steady state operation. By reducing the number of spurious trips, the time spent in startup or shutdown modes is reduced, thereby decreasing the risk to the facility.

The laser-based sensors installed on the Terra Nova FPSO have a minimum detection threshold that is much lower than the older IR-based detectors. Instead of a hydrocarbon detection threshold of 1 LELm/2.5 LELm (low/high alarm), the laser-based detectors can be set to a threshold of 0.2 LELm/1 LELm (low/high alarm), without experiencing any drifting and related spurious alarms. The effect of this five-fold increase in sensitivity is that the detectable volume of any gas cloud is larger. Increasing the sensitivity of detectors increases the detectable volume and makes it more likely that any given detector will be exposed to detectable gas before the flammable volume reaches a dangerous size. Furthermore, the H2S content on Terra Nova means...
even small leaks can be hazardous, thus increased sensitivity is an important tool to ensure worker safety.

A comprehensive dispersion analysis based on worst case H2S concentrations in the production stream was performed for the entire FPSO. This study revealed that hazardous levels of H2S could occur in the port half of module M04, the area of the process facility where regeneration of glycol and treatment of gas and produced water takes place. Consequently, a dedicated H2S detection system was developed and installed in the M04 module utilising laser-based LOS devices.

Impact on Maintenance and Offshore Operations
A review of performance data from the Terra Nova data historian shows dramatic improvement over the IR devices in spurious trip avoidance. The key metric reviewed was the number of faults/blocked beam indications. Performance data was reviewed from January to December of 2011 for the IR-based detectors as the FPSO was off station for maintenance for portions of 2012 and 2013. Data from June 2013 to June 2014 was used to capture the performance of detectors that had been changed to laser-based systems.

With such a significant decrease in the number of faults, the requirement for technician response and troubleshooting has been drastically reduced. From 2009 to 2013, an average of 234 maintenance work orders per year was generated, relating to IR LOS detectors being in fault. Note that this number does not include the significant number of maintenance call outs during conditions of limited visibility (rain, fog, mist and snow) to clean detectors as these calls are not tracked. From June 2013 to July 2014, there were only 13 maintenance work orders created relating to issues with laser-based devices.

Impact on Production
Historically, the Terra Nova FPSO has experienced three to four production trips per year due to false gas detection. These trips have resulted in production deferments of approximately 50,000 to 100,000 barrels per year. During a trip initiated by gas detection, emergency shutdown valves are closed quickly, equipment is tripped and gas inventory is sent to the flare system.

Shutting down the plant in this manner has potential damaging effects on plant equipment such as generators and gas compressors. The FPSO experienced damage to process equipment during emergency shutdowns several times prior to the installation of the laser-based gas detectors, resulting in prolonged outages and significant repair costs. Conversely, there has not been a single instance of false gas detection with the laser-based gas detection technology.

The experience from Terra Nova demonstrates that implementation of advanced laser-based gas detection technology can result in a significant improvement in safety, reliability and process uptime in industrial facilities where the threat of a toxic or flammable gas leak exists.

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