Title	Health and safety issues associated with changes from dry gas to wet gas operation		
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Introduction

This document has been produced for the guidance of inspectors and highlights health and safety issues to consider when assessing installations that have or plan to change from dry gas to wet operations.

This guidance updates and replaces SPC/TECH/OSD/18 (which is now withdrawn).

Background

Operators of offshore gas installations are adopting a number of strategies to reduce costs. These include reducing permanent engineering and operations staff, employing more contract staff, changing the installation mode of operation from attended to normally unattended (NUI) with remote control and monitoring of operations.

Reduced reservoir pressure from the ageing fields is also driving this trend towards minimum facilities installations.

However a number of recent incidents involving release of production fluids on the installations that have changed from dry gas to wet gas operations have raised some concerns. This guidance outlines key safety issues, which installation operators need to address when considering a change in the mode of operation.

Legal requirements

Regulation 14 of the Offshore Installations (Safety Case) Regulations 2005 requires a duty holder to revise a current safety case when appropriate.

Regulation 24 of the Offshore Installations (Offshore Safety Directive (Safety Case etc.) Regulations 2015, a duty holder must revise a current safety case – when appropriate.

Regulation 22 of the Pipeline Safety Regulations 1996 requires the operator of a pipeline to notify the Executive if there is to be to any change in fluid composition or type.

The changeover to wet gas operations is considered significant enough to require the operator to revise the safety case and instigate appropriate action to comply with the Pipeline Safety Regulations.

Key safety issues

Corrosion management

A change from dry gas to wet gas operation processing is expected to change the corrosion rate as well as corrosion pattern in topsides equipment to a limited extent but more significantly in the pipeline. Presence of CO_2 in the wet gas stream will also increase the general corrosion rate. H_2S in wet environment can cause rapid development of sulphide stress corrosion cracking in susceptible materials.

As part of the changeover to wet gas production the operator should have reassessed the corrosion risks, identified the high risk items and implemented corrosion control measures. Systems known to be particularly at risk include process system sections running wet gas and pipelines. The favoured control measure tends to be the use of corrosion inhibitors (note this is not effective in dealing with H_2S induced cracking problems). Additional corrosion monitoring using corrosion coupons or probes may be required in order to evaluate the effectiveness of the inhibitor.

Pipelines in particular will require special attention.

The operator should have carried out the following as a minimum:

- Model the pressure, temperature, glycol/methanol and corrosion inhibitor concentration along the pipeline. The software tools currently available have limitations which the operator should have allowed for in their assessment.
- Prediction of new corrosion rates and patterns of corrosion. Erosion due to liquid droplet impingement will also need to be considered as part of the reappraisal.
- Establish the maximum corrosion rates and defect sizes that can be tolerated in the pipeline without affecting safety.
- Reappraisal of the remaining life of pipeline and topside piping and pressure equipment based upon the changes in the corrosion rate and pattern.
- Assessed through laboratory tests the effectiveness of corrosion inhibition chemicals.
- Revise the corrosion management system to include injection of corrosion inhibitor, enhanced inspection and continuous corrosion monitoring program and more frequent pigging to remove liquids and maintain an effective film of corrosion inhibitor along the pipe wall.

Pipeline integrity management

Change to wet gas operation will introduce additional hazards which the operator needs to consider when developing the pipeline integrity management plan. Issues to be addressed include:

- **Safety implications of increase in pigging frequency**. Increased liquid content means that the frequency of pigging will be higher thereby increasing the exposure to hazards associated with handling pig launcher and receivers.
- Change in pressure profile and its effect on flow.
- Suitability of existing material for new conditions.
- Increased liquid content (corrosion inhibitor, water and or chemicals to control hydrate formation) will change the flow pattern such that it is difficult to predict thereby creating problems in managing the multi-phase fluid.
- Slug flow in particular will require careful management in terms of ensuring adequate capacity of vessels (slug catchers) at the receiving end of the pipeline to contain the liquid, pressure control to ensure minimum impact loading etc. Computer simulation programmes available commercially are generally very poor in predicting flow pattern under transient conditions such as shut down and start up. Without such tools management procedures will clearly need to be sufficiently robust to accommodate the unpredictable flow regime.
- Hydrate formation within the pipelines will have to be controlled using chemical or other suitable means
- A ‘base-line’ In Line Inspection (ILI) should be carried out before wet gas operations commence. Follow up ILI should then be done (initially after a couple of years then dependant on results) to review if predicted corrosion levels match actual.

- Specialist advice on the subject of pipeline integrity management should be sought from the Gas and Pipelines Team.

Process system and operating parameters

Change in the process fluid composition could result in a significant change in the operational characteristics of the process system, which in turn will markedly influence the operating parameters. The change to wet gas operation should be treated as a major modification requiring a complete reappraisal of the process design, assessment of the adequacy of the plant to operate under the new process conditions and operating parameters i.e. liquid levels in vessels, in particular interface between water and condensate. There should be clear indication of where additional liquids can upset the process balance and this should be reflected in a reappraisal of capacities, protection settings and operating procedures.

There may also be an impact upon the blowdown sequence as liquids are harder to get rid of. This means a re-appraisal of blowdown times etc. Other protection systems such as HIPPS (valve closure times) may be affected by increased liquid inventory within the pipework.

Failure to follow such an approach will lead to problems such as hydrate formation and blocking of fuel lines, liquid carry over to flare or vent system, salt deposition etc. Issues to be considered include:

- Assess the capability of topsides process system to handle large unpredictable movement of liquids during upset and worst case scenarios. With the new commercial gas regime requiring installations to operate at varying outputs the movement of liquid slugs is far less predictable. This means that measurement and control of liquids becomes more critical as the existing equipment may not be able to cope with transient effects.
- Ensuring the adequacy of existing ESD philosophy for new operating conditions.
- Adequacy of existing pressure equipment for new operating parameters.
- Changes to liquid level interfaces in vessels as well as temperatures and pressures.
- Modifications to alarm levels, emergency shut down philosophy/functions.
- Detection (gas, fire) and protection systems (eg pressure relief valves, HIPPS system etc.) would need to be assessed for adequacy. Increased liquid in gas could lead to a reduction in the effectiveness of the existing detection system as a result of changes in the release distribution pattern. The wet releases may remain at lower levels for a longer time and hence be undetected by detectors at higher levels or be registered only after a larger release. The reappraisal may show that greater low level detection is necessary.
- Monitoring and control of precipitation onto system components such as corrosion coupons, control valves and compressor blades.
- The plant will need to be HAZOPed again to account for process, fluid and operation changes.
- Liquids trapped in dead legs. Liquids freezing in instrument tapping pipework causing "trapped pressure" pockets resulting in false readings.

Redundant equipment

The redundant gas drying equipment would need to be made safe and mothballed or removed. Hazards associated with such activity also need to be assessed and the risks managed.

- Redundant equipment should be made safe.

Valve specification (including pipeline valves)

Greater water content could increase corrosion of valve seating material requiring more frequent inspection or replacing with a more resistant material. Presence of liquid may also affect the closure times, which would need to be considered when developing the emergency shutdown logic/philosophy. Issues to be considered include:

- Effect of the increased liquids on the closure times of valves in High Integrity Pressure Protection System and/or High Integrity Pipeline Protection Systems (HIPPS) and emergency shutdown systems under worst case scenarios.
- Enhanced corrosion of valve internals.
- Effect of liquid slugs on valves.
- Potential for hydrate formation and its effect on the ability of valve to operate.

Hydrocarbon release

Increased liquid content may lead to a change in the dispersion characteristics of the hydrocarbon release, which in turn will affect the estimation of explosion overpressure calculations, and fire characteristics.

- The operator would need to assess the significance of any of the changes and instigate appropriate remedial measures.

Structural changes

Structural assessment should be carried out in order to check the effect of any addition or reduction of hardware or any other operating loads as a result of this change.

- Evaluate structural implications.

Drains handling capability

Issues to be considered include:

- Capacity to remove increased fluids.
- Sufficient capacity to treat the increased fluids to discharge specification.

Maintenance regime

Installations, which were designed for all dry gas operation, may require a higher degree of scrutiny of material specifications. Pipework and instrumentation may not be as robust against corrosion attack in a wet environment and this should be reflected in revised maintenance frequencies.

- The impact of liquids service on equipment designed for dry service should be assessed and at the very least, temporary revised maintenance intervention should be catered for until the effects are known.

Installation attendance pattern

Change in mode of operation from attended to normally unattended, will have a significant effect on the maintenance of equipment particularly where a number of trips have to be made in order to complete a task. For example, in a study carried out for a typical southern North Sea gas platform, it was estimated that three eight hour visits by nine persons per week would be required in order to carry out the maintenance work.

This is based on the assumption that all the tools would be available to carry out the particular task, that the weather would be favourable, that the fastenings would be easy to remove and that sufficient aids will be on hand to assist in lifting, manipulating and moving of heavy parts. Until more experience has been gained in managing this activity, including the very detailed planning, it is recommended that safety implication of the change in attendance pattern is assessed before the change is implemented.

By de-manning the beneficial effect of operator intervention to control an unsafe situation is also removed.

- Safety implications of the change in attendance pattern need to be assessed.

Installation flare/blowdown philosophy

Increased water content in the gas could lead to formation of hydrates during blowdown and possibly block the pipes and valves. Pipework and knock out drum capacity need to be assessed for adequacy to cope with increased fluid. The change in the gas composition could lead to a significant change in the combustion characteristics and affect the flare tip's ability to burn the product efficiently and safely. The effect of drop in temperature on the material performance during blowdown should be reassessed.

- Effect of wet gas on blowdown, flare and vent systems needs to be assessed.

Training and consultation

Change in the mode of operation would require retraining of the operatives. This could be accomplished by posting the operations staff to work with the commissioning and testing contractor during both the construction and commissioning phases. Although views of the operations staff were sought by some operators in designing the modifications, they were not always implemented. This is an area where improvement is needed. Use of computer-based training also appears to be popular and has been found to be very effective by some operators.

- Retraining of operatives should be carried out.

Health issues

Hazardous substances

The amounts of methanol, mono-ethylene glycol and corrosion inhibitors are expected to increase following the change in operational mode. The operator will need to reassess the risks, taking into account the increased inventory on the installation and more frequent replenishment from the supply boats. Additional control measures, training of operatives, modifications of management and work procedures and changes to the requirements for personal protective equipment could result from the change in operational mode.

As part of the initial survey of the existing equipment carried out to gather information for designing the modifications, hazardous materials, including asbestos, should be identified so that appropriate precautions can be implemented during the execution of the modifications.

- Hazardous substance risks will require reassessment and management.

Physical hazards

The presence of low specific activity (LSA) scale may increase over a period of time, following the conversion to wet gas processing. The operator will have to establish the likelihood of this occurring by analysing the product and carrying out laboratory tests. If the possibility is established then the organisational structure may need changing to reflect the additional responsibilities concerning the management of all activities that could involve contact with LSA scale. Control of exposure to the radiation is vital, so strict working and monitoring procedures would have to be followed. Extensive PPE will have to be used, including wet suits, breathing apparatus, rubber boots and gloves. In order to prevent contamination of other parts of the installation, strict decontamination procedures would be required. Safe disposal of the LSA scale will also have to be managed.

- LSA scale risks need to be assessed and appropriate control measures implemented.

Ergonomic hazards

As part of the modification of the plant, manual handling of various items is expected. To reduce the possibility of this causing harm to the workers, these activities would have to be planned and appropriate equipment provided to assist with handling the items. Training of operatives to recognise the harm that can be done through unsafe handling and how to carry out these tasks

safely will also help. Sufficient time to complete the task without hurrying will ensure that short-cuts are not taken and thereby reduce the possibility of causing damage.

- Plant construction/modification risks need to be assessed and managed.

Psychosocial hazards

The change in the installation operational mode could lead to an increased feeling of insecurity and helplessness if the operator changes the staffing arrangements at the same time. By involving the workforce in discussions concerning the change and addressing their fears honestly and fairly, some of the feeling of insecurity could be deflated. It would also help if their workloads are manageable and they are adequately trained to meet the demands of the job.

- The operator needs to consider the implications of psychosocial hazards.

Management of change

Issues that the operator needs to consider in planning and implementing the changeover to wet gas operation include:

- Ensuring that organisational changes are addressed.
- All personnel are informed/consulted about the change.
- Responsibilities clearly established.
- Complete safety review (eg HAZOP) is carried out.
- Ensure qualified safety assessors are involved in all stages of the change.
- Implications for training, operational and maintenance procedures etc are recognised and dealt with.
- Checks made to ensure compliance with current safety case documentation such as hazard identification and consequences analysis.
- Ensure safety related changes are facilitated by organisational changes.
- All engineering records, drawings, process diagrams etc. are checked and updated.

Effect on onshore plant

Main purpose of the change is to decrease offshore operational cost, by shifting some of the processing to onshore base. However, this in turn can affect the risk on the onshore operation. Therefore it is very important for Offshore, and Gas & Pipelines inspectors to maintain close liaison with HSE colleagues responsible for regulating the onshore operations.

Conclusions

In the drive to reduce costs a number of operators have either changed or plan to change over to wet gas operations. Recent incidents involving hydrocarbon releases suggest that the change has caused problems with significant safety implications. In this guidance a number of the safety and health issues have been identified that the operator should address in order to reduce the possibility of similar incidents occurring and to generally improve installation safety.

Reduction in the inventory and maintenance requirements as a result of removing the drying equipment will no doubt reduce the risks on the installation. However the transference of the gas drying system to the onshore base is likely to lead to an increase in risk both at the onshore base and in the connecting pipelines.

Further information

For further information, please contact ED 3.1 (Process Engineering).