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Performance Monitoring in Teekay Petrojarl

Criteria, Metrics, Utilisation of Data and Improvement Processes

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Operation of a complex facility in a technology-intensive industry is heavily dependant on accurate and reliable information. Technological development seen in past decades has enabled a digital approach in offshore petroleum industry. All parts of operations are now dominated by digital technology. The objective of a performance monitoring system is to facilitate for skilled professionals to identify opportunities and measures to improve future performance through data collection and validation, development appropriate presentation of information.

This thesis studies Performance Monitoring Systems in offshore oil and gas production and seeks to identify factors that are critical for the system to function successfully. Teekay Petrojarl is used as a case, with an emphasis on loss reporting and indicators. These play a central role in the practical execution of performance monitoring of the company.

The thesis will assess how the system at hand functions as a part of an organisation and as an independent platform of subsystems. An evaluation of a systems ability to collect and validate of data, and to generate and present information, is done. This includes mechanisms to eliminate errors and data limitations as well as means to support decision-making processes.

Statistical data on production loss provides insight into the performance of the facility, as well as basis for further analysis. Key Performance Indicators reflect performance of a facility and are a basis for decision-making processes in the organisation. The study considers the function and value of using KPIs in operations management.

The development of a criteria framework for design and assessment of a performance monitoring system will contribute to improving knowledge and quality of such systems in the industry. Application of the framework on Teekay Petrojarl will provide increased knowledge of the practical application of performance monitoring systems. Potential measures that can improve operational performance are to be in line with the mentioned framework and in accordance with the findings in the analysis of the case study.

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Abstract

The petroleum industry is capital intensive and oil companies are dependent on stable and reliable production. Costs in early project phases must be balanced by revenue in production phases. Improving performance to ensure positive cash flow and competitiveness in the market is imperative. An understanding of past performance is important when the task at hand is improving future performance.

These systems have the objective to improve operational performance by facilitating for well-informed, proportionate and timely decisions. This is done through collecting and validating data, developing it to tangible information and through appropriate presentation. The thesis argues that a Performance Monitoring System can provide opportunities for increased production and therefore revenue, through a reduction of production losses and a higher overall facility output.

An explorative literature review in Operations management, Systems Engineering, Petroleum-Production, and industry experiences is carried out to create a multidisciplinary and integrated theoretical framework. This is synthesised in criteria for system structure, data management and indicators, and can be used to design and assess Performance Monitoring Systems.

The multi-national oil-company Teekay Petrojarl is used as a case where empirical data from two production units illustrate practical execution of performance monitoring in the Norwegian offshore oil and gas industry. An emphasis is given on loss reporting and indicators. The criteria are used to assess the system to reveal strengths and weaknesses, and to serve as a basis for improvement suggestions both for the criteria and for the company.

Integrating internal and external stakeholder interests in the Performance Monitoring System shows as important. Developing a policy that formalises roles, responsibilities and processes is needed for the system to function optimally. The company is advised to revise its system according to this. Management of data is a recurring issue in the industry and the case confirms this impression. Data is available and accurate, but an overall plan for the intent and objective of collecting and processing it is missing. The company should standardise reporting formats and tags to facilitate for internal benchmarking. Increasing visibility of loss causes in the presentation-end could increase system quality.

The thesis increases knowledge on how Performance Monitoring Systems ideally should be structured and establishes a framework to be used in design an assessment of such systems. It also contributes to Teekay Petrojarl by giving important advise on how to improve their system. Further development of the criteria can provide a more robust framework that can improve the practical execution of performance monitoring in offshore oil and gas production.

Norsk abstract

Som deltaker i petroleumsindustrien er et oljeselskap avhengig av stabil og pålitelig produksjon. Kostnader i prosjekters tidlige faser må balanseres av inntjening i produksjonsfasen. Et oljeselskap er også avhengig av å forbedre operasjonell ytelse for å ivareta konkurransekraft og utvikle komparative fordeler.

Denne oppgaven studerer ytelsesmålingssystemer i offshore olje- og gassproduksjon. Disse systemene har som mål å øke operasjonell ytelse gjennom å fasilitere for riktige valg til riktig tid. Dette gjøres gjennom å samle og kvalitetssikre data, bearbeide dette til informasjon og presentere det på en hensiktsmessig måte. Denne oppgaven argumenterer for at et ytelsesmålingssystem kan danne grunnlag for økt produksjon, og derfor inntjening, gjennom en reduksjon av produksjonstap og et høyt og stabilt produksjonsnivå på oljeinstallasjonene.

En utforskende litteraturstudie i driftsteknikk, systems engineering, olje- og gassproduksjon og erfaringer fra industrien danner grunnlag for et integrert og tverrfaglig teoretisk rammeverk. Dette rammeverket blir sydd sammen til et sett av kriterier som kan brukes i design og vurdering av ytelsesmålingssystemer.

Det multinasjonale oljeselskapet Teekay Petrojarl er brukt som case. Her illustrerer empirisk data fra to produksjonsenheter praktisk gjennomføring av ytelsesmåling i Norsk oljenæring. Kriteriene blir brukt til å vurdere dette systemet for å avdekke styrker og svakheter, samt å danne et grunnlag for forbedringsforslag både for kriteriene og for oljeselskapet.

En helhetlig strategi som integrerer alle interessenters interesser i ytelsesmålingssystemet viser seg som viktig. Å utvikle en strategi som formaliserer roller, ansvar og prosesser er viktig for at systemet skal virke optimalt. Selskapet bør revidere systemet sitt i tråd med dette. Håndtering av data er et stadig tilbakevendende problem i oljeindustrien, et inntrykk som også underbygges av casen. Datamateriale er tilgjengelig og riktig, men det mangler en klar plan og hensikt for å samle og behandle data. Selskapet burde standardisere formater og tager slik at intern sammenligning mellom enhetene er mulig. Å øke synlighet i årsaker for tap i presentasjonsdelen av systemet kan også øke kvaliteten.

Oppgaven tilfører kunnskap om hvordan et ytelsesmålingssystem ideelt skal utformes og fastslår et rammeverk som kan brukes i design og vurdering av slikte systemer. Den bidrar også med å gi Teekay Petrojarl viktige råd for hvordan de kan forbedre sitt ytelsesmålingssystem. Videre utvikling av kriteriene vil gi et mer robust rammeverk som kan bidra til at industrien forbedrer praksis med å måle ytelse i olje- og gassproduksjon.

Preface

This document is the thesis of Lars Kristian Holgersen, MSc. student specialised in Marine Operations and Maintenance Management at the study programme Marine Technology in the Department of Marine Technology, Norwegian University of Science and Technology (NTNU).

The thesis is of 30 credits ECTS and is prepared in the spring semester of the final year of studies. It was preceded by specialisation courses and a preliminary project that formed a foundation for the master thesis.

A special gratitude is given to supervisor Professor Ingrid Bouwer Utne and supervisor for the preliminary project Trond Michael Andersen for council and guidance throughout the year. The thesis has been written in collaboration with Teekay Petrojarl who has generously has provided a comprehensive data material and access to all relevant software and documentation. Operations Strategies and Support Manager Roar Bye deserves respect for taking his time and dedicating company resources to give students the opportunity to use Teekay Petrojarl as a case. I would also like to thank the staff in divisions of operations support and engineering for rapid and thorough response to both complex and trivial questions.

Writing the thesis has been both exciting and demanding, personally and professionally. To be able to focus my energy and attention entirely on one topic – with the freedom of disposing time and resources according to my own schedule and needs – has been a very positive experience. Periods with poor progression were quite the contrary.

Finally I would like to thank my friends, family and SO for supporting me and making the master thesis period as painless as possible.

Trondheim, June 2014

Lars Kristian Holgersen

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Terms and Definitions

Availability	The ability to be in a state to perform as and when required, under given conditions, assuming that the necessary external resources are provided.
bbls	Barrels of oil (volume)
bbwp	Barrels of water produced (volume)
BSC	Balanced Scorecard; system used to develop and measure performance in a project or operation
CE	Contract Efficiency; indicator used to measure efficiency relative to a contract
Contractor	Company that owns and operates a drilling rig; Company that manages operation of a petroleum asset on behalf of the operator
Deliverability	Ratio of deliveries to planned deliveries, including effect of compensating elements
Downstream	Sector consisting of refining of petroleum products after midstream sector
DRA	Daily Report Application; software used to validate and present historical performance of facility
Dry Oil	Processed oil that contains a small amount of sediments and water relative to the amount of hydrocarbons
E&P	Exploration and production of petroleum resources
ECTS	European Credit Transfer System; credits given for subjects in higher education
FPSO	Floating Production, Storage and Offloading Vessel; vessels used for oil and gas production
IAEA	International Atomic Energy Agency; organisation for the development and organisation of atomic energy
ISO	International Standards Organisation; international industry standards provider
KPI	Key Performance Indicator; metric used to measure performance
Maintainability	The ability of an item under given conditions of use, to be retained in, or restored to, a state in which it can perform a required function, when maintenance is performed under conditions and using stated procedures and resources
MARPOL	International Convention for the Prevention of Pollution from Ships
MDT	Mean Downtime; average time system is non-operational
Midstream	Sector consisting of transportation of petroleum products after upstream sector
MMscf	Million standard cubic feet; measure of gas volume
MTD	Month do date; subscript used to indicate accumulated values for a month
MTO	Man, Technology and Organisation; methodology focused on relationship between and dynamics of these

MUT	Mean Uptime; average time system is operational
NCS	Norwegian Continental Shelf
NMD	Norwegian Maritime Directorate; national maritime regulatory authority in Norway
NORSOK	Norwegian Petroleum Industry Standard; industry standards provider of Norway
NPD	Norwegian Petroleum Directorate; national petroleum regulatory authority in Norway
OEE	Overall Equipment Efficiency; indicator used to measure performance
OLF	Norwegian Oil and Gas Association; association for companies and organisations within the industry
Operator	Company that manages operation of a petroleum asset, either production or drilling; Company that owns the production licence
PA	Production Assurance; Integrated way of understanding reliability concepts; Activities implemented to achieve and maintain a optimal level of performance in terms of overall economy consistent with the given framework conditions
PAP	Production Assurance Program; program to implement production assurance
PI	Plant Information System; system used for monitoring and control of production plant performance
PIMAQ	Plant Information System delivered by Siemens
PMS	Performance Management System; set of metrics that measure performance
PUF	Production Utilisation Factor; indicator used to measure the actual production with regards to the planned production of an oil production facility
Reliability	The ability of an item to perform a required function under given conditions for a given time interval.
Sm^3	Standard cubic metres, measure of gas volume
SMS	Safety Management System; system to ensure safe operations
SOLAS	International Convention for Safety of Life at Sea
TA	Throughput Availability; availability based on a facility throughput
Upstream	Sector consisting of exploration and production of hydrocarbons
Variability	Variation in performance measures for certain time period under given framework conditions
Wet Oil	Oil that contains a significant amount of sediments and water relative to the amount of hydrocarbons
YTD	Year to date; accumulated values for a year

Chapter 1: Introduction

1.1 Background

The oil and gas industry is technology and capital-intensive. Large and stable cash flow that is reliant on complex and advanced technology is needed to balance the finances in projects with great costs. The oil company is sensitive to failures and must constantly be focused on its fundamental goal in order to stay competitive: improving performance, increasing income. Explicitly the company must maximise revenue with minimal spending. Delivering services and products of sufficient quality and according to contractual obligations and also complying with the legislative framework is imperative to preserve the integrity of the company.

Operation of complex facilities is dependent on accurate and reliable data. Information from upstream processes and equipment enables optimisation of the facility through strategic and ad-hoc improvement processes. A Performance Monitoring System is introduced to facilitate well-informed, timely and proportionate decisions in facility operation by managing data from production.

Advances in technology and the dynamic nature of knowledge-based industry increase complexity in the organisations and in the systems that are used. Combination of new or modified components and organisational changes can generate unwanted effects, such as function duplication and lack of integration of the systems used to execute tasks and misalignment of the objectives of the company and practical execution.

Teekay Petrojarl Production (Teekay Petrojarl) operates nine petroleum production units in the North Sea and in Brazil. Performance monitoring is an important part of continuous improvement onshore and offshore. Erroneous or inaccurate information can result in lost revenue for the company, for instance because potentials for improvement have not been identified, or warning signs for a weary component have not been spotted.

The units continuously face technical and organisational challenges. How problems are solved and day-to-day operation is carried out can be illustrated through assessing empirical data. A case may provide insight in how the company handles complex challenges as trivial problems Ideally the skills, technology and company objectives should be harmonised towards the tasks at hand. Harmonisation of the systems may be a path to obtain a more efficient organisation and also improve performance of assets. In turn this can give increased production and thus revenue.

1.2 Objectives

Four objectives have been defined for the thesis. These are: (1) reviewing relevant and up-to-date literature on the core-topics, (2) introducing a case example with empirical data, and (3) using the literature review to cast a light over the case system in question. This in turn produces (4) key learning points and improvement suggestions for the client company. The objectives will be adressed in a successive order:

I. Literature review

A literature review of performance monitoring of petroleum production and related fields will be given. Industry practices and experiences, established theory from operations management and systems engineering and advances in research can generate a framework of criteria that can be used when designing and assessing a Performance Monitoring System.

II. Case example

The systems used to monitor performance in Teekay Petrojarl are to be described. Processes and indicators will be documented according to how they function as a basis for decision support. Empirical data gives example of how the system functions in practice.

III. Analysis

The described system will be evaluated in the light of the theoretical basis from the literature review. The criteria will be used to assess and score the system as it is documented in the case and empirical example.

IV. Discussion

Potential measures for improvement will be identified. Uncertainties will be discussed together with findings that can improve a Performance Monitoring System. Proposed future development to the criteria and advice to the company will be given.

1.3 Scope and limitations

Performance Monitoring Systems used in petroleum production is the core of the study. The thesis is limited to oil production in the plateau and decline-phase of a field life cycle, where production strategy is aimed towards optimising operational performance, maximising revenue at minimal cost.

Rules and regulations related to the study are based on Norwegian legislation. Industry standards are considered as an important influencing factor on operations since they are applied on a national as well as an international level.

Economics and financial aspects are not regarded as governing aspects, but fundamental assumptions are made, as a required minimum basis for discussion of operations in general.

The scope of the thesis is restricted to assets of Teekay Petrojarl. Processes, systems and equipment within the objective of the thesis but owned or managed by an external party are excluded from the study.

Chapter 2: Method

2.1 Literature review

The first leg of the literature review was carried out in the preliminary project, autumn 2013. Operations Management, Systems Engineering, Petroleum Production and Information Management were established as the key research-fields of interest. The second leg was done in the master thesis project. Importance of elements from information management was reduced and emphasis on Operations Management and Systems Engineering were increased.

Documentation from the company was retreived to provide an understanding of the functional and technical properties of Performance Monitoring Systems. The suite of documents comprised of user manuals, technical documentation and organisational and operational procedures. These documents are subject to non-disclosure. A complete list of internal documents is given in Appendix 1.

2.2 Research strategy

- **Preliminary project**

Autumn 2013 a project investigating the literature and feasibility of future work within the field of performance monitoring and reporting of production performance was done. The project was 7,5 ECTS with Trond Michael Andersen as supervisor and was delivered December 2013.

- **Evaluation and redefinition of problem**

Professor Ingrid Bouwer Utne was assigned as new supervisor. Together with Teekay Petrojarl the scope and limitations for the master thesis was established. Sub-objectives have changed at different occasions during the course of the semester as the project evolved.

- **Literature review**

With the objectives as a viewfinder theory and practices are explored. A literature study in related fields for the scope of the thesis is conducted, with a firm base in the work done in the preliminary project.

- **Case study**

Teekay Petrojarl is used as a case where the Performance Monitoring System is described. Empirical data from two production units is used to illustrate the system properties. A large access to company databases and system documentation is given, enabling a comprehensive case study

2.3 Performance Monitoring Systems

2.3.1 Measurement

One of the key objectives in the operational phase of the lifecycle from a systems engineering perspective is assessment of ensuring desired performance from the system (Blanchard, 2008). Essentially this is information management from operations:

- Collecting and providing data for assessing performance and effectiveness
- Collecting and providing data for historical purposes and feedback

Working systematically to improve performance is in effect increasing the efficiency and effectiveness (Wilson, 2002). Effectiveness is focused on equipment and reflecting performance and condition of a given system. Efficiency is used to measure performance of resources and techniques applied.

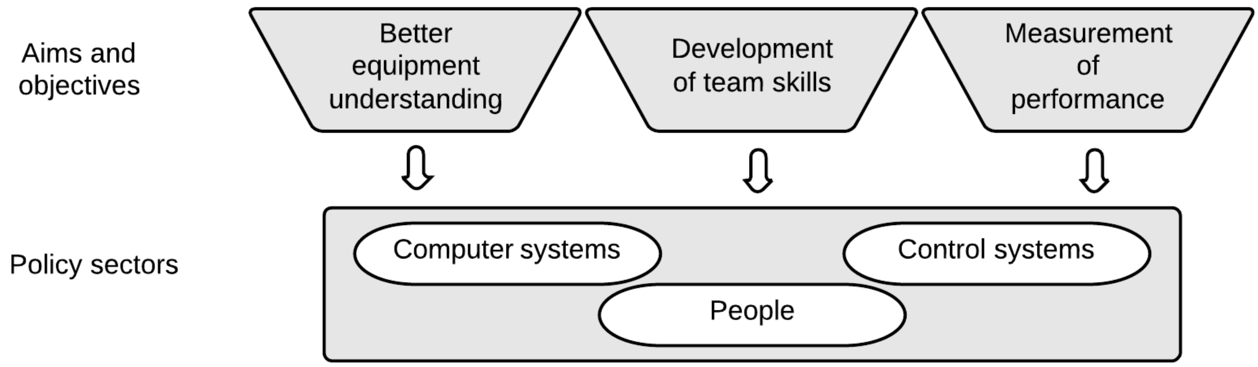


Figure 1: Functions in operations management (Wilson, 2002)

A common method to execute performance measurement (PM) is data collection from the system and processing it into tangible information. The output can be historical data, trends and evaluations of past performance relative to pre-set objectives (Wilson, 2002). Neely, Gregory, and Platts (1995), from fields of operations, production and manufacturing, define performance by using efficiency and effectiveness of action:

- PM is the process of quantifying efficiency and effectiveness of action
- A measure is a metric used to quantify efficiency and/or effectiveness of action
- Performance Management System (PMS) is the set of measures that quantify performance

Amaratunga and Baldry (2002), with background from facilities management, conclude that the primary function of a PMS is to provide a language to formulate expectations in the organisation and to describe the subsequent performance. It is a tool for communication as well as a tool for measuring and evaluating performance and identifying improvement potential.

Neely et al. (1995) state that a PMS can be studied using a structure of three levels:

1. Individual performance measures
2. Performance Management System
3. Relationship between the system and its environment

Tools to quantify performance are metrics, or indicators, that measure or estimate the performance. Indicators should be firmly connected to the objectives of the company, commonly summarised in a set of aspirational statements in strategies and similar or through Critical Success Factors (CSF). Key Performance Indicators (KPIs) are metrics of how well a company has performed in relation to established CSF. The Balanced Scorecard method (BSC) is frequently used to develop and implement metrics, covering the most important areas of a company or an organisation and measure the performance of these (Stapenhurst, 2009).

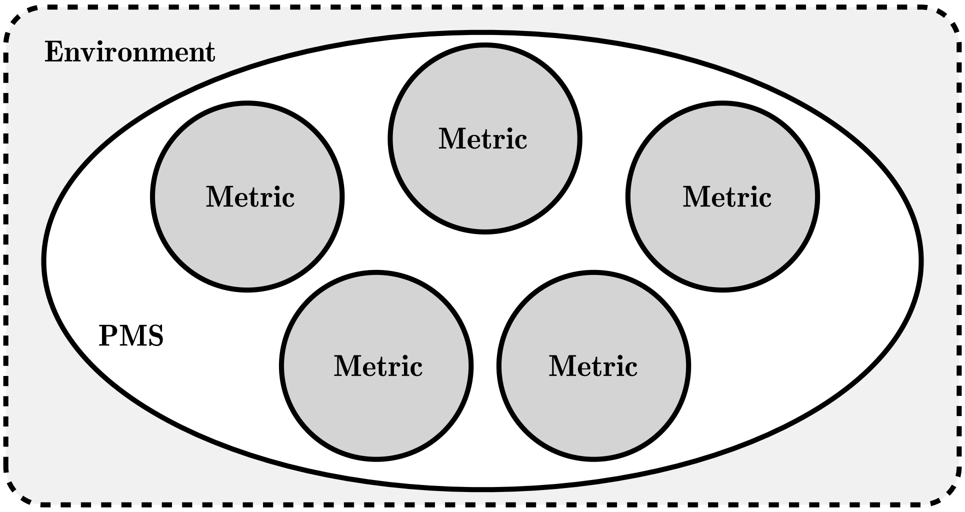


Figure 2: Performance Management System concept according to Neely et al. (1995)

The time orientation of metrics is a characteristic property. Short-term metrics may be more sensitive to change, whereas long-term metrics may provide a more robust indication of the long run. Metrics are internal or external, where internal metrics are measured by the organisation itself, and external metrics are applied by entities outside of the organisation. Leading metrics are characterised by helping to predict future performance, while lagging metrics quantify past performance (Stapenhurst, 2009).

Parnell, Driscoll, and Henderson (2011) discuss measures for monitoring effectiveness and performance of a system in a decision-making context. Developed during the design phase of a system Measures of Performance (MOP) are quantitative expressions of how well a system is able to meet its design specifications. Measures of Effectiveness (MOE) are quantitative expressions of how well the operation of a component or subsystem contributes to the success of the greater system. The importance of the measures to be based on stakeholder values is emphasised. The measures must be connected to objectives so that the requirements of the stakeholders are fulfilled.

Developments in performance monitoring are discussed in Tangen (2004). Metrics should not be solely business- and financially based, but covering several fields. Systems that employ the metrics should move management efforts from being reactive to become proactive and improve the actual performance of the company. The author suggests a PMS to ensure the following criteria if it is to be successful:

- Support strategic objectives in the company
- Have appropriate balance, covering important, success-critical aspects of the company
- Guard against sub-optimisation, providing harmony between improvement potential and what is measured
- Be limited in number
- Be easily accessible
- Be understandable and have a clear purpose for the users.

The International Atomic Energy Agency is a leading industry player in developing performance indicators. The agency has created criteria for selecting indicators for monitoring purposes (International Atomic Energy Agency (IAEA), 2000, 2006):

- Direct relationship between indicators and area covered
- Able to be expressed in quantitative terms
- Unambiguous and well understood
- Goals and thresholds can be specified
- Able to be validated
- Corrective actions can be taken on the basis of the indicator
- Data must be available or able to be generated at high standard
- Data must not be able to be manipulated

Utne, Thuestad, Finbak, and Thorstensen (2012) summarise these criteria as in their paper on opportunistic maintenance in shutdown preparedness. The authors give four key characteristics for the metrics based on Vaisnys, Contri, Rieg, and Bieth (2010) as well as International Atomic Energy Agency (IAEA) (2006):

- Direct relationship between indicators and shutdown preparedness and utilisation
- Relevant data has to be available or capable of being generated
- Indicators must be unambiguous, meaningful and not susceptible to manipulation, possible to validate and importance should be understood
- Indicators should be integrated into normal operational activities and data should be possible to control and verify.

2.3.2 Production assurance

Production Assurance (PA) is an effort to describe the performance of a system one step further than traditional concepts within reliability engineering do. It was initially developed by the Norwegian oil and gas industry in order to face arising issues with production control and meeting customer requirements (Barabady, 2007).

Reliability is well established in most industries when assessing the technical properties of systems. An integrated standardised reliability approach implementing the elements in a systematic manner is key to reach optimal production assurance (International Standards Organization (ISO), 2010).

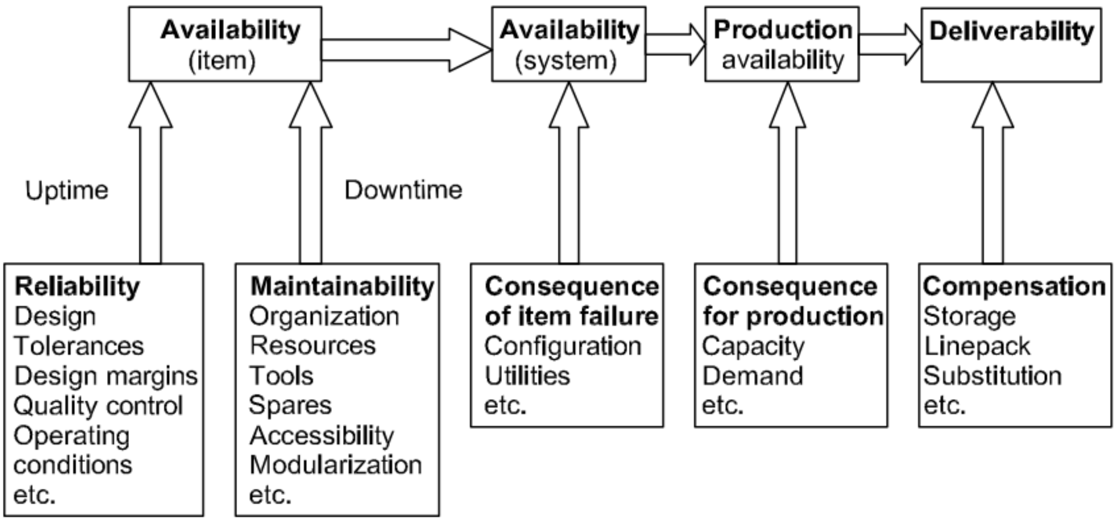


Figure 3: Illustration of the relationship between terms in Production Assurance

International Standards Organization (ISO) (2010) also establishes PA as an integrated way of understanding reliability concepts. They state two recommendations for executing Production Assurance in oil and gas industry:

- It should be carried out and implemented throughout both the design and operational phase of the project
- It should cover broadly across the activities

Formal application of PA can be done through a production assurance program (PAP). This is a system that collects, sorts, processes and communicates the state of the system to ensure that it fulfils the criteria and goals that are set for performance. It will provide a basis for improvement processes, where personnel can find opportunities and measures to improve performance (Barabady, Markeset, & Kumar, 2010b).

International Standards Organization (ISO) (2010) suggests a given setup for a PAP. In the operational life-cycle-phase a continuous or interval-based collection of data together with a regular analysis to identify opportunities for improvement is recommended. The data analysis should be organised and systematic and serve as the fundamental basis in decision-making. Criteria and objectives for performance analysis should be transparent and specified when starting the analysis process. The constituents of the process can be:

- System description covering relevant aspects
- Reliability data from operations
- Model describing the system and process covered
- Analysis of performance, using
  - Performance measures
  - Sensitivity analysis
  - Importance measures
- Results and recommendations

Performance measures can according to the standard be used to successfully carry out analysis in order to optimise production. Production availability of oil, gas and water injection and production, facility availability and deliverability, flaring figures and statistics on loss contributors in terms of components and systems are all mentioned as possible metrics. The standard suggests that all metrics to be within characteristic time-periods, such as plateau period, first year of production or maximum-water-production-period.

Production availability P_A is given in terms of produced volume V_p and reference production volume V_R:

$$P_A = \frac{V_P}{V_R}$$

The standard suggests different methods for determining the reference value:

a. Contracted volume: Specified deliverable from production as specified in contract regulating production
b. Design capacity: maximum production level of the facility, as regulated by technical factors
c. Well-production potential: maximum level of production possible from the well
d. Planned production volume assuming no downtime: Target based reference value using predetermined produced quantity
e. Planned production volume: Target based reference value using predetermined produced quantity, eliminating scheduled downtime

Time-based metrics for production availability using uptime and downtime is also suggested as a metric. Given mean uptime (MUT) T_u, mean downtime (MDT) T_d, the average operational availability A_O is:

$$A_O = \frac{T_u}{T_u + T_d}$$

Some of the methods use planned or scheduled targets as reference. Stapenhurst (2009) defines metrics that are developed using this methodology as plan versus actual-metrics. Having a target value and an actual value generates a variation. Effectively this can be considered as a loss.

$$\text{variation} = \text{actual value - planned value}$$

$$\text{normalised variation} = \frac{\text{actual value - planned value}}{\text{planned value}}$$

Barabady et al. (2010b) criticise conventional availability arguing that it is a poor metric because it does not take into account complex factors such as ageing, lagging behind on technological development, bottlenecks and organisational factors. These are all elements that reduce the efficiency and effectiveness of a facility. Production Assurance is according to the authors a better suited approach because it takes into account the dynamics of a production facility.

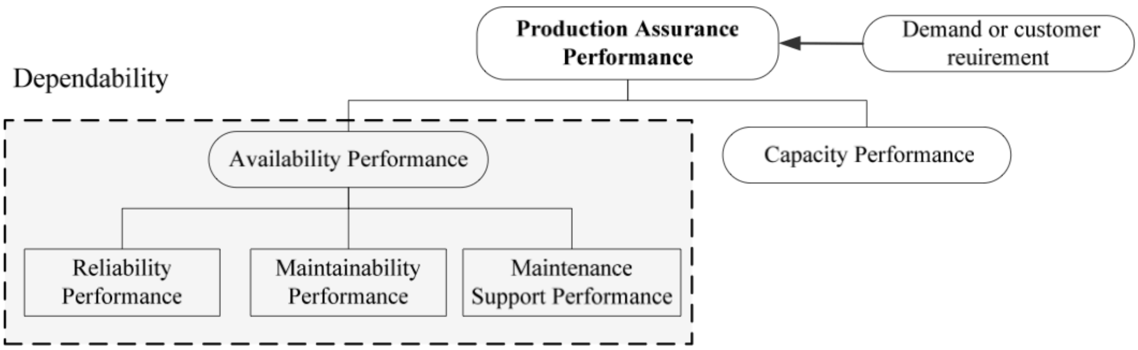


Figure 4: Production Assurance concept (Barabady et al., 2010b)

Capacity performance is the ability of a system to deliver according to its capacity or to its demands. Many factors may cause a suboptimal performance in a production facility, such as reduced equipment or process capacity due to wear and aging and a sub-optimal handling by operators, or composition of material being processed.

Systematic break-down of system together with a capacity performance analysis, may aid the operator in discovering and removing bottlenecks or constraints on the performance (Barabady et al., 2010b).

There are several methods to quantify Production Assurance. A selection of these are given in Barabady, Markeset, and Kumar (2010a). Let actual production rate be denoted by D(t) and planned production rate be $D_0(t)$ the throughput availability (TA) is:

$$\mathrm{A}_{\mathrm{TA}}(t_1,t_2)=\frac{\text{Mean actual production in }(t_1,t_2)}{\text{Demand production in }(t_1,t_2)}=\frac{\int_{t_1}^{t_2} E(D(t))\,dt}{\int_{t_1}^{t_2} D_0(t)\,dt}$$

The TA-method compares actual production towards the demand, defining the demand or maximum capacity for the system together for a given period, and measuring the actual production for the same time period. The TA-method uses a fraction that may surpass 100%. This means that production under the maximum demand of the system may be caught up with a period of production that surpasses the demand.

Production availability can also be calculated using demand availability (DA-method). This method is probabilistically based, and provides an expectancy of the production to be equal to or exceed the planned quantity. On stream availability is another method (OSA-method), which also is probabilistic and gives the expected time proportion of production larger than zero.

Further calculating PA using availability at given level of production in e time period is possible (LTA-method). The research conducted in the thesis of Barabady (2007) resulted in a new metric to reflect the production assurance. Take a given time period and operational availability and Production Assurance can be given:

$$\text{Operational availability}=\frac{MTBM}{MTMB+MDT}$$

$$PA=\frac{\text{Mean predicted operational availability}}{\text{Demand operational availability}}\times\frac{\text{Mean expected capacity performance}}{\text{Demand capacity performance}}$$

Combining this Production Assurance measure with Quality Effectiveness (QE), a new metric can be developed. This is called Overall Production Assurance Effectiveness. This metric can be a possible contender in reflecting operational performances of a facility, competing with the Overall Equipment Effectiveness (OEE) measure.

$$OPAE=PA\times QE$$

$$OPAE=\frac{\text{Mean predicted OEE}}{\text{Demand OEE}}$$

Overall Equipment effectiveness (OEE) originates from Total Productive Maintenance (TPM), a concept developed with a system-oriented approach to maintenance with focus on maximising productivity in the system life cycle (Blanchard, 2008). OEE is defined by Campbell, Jardine, and McGlynn (2010) by combining availability, performance and quality together in one metric.

Although the purpose and application of OEE often is related to maintenance management, it also reflects the performance of the system as a whole. The result is the overall operating effectiveness of the system, corrected with scheduled and unscheduled losses:

$$OEE = \text{Availability} \times \text{Process efficiency} \times \text{Use rate} \times \text{Quality}$$

2.4 Operations management

2.4.1 Introduction

Operations are the technical, administrative and managerial actions that result in that system is at a functional state (Norwegian Technology Standards Institution, 2010). In a commercial environment the overall objective is to generate revenue streams through minimal use of resources. The revenue created by a production facility is increased when losses are reduced and production output is increased.

Production facilities have a maximum level of output and operating at this level at all times is possibly an unrealistic target but maximising facility performance is vital in any event. Efforts to improve performance involve developing knowledge, improving culture, collecting and managing data, and using strategies for continuous improvement.

The internal stakeholders will combine their interests to generate requirements for a Performance Monitoring System. These may be formalised through functional or technical specifications. Jahn, Cook, and Graham (2008) discuss internal factors that need to be managed in a successful operation. They mention key factors being:

- Organisational structure and manpower
- Planning and scheduling
- Reporting requirements
- Reviews and audits and
- Funding

Internal requirements, norms and demands to both technical and organisational systems will typically be developed as the organisation acquires knowledge, develop skills and evolves in a business setting.

2.4.2 Human-System interface

People are at the core of any organisation. Human factors is defined as the human elements in a system, and the interfaces that the human has between the system and subsystems that are studied (Blanchard, 2004). The Human Performance Handbook (US Deparment of Energy, 2009) separates incident causes between experts and first-line workers. Human errors done by experts are more prone to cause significant damage if not discovered early.

Engineering errors are in risk of being undiscovered for long time periods, particularly in design and modification of systems. Preventing human errors in all phases and parts of the organisation should be prioritised in management of operations.

Integrated Operations and Digital Oil-fields are terms that are descriptive of the paradigm governing the industry digitising the petroleum production environment is a prioritised objective. Integrating the systems and interfaces in such a manner that harmonisation between organisation, communication tools, hardware and software is reached is an industry focus.

Connecting skilled workers together in an environment that facilitates for multidisciplinary collaboration with digital technology is an important part of this approach. Data flows between offshore assets and onshore operation centres may reduce barriers for efficient communication and decision-making. New methods for working and cooperating are introduced in Integrated Operations and decision-making can with these methods change from being reactive to proactive (OLF, 2007; Verhelst et al., 2010).

The first generation of integrated operations is broadly implemented today and includes operations centres facilitating for efficient communication and direct data flow and location-independent collaboration. System integration has been commenced, but has not been realised to its full potential.

The future second generation also includes operators and vendors in the system integration. The facilities and processes are digitised and automated. The system integration is implemented and matured, and the potential of integrated operations may be realised (Verhelst et al., 2012).

2.4.3 Managing losses

Landgren, Abraham, and Das (2013) of SAP labs state that equipment failure is one of the most common causes for production losses and argue that a proper method of addressing it is identifying the root causes of the failures in a systematic way and analysing trends and correlations. Causes for failure must be described and documented so that this analysis can be accurate and carried out without unnecessary effort. The knowledge developed through such a process should be implemented in an overall plan for the facility. To manage losses decisions must be made on what action to carry out as a measure to minimise consequences. Some production loss scenarios can be seen below in the figure from Barabady et al. (2010a).

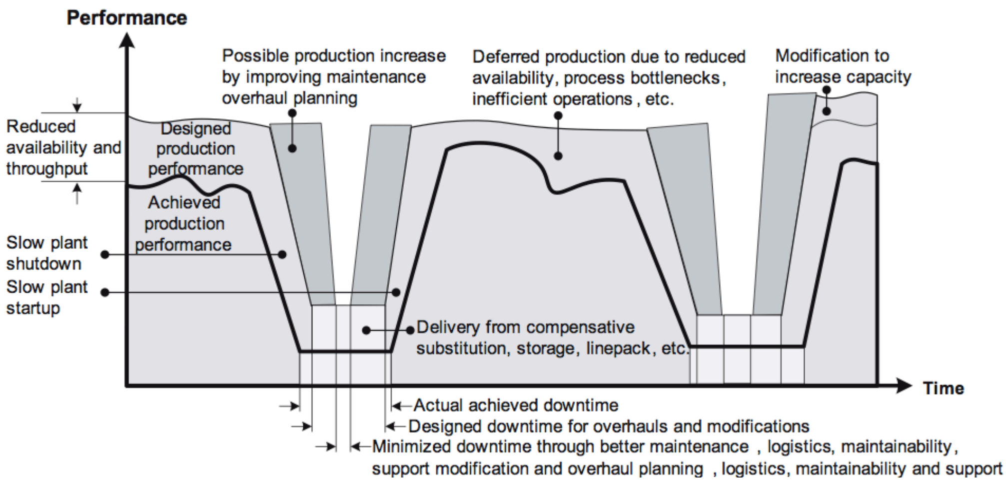


Figure 5: Production performance scenarios (Barabady et al., 2010a)

Literature on production losses in the oil and gas industry is not plentiful. Because of this a integration of the discussed fields can produce a framework for defining production losses. Using the definition of shutdowns by Utne et al. (2012), and combining this with reduced output, meaning a suboptimal production on the facility.

The left hand side of Figure 6 represents the already established definition on shutdowns, while the right hand side is the new definition that includes reduced output from the facility.

According to this a structure that illustrates the causes of the production losses can be constructed, as is shown in Figure 6. If these losses are avoided or eliminated a higher income from the production is obtained and output will be more aligned with the objectives that are set. A further development of the understanding and application of production losses is given in section 3.4 Loss Reporting and Indicators.

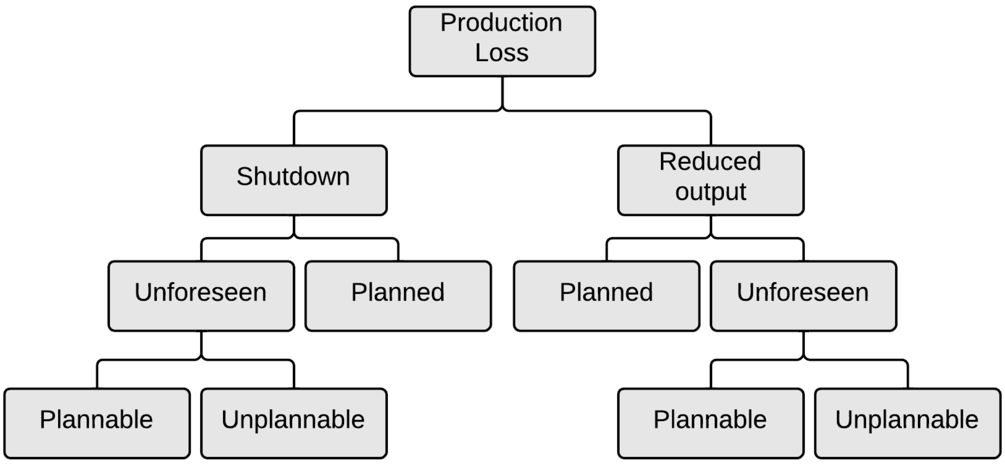


Figure 6: Production loss definition with causes

When production deviates from the optimal or potential performance a loss is generated. In the oil and gas industry the product itself is measured in volume, as is the loss. Since the product is commercially exploited the loss of produced volume is logically equivalent to loss of revenue. The accountability of the loss is regulated in contracts and between the involved parties.

International Standards Organization (ISO) (2010) suggests a classification system for losses in upstream, midstream and downstream segments. The subcategories may be used to assign liability of losses to either contractor or operator and be affiliated with penalties or bonuses. For the production facility there are eight loss categories.

Category	Production loss allocation
A	Well and reservoir
B	Subsea installations
C	Production facilities
D	Process and utilities
E	Export facilities
F	Turnaround and modification
G	Other
H	Pre-production

Table 1: Production loss categories (International Standards Organization (ISO) (2010))

2.4.5 Data management

Collecting and organising data is an important part of performance monitoring. In its standard regarding collection and exchange of reliability and maintenance data for equipment, the International Standards Organization (ISO) (2006) develops an extensive foundation for data management in reliability applications. As a related field to reliability, it can also be considered to apply to production performance measurement.

This standard holds the ability to exchange data on common formats as a major objective of data management. Within this some specific aspects are underlined to be handled with care, such as data sensitivity, security and actual value or cost for the company to retrieve the data.

The data quality is also a central and is characterised by completeness and compliance with established norms with regards to formats and parameters and correct handling in the system that manages it. The resolution should be sufficient so the statistical confidence is preserved and that it is connected to the actual demand reporting of what is to be reported. Importantly the standard emphasises the need for the data reporting effort to be planned and founded in roles and responsibilities in the company. It should be a planned activity, with a clear intent and objective.

International Standards Organization (ISO) (2010) also suggests principles to ensure data consistency and coordination in reliability data in its Production Assurance standard. These principles could also be transferrable to a production performance environment:

- Comparability
  The origin of data collected must be from same type, or identical, equipment and technology. Also operating and maintenance conditions should be comparable.
- Stability
  Data should be sourced from stable operation
- Validity

Data should be of a sufficient integrity as to eliminate statistic invalidity and ensure significance, i.e. sufficient volume or data points and bias

When the Performance Monitoring System facilitates for decision-making processes it does so trough delivering information. The Decision-making itself can be categorised as structured or unstructured and strategic or operational. Strategic decisions will affect the organisation as a whole - tactical is decisions on a middle-management level in the organisation, while operational are in the execution of the actual activities that are the objective of the organisation.

Decision support systems (DSS) provide important information on the state of a system, in order for skilled workers with specialist knowledge to make well-informed decisions. In some cases DSS can be imperative to secure correct decisions (Mallach, 1994).

Combination of hardware and software that communicate and share input and output of information is systems integration (SI). Software cooperating on one system interface is one type and hardware integration signifies combination of hardware and is another. A mix of software and hardware integration is the most common application.

2.5 Petroleum production

2.5.1 Technology

Technology, process stages and components and equipment needed for the hydrocarbon production vary and determine engineering solutions for a petroleum project. Reservoir geometry, thermodynamics and fluid composition are among many factors that determine the design. These reservoir factors are the result of hydrocarbon accumulation trapped in certain rock-formations, at given depths and temperatures (Paik & Thayamballi, 2007).

The units considered in this thesis are FPSO vessels. These are either ship shaped or cylindrical: ship shaped vessels can be designed and built as a petroleum production facility from start or cargo vessels that have been converted to their new purpose, cylindrical are commonly new builds.

Ship-shaped FPSOs depend on turrets for the coupling of the subsea-side of the installation to the topside because the vessels must adhere to the wind, wave and current direction. The cylindrical units are symmetrical, which eliminates the need for a turret (Paik & Thayamballi, 2007).

2.5.2 Facility

The fluid from a reservoir contains hundreds of different compounds, where oil, gas and water can be seen as the main constituents. The composition of these is different for every hydrocarbon deposit. Specific characteristics of these constituents are described by lab testing at the FPSO. The reservoir pressure forces the fluids out through the wellbore and out of the reservoir. The main source of pressure is gas, oil or water, depending on the trapping characteristics of the reservoir. The fluids are transported in a mixed or partly separated state from the reservoir, through the wellbore and towards the wellhead on the seabed. Finally it will reach the topside where it will be processed (Guo, Lyons, & Ghalambor, 2007; Paik & Thayamballi, 2007).

The petroleum production facility consists of a range of equipment. The wellhead contains the pressure and fluid flow from the reservoir, and is located below the master valve just on the top of the seabed. During drilling it will control the fluid flow through a series of valves and therefore the quantity transported to the production facility (Guo et al., 2007; Paik & Thayamballi, 2007).

A Christmas tree is installed on top of the wellhead. As the reservoir fluid is mixed it will need separation. Unwanted particles and must be extracted, and water, gas and oil must be separated from each other. This should be done as soon as possible after the fluid being transported from the reservoir. Separators have different designs, being horizontally, vertically or spherically based, depending on their geometrical shape and physical alignment (Guo et al., 2007; Paik & Thayamballi, 2007).

After the fluid has been separated it will need to be transported further, towards the tail end of the system for export. As the pressure from the reservoir does not drive the fluid flow, pumps will act as the driving force for the transportation. Pumps also have an important role in water injection operations. For the gas transportation a gas pressure has to be created. A gas compressor will provide this, and also support oil-lift operations (Guo et al., 2007; Paik & Thayamballi, 2007).

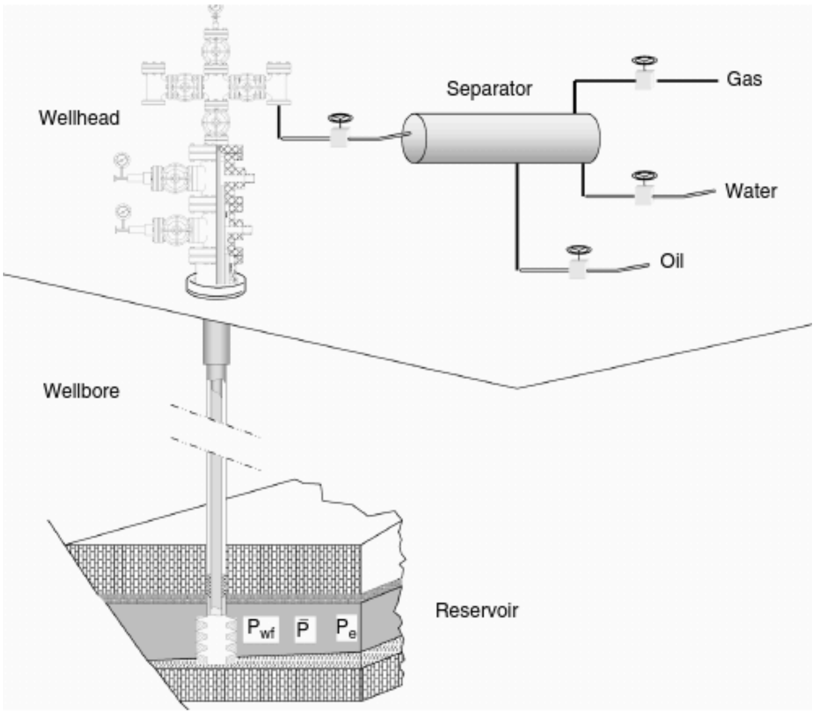


Figure 7: Upstream production processes (Guo et al., 2007)

2.5.3 Petroleum projects

Petroleum projects have varying lifespan depending on the reservoir volume and production potentials. The life cycles of a petroleum project is divided in several phases, defined as follows by Jahn et al. (2008):

1. Gaining access to resources
2. Exploration and appraisal of reservoir and wells
3. Development planning of the production project
4. Production of petroleum products
5. Decommissioning of installation and equipment

When planning for operations the production profile is an important factor as it depicts the expected production of the field as well as the factors mentioned that is to determine the facility design. In the pre-production life cycle phases there are bound to be large expenses and small income. Optimising the operations by maximising production is therefore important to increase the revenue of the projects.

The stages that lead towards the production phase are costly. Design engineering, procurement and chartering of units such as seismic vessels and exploration rigs are expensive endeavours. Construction or acquisition of production installations themselves is also a large investment.

These expenses are at a time where the project itself does not generate any income, resulting in a negative cash flow for the project. The production phase is recognised by commercial exploitation and includes periods of build-up, plateau and decline, and this is the period where the company actually generate income. A large company would have several projects and is somewhat independent of the phases on a specific unit, but is nevertheless just as reliant on a stable cash flow.

Variation, or losses, is the deviation between target and actual values. Targets can be subject to negotiation with authorities as well as cooperation between operator and contractor. A specifically important part of determining targets given a facility designed to handle a maximum level of output is reservoir potential. This is often the limiting factor in production volume (Jahn et al., 2008).

2.6 Rules, regulations and standards

2.6.1 Legislation

Norwegian legislation has three important documents regulating measurement of production variables. Laws and regulations are summarised in guidelines that prove helpful in understanding the legislation. The guidelines are located at Norwegian Petroleum Directorate webpages.

The Petroleum Act (Petroleumsloven - petrl., 1997) is the main fundament in regulation of petroleum resources.

Material and information from production monitoring is regulated in §10-4. Operations must be documented and made available to the authorities at any given time. Additional studies may be required to carry out per request from authorities.

The Petroleum Regulation (Forskrift til petroleumsloven, 1997) is connected to the Petroleum Act, and spans over a broad selection of topics, with some specifically applying to production and monitoring.

Section 26 Metering of petroleum produced states that the licensee is to meter and analyse the petroleum that is produced and sold in accordance to accepted procedures.

Section 27 Monitoring of the deposit and process during production applies specifically to production and requires monitoring to be done in order to achieve optimal operations. Pressure, flow conditions and produced or injected volumes are relevant variables to be continually monitored. A monthly statement on production and injection on the wells being produced from is to be made.

Section 48 Information on petroleum produced etc. requires documentation on volume, composite, test production and extraction in formation testing to be submitted to authorities. Any information produced as a result of the requirements in section 27 is subject to the same reporting requirement.

The Resource Management Regulation (Ressursforskriften, 2001) is the final regulation directly applying to production monitoring. It promotes effective dialogue between stakeholders and assuring satisfactory data acquisition and reporting.

Section 22 Reporting during drilling and well activities states that the licensee is to submit daily reports from drilling and well activities, and also that the on-going activities are to be reported to the authorities to the drilling database CDRS.

Section 25 Descriptions, analyses and interpretations of well data requires well data to be made available continuously to the authorities.

Section 27 Daily reports during the production phase determines that information on the most important production parameters such as gross and net shall be available to the authorities directly.

Section 28 Monthly reporting of production data specifies what is to be reported monthly, being production on each well and facility, import/export per facility, consumption of flare, fuel, diesel, etc., on every facility, injection on each well and facility, stock quantities, and hydrocarbon sales.

2.6.2 Standards

Stakeholders in the petroleum industry frequently use industry standards as requirements. Examples of this may be insurance, authorities, and classification societies. Standards tend to be a norm in design and operation of equipment and facilities.

Standardisation organisations are non-governmental and originate from industry. The current hierarchy consists of industry specific standardisation organisations that join together forming a national standards organisation. Further these associate and become an international standards organisation, for instance related to a discipline or to an industry.

Standards Norway is the central of standards in Norwegian petroleum. The international Organization for Standardization (ISO) is the most important body globally, being a network of the national standardisation organisations, harmonising the specific standards to an international version.

In performance monitoring and PA international standards have replaced the Norwegian standards. NORSOK Z-016 Regularity Management and Reliability Technology (Norwegian Technology Standards Institution, 1998) previously played an important role. It treated PA in a risk-based perspective and provided with a reporting scheme for performance monitoring. ISO Standard 20815:2008 Petroleum, petrochemical and natural gas industries – production assurance and reliability management (International Standards Organization (ISO), 2010) replaced the standard.

Production Assurance is treated in this standard giving activities, processes and guidelines to actions and procedures for sound operation. Annex B and G are specifically relevant, as they give specific measures for performance monitoring.

A boundary area of performance monitoring is fiscal measurement, where Norwegian standards NORSOK I-104 Fiscal measurement systems for hydrocarbon gas (Norwegian Technology Standards Institution, 2005) and NORSK I-105 Fiscal measurement systems for hydrocarbon liquid (Norwegian Technology Standards Institution, 2007) provide standards on the fiscal measurement on sales and export for the petroleum sector.

2.6.3 Contracts and Petroleum Economics

Roles and responsibilities for stakeholders in a project are commonly regulated in contracts. When outsourcing a service a business owner will use a contract to regulate applicable areas, as the operator does towards the contractor on an oilfield. For operation the contractor is given an economic compensation regulated by the contract (Gudmestad, Zolotukhin, & Jarlsby, 2010). Jahn et al. (2008) describe four common contract types being used in the petroleum industry:

- Lump sum
  Operation is managed and executed by a contractor on a fixed price basis. Penalties may be given on deviancies from the contract specification
- Bills of Quantities
  Operation is split into sub-operations, each priced on given rates, also with penalties given on deviance from contract
- Schedule of rates
  Several rates are given for labour, costs of material and use of time is not given
- Cost plus profit
  Contractor costs are covered and is a percentage of the profit that is given

Some contracts are derived from the shipping market. These are frequently in oil companies operating with FPSOs. Shimamura (2002) defines two important contract types:

- Bareboat charter
  The FPSO is rented out to an entity with its facilities and operational abilities. It does not include any services beyond the disposal of the vessel and itself. Responsibilities and liabilities lie mainly on the entity renting the vessel
- Time charter
  The FPSO is provided with its facilities, operational abilities and staff. The contract specifies the operation that is carried out. Provision will be paid for operational expenditures in addition to the margin required by the operating party.

Profitable operations are a requirement posed by internal and external stakeholders. Offshore oil and gas industry is capital intensive, meaning that the business requires large investments that must provide high return in order to be profitable.

Production in an offshore environment requires complex industrial facilities that have high acquisition and operational costs. However, oil and gas are common goods in the global marketplace. This means that the price paid for the oil and gas products is volatile and often beyond control of seller and buyer.

In petroleum projects there is limited income being generated in the early phases. Credit from loans and equity from shareholders is used for exploration and procurement of installations that will produce on the field. After the production commences the income that is generated must be used to repay the debt and pay dividends to shareholders (Jahn et al., 2008).

Revenue items	Expenditure items
Hydrocarbon sales	Capital expenditure (CAPEX)
Tariffs	Operating expenditure (OPEX)
Project farming payments	Government take

Table 2: Revenue and expenditure items (Jahn et al., 2008)

Net cash flow of a petroleum project is given by the revenue and expenditure:

$$\text{Net cashflow} = \text{Revenue - Expenditure}$$

On the revenue side income from sales is subject to oil price volatility and product quality. Forecasts are made to predict the income in a given time period. Tariffs may be paid to the operator for the project or activity it is involved in. Furthermore the company may receive farming payments on projects that is it a part of.

The expenditures are separated in three parts. Capital expenditures are costs involved in investment and procurement of facilities and installations such as platforms, pipelines and wells. Operating expenditures are related with maintenance, insurance and services of the project. Operational expenditures may be separated into fixed and variable expenses. Fixed OPEX is proportional to CAPEX while variable OPEX is proportionate to the produced volume, and thus the performance.

The government has a substantial take due to taxation, royalty and allowances. The fiscal regimes regulating the government take will vary according to the host country legislation, and may be based both on volume sold, revenue and fixed rate (Jahn et al., 2008).

2.7 Criteria for a Performance Monitoring System

The literature study covers a multitude of disciplines and research areas. Together these can be synthesised to form criteria that define factors that are critical for a Performance Monitoring System to be successful.

Operations Management and Systems Engineering provide an environment where the system is to exist and allocates it responsibilities within an organisation. The integrated operations mind-set and data management puts forward requirements for an advanced ICT-infrastructure. Industry research on development and application of indicators has firm directions for how indicators should be developed and how they should be utilised.

The criteria are intended as a framework for design and assessment of Performance Monitoring System. A case can be evaluated relative to the criteria and scored according to if the system at hand can be seen to fulfil the criteria. The criteria are formulated on the form as descriptors and are divided in three groups: reporting system, data management and indicators used for performance measurement.

The main objective of the Performance Monitoring System is to collect and provide operational data and to produce information on the performance of the units and the company. The system has important functions in historical reporting, complying with regulatory requirements and processes for improvement of operation. Based on this core criterion, further criteria may be developed for the reporting system, data and indicators.

2.7.1 Reporting system

Criteria	Description	Sources
System optimisation	The system shall contribute to maximising revenue and minimising losses through prevention of sub-optimal operations and incidents leading to losses. The system shall be connected to success critical areas of operations.	Barabady et al. (2010b); Parnell et al. (2011); Stapenhurst (2009); Tangen (2004)
System transparency	The system, with its functions and processes, must be transparent.	Tangen (2004)
System accessibility	It should be accessible with easy access to the contents. System should be readily available when needed by user and possible to export to desired use.	International Standards Organization (ISO) (2010); Tangen (2004)
System regulatory compliance	The design and use of the system shall fulfil regulatory requirements for formats, functions and structure.	Jahn et al. (2008)
System structure	A Performance Management System structure should be applied, giving an as-close-as-possible perspective to the actual performance.	International Standards Organization (ISO) (2010); Neely et al. (1995)

2.7.2 Data

Criteria	Description	Sources
Data comparability	The data collected must be of the same format or be able to convert to common format and unit, facilitating for efficient comparisons and streamlined archiving	International Standards Organization (ISO) (2006, 2010)
Data stability	The data stream should have stability. Either it is a variable that is logged continuous value or if it is sampled at time intervals. Equipment and processes that is used for data sourcing should be reliable.	International Standards Organization (ISO) (2006, 2010)
Data validity	The data should have a sufficient integrity so that statistic invalidity is avoided. The data shall be of sufficient volume and resolution. Successful verification of data must be in place.	International Atomic Energy Agency (IAEA) (2000, 2006); International Standards Organization (ISO) (2006); Utne et al. (2012)
Data security	Data in the system should not be able to manipulate and access should be restricted to wanted users.	International Atomic Energy Agency (IAEA) (2000, 2006); International Standards Organization (ISO) (2006); Utne et al. (2012)
Data uniqueness	Duplication should be avoided and data should not overlap.	International Standards Organization (ISO) (2006)

2.7.3 Indicators

Criteria	Description	Sources
Indicator directness	Indicators should be calculated by using data as close as possible to the operations. Aggregated or modified data is not optimal to use in the calculation of indicators.	International Atomic Energy Agency (IAEA) (2000, 2006); Utne et al. (2012)
Indicator relevance	Indicators must reflect success critical areas. They should provide valuable insight in that actual state of operations and be integrated into normal activities, giving an added value to the user.	Amaratunga and Baldry (2002); Parnell et al. (2011)
Indicator balance	There must be a balance in the number of indicators and what areas of operation they are applied to.	International Standards Organization (ISO) (2010); Tangen (2004)
Indicator clarity	Indicators should be intuitively understood and be clearly defined, what is measured should be unambiguous and carried out within characteristic time periods.	International Atomic Energy Agency (IAEA) (2000, 2006); International Standards Organization (ISO) (2010); Tangen (2004); Utne et al. (2012)

Chapter 3: Case study of Teekay Petrojarl

3.1 Organisation

3.1.1 Corporate

Teekay Petrojarl Production AS is a part of the Teekay Corporation, an international enterprise that owns and operates vessels within shipping, storage and offloading, and petroleum production. With a flexible and diverse fleet the enterprise controls upstream and midstream value chain (Teekay Corporation, 2013b).

Top leadership located in the Teekay Corporation governs the organisation, including Teekay Petrojarl. Five subsidiaries form the operational organisations in the corporation (Ingpen, 2013):

- Teekay Tanker Services
- Teekay Navion Shuttle Tankers and Offshore
- Teekay Gas Services
- Teekay Marine Services
- Teekay Petrojarl Production

3.1.2 Teekay Petrojarl Production

Teekay Petrojarl Production operates and manages the petroleum production units. It is registered as a shipping company with main office in Trondheim. Operational offices are located in Stavanger – Norway, Aberdeen – United Kingdom, Aracaju – Brazil, and Macae – Brazil (Teekay Corporation, 2013d).

The responsibilities for Teekay Petrojarl are according to Teekay Corporation (2013c):

- Operation of offshore units processing and storing crude oil
- Transporting crude oil from offshore units to shore with shuttle tankers
- Design, contracting and supervision of new build and conversion projects
- Offshore operation and engineering support

This organisation consists of divisions with designated functions: Business Development, Operations, Projects and Engineering. Divisions are project and process owners and have distributed leadership through these. The support functions; Quality Assurance, HSE, Human Resources, IT and Finance and accounting, provide their services and expertise towards the four main divisions.

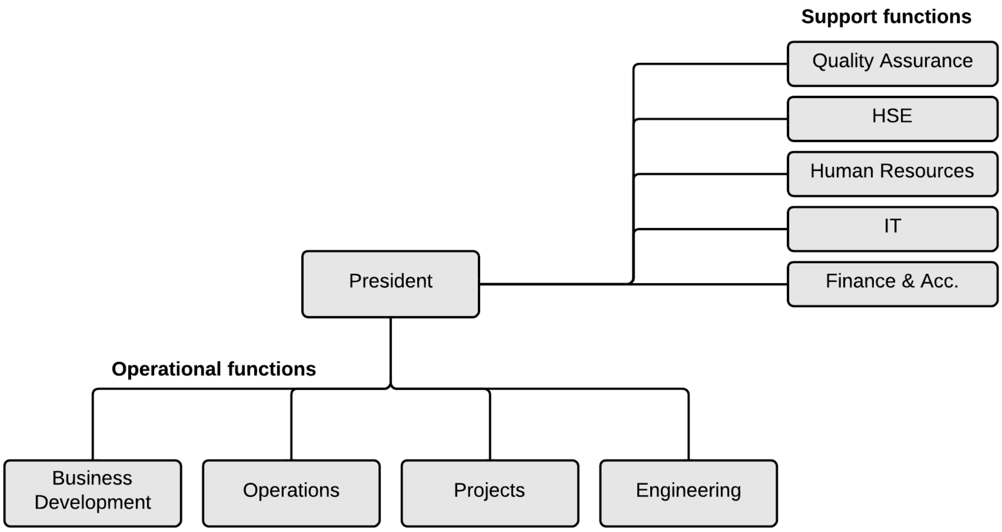


Figure 8: Organisational structure in Teekay Petrojarl (onshore)

The Oil Installation Manager (OIM) manages the units in the offshore domain. Subdivisions are Maintenance, Marine and Production. Support functions service the unit and consist of Safety officer, Radio Operator, Medical, Chef and Accommodation.

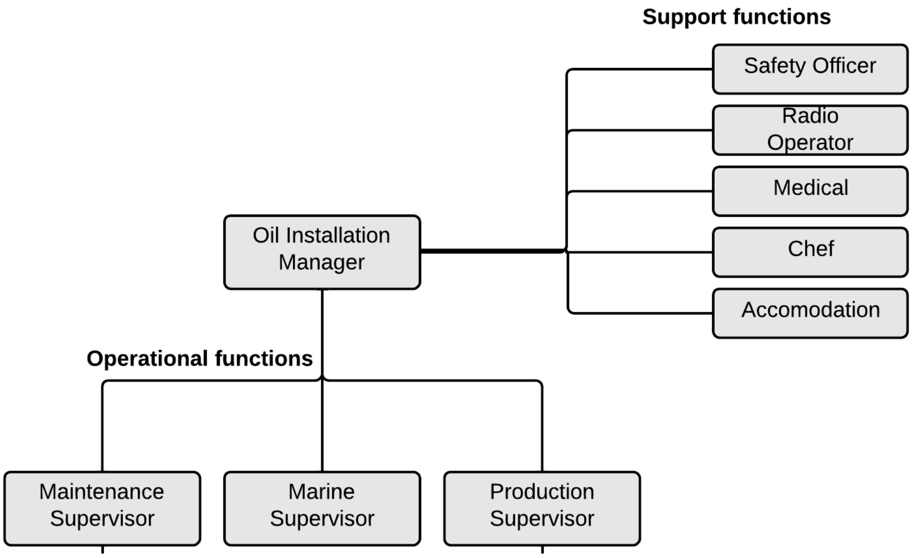


Figure 9: Organisational structure in Teekay Petrojarl (offshore)

3.1.3 Management System

The company has developed a process-based management system to ensure compliance with codes, standards, legislations and guidelines from national authorities, classification societies and flag states. Industry standards are also an important part of the management system.

The system itself consists of processes and procedures specified in the various fields. The main relevant documentation for Performance Monitoring Systems include:

- Personnel Handbook
- Shore-based Operational Manual
- Administrative Procedure Manual
- Operation Manuals
- Health, Safety and Environmental Management manual

The management system requires records of company activity to be kept on file. Specified documents included in this and related to the scope are operational reports, nonconformities, corrective and preventive actions and maintenance status reports. To ensure good communication, both within the organisation and to external stakeholders, a meeting structure is used.

All internal communication besides meetings is focused through the company intranet, including data and reports, IT-systems, access to procedures, routines, policies, etc. Meetings related to offshore operations include:

- Daily morning meeting in SLT
- Daily morning meeting with onshore operation parks
- Daily operation meeting between onshore organisation, costumer and vessel
- Weekly operation meeting between head office and branch offices
- Monthly operation meeting with client
- Regular internal meetings within department and disciplines

Project goals for the different life-cycle-phases are established in the management system. The primary objective of operations is according to the company:

> Optimisation of production in the most cost effective manner whilst ensuring health and safety of personnel, preventing harm to the environment and ensuring technical integrity of the unit (Teekay Corporation, 2013c, p. 18).

The responsibility for realising this is given to the operations department. Goal fulfilment is measured through Key Performance Indicators (KPIs).

3.1.4 Production units

Units are managed through the main office in Trondheim and branches of operations offices in Norway, United Kingdom and Brazil. The difference of the units relating to design, reservoir and the wells calls for designated and specialised teams that have expert competence on the system on the specific vessel. The organisation does this through team-based units with interactions from the support functions when needed.

Responsibility of operational performance in the line organisation of units is according to the organisational structure: offshore supervisors have responsibility for their respective fields. The operations manager is responsible for the dedicated units, while the vice president of operations is responsible for the operational performance of the fleet as a whole (Teekay Corporation, 2013c).

The fleet consists of nine FPSOs: six based in the North Sea and three off the coast of Brazil. Six of the vessels are ship shaped, with three conversions and three new-builds. The cylindrical vessels have Sevan designs. These vessels were previously owned and operated by Sevan Marine, and were acquired by Teekay Petrojarl in 2011 and 2012. They were integrated as a part of the fleet in 2012 (Teekay Corporation, 2013a).

Vessel	**Year**	**Location**	**Design**	**Production**	**Client**
Petrojarl 1	1986	NO	Newbuild	46.000 bopd	N/A
Petrojarl Foinaven	1996	UK	Conversion	140.000 bopd	BP
Petrojarl Varg	1998	NO	Newbuild	57.000 bopd	Talisman
Petrojarl Banff	1998	UK	Newbuild	90.000 bopd	CNR
Petrojarl C.d.R.d. Ostras	2007	BZ	Conversion	25.000 bopd	Petrobras
Petrojarl C.d. Itajaí	2012	BZ	Conversion	46.000 bopd	Petrobras

Table 3: Ship-shaped production units

Vessel	**Year**	**Location**	**Design**	**Production**	**Client**
Piranema Spirit	2007	BZ	Newbuild	25.000 bopd	Petrobras
Hummingbird Spirit	2008	UK	Newbuild	25.000 bopd	Centrica
Voyageur Spirit	2008	UK	Newbuild	30.000 bopd	E.ON

Table 4: Cylindrical production units

Petrojarl Knarr is currently being commissioned and is to be launched in third quarter of 2014. It is built by Samsung Heavy Industries in South Korea. Teekay Petrojarl is also developing other projects with possibility of tendering for future realisation.

The units are regulated by contracts with elements that determine how the operation is ideally conducted. Some have fixed rates, such as a day rate, a service rate and a charter rate, elements that pay a certain fixed amount of money per volume or time produced. Others may have negative tariffs that are applied after suboptimal production.

A unit may also have incentives specified in the contract, giving extra payments when performance is especially satisfying for the client (Teekay Corporation, 2013b).

	Daily rate	Service rate	Charter rate	OPEX rate	Incentives	Tariff	OPEX covered	Shuttle Surcharge
Petrojarl Piranema		X	X					
Petrojarl Varg			X	X	X	X		
Petrojarl Knarr				X		X	X	
Petrojarl Foinaven	X		X			X		
Petrojarl Banff	X					X		X
Voyageur Spirit	X						X	
Hummingbird Spirit	X						X	
Cidade de Itajai		X	X					
Cidade de Rio Das Ostras		X	X					

Figure 10: Production units contract elements

3.2 Performance Monitoring in Teekay Petrojarl

3.2.1 Overview

The understanding of the Performance Monitoring System was developed using internal sources from the company. Teekay Petrojarl also provided a desktop at the main office in Trondheim, giving direct access to both personnel and documentation. A series of informal interviews with company staff was an important source of learning how the subsystems functioned. Available documentation that was retreived and used as basis for understanding them can be found in Appendix 1.

During the preliminary project a basic understanding of data management and performance indicators was established. In the master thesis project this was extended with deeper understanding. The company management system was considered as the governing document in the company, assigning roles and responsibilities.

There is no formalised strategy on the technical or functional functions for a Performance Monitoring System in Teekay Petrojarl. There is however a set of subsystems that fulfil objective of such a system in the company.

The various sub-systems that fulfil the role of being a Performance Monitoring System are the result of operational history and evolution of the company. Experiences and knowledge acquired through operation of the units have been absorbed and used to develop the systems resulting in the current structure.From this point the set of sub-systems will be considered as one system that are equivalents of, but not formalised as, a Performance Monitoring System.

As an introduction to how the system works, four workflows that are vital for the functionality are established, merging the recommendations from Amaratunga and Baldry (2002); Blanchard (2008); International Standards Organization (ISO) (2010). The data flow from production operation is here input at left hand and output at right hand side.

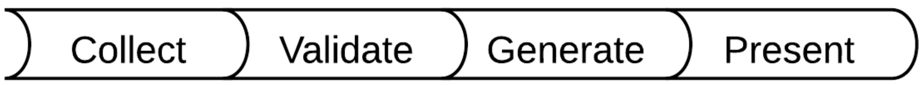


Figure 11: Production monitoring system workflows

Collect

Data from the process must be collected. This involves measurement and logging of production data and storing it in a suitable format in a designated system.

Validate

Ensuring that data is accurate.. This is done by checking, controlling and ensuring that the data collected is correct.

Generate

In order to be used in a meaningful way, the system refines the data to information that can be used in several contexts.

Present
The final step of the system presents the information generated in the system.

Data sources are considered as primary or secondary. Primary data is automatically recorded and collected through sensors, meters, automatic calculation, etc., while secondary is provided by manual operator input. Large volumes of data from the facilities are recorded or reported at any given time, supplemented by manually entered data by offshore personnel.

The variables are assigned a tag that will identify it for future use. Recorded data can be any variable in the production facility, well or reservoir, such as pressure and temperature. Data is made available to both onshore and offshore users, as well as the operator and the authorities. In some instances a second party will duplicate the data in a parallel system, as is done on the Brazilian units, where PI-data is mirrored in a equivalent system in Petrobras.

Real-time data is recorded directly from the facilities through process monitoring equipment. To ensure that the data is accurate staff validates it through a control loop. The data maturity will increase as time lapses. The final matured data that has been validated is tagged “RPT”.

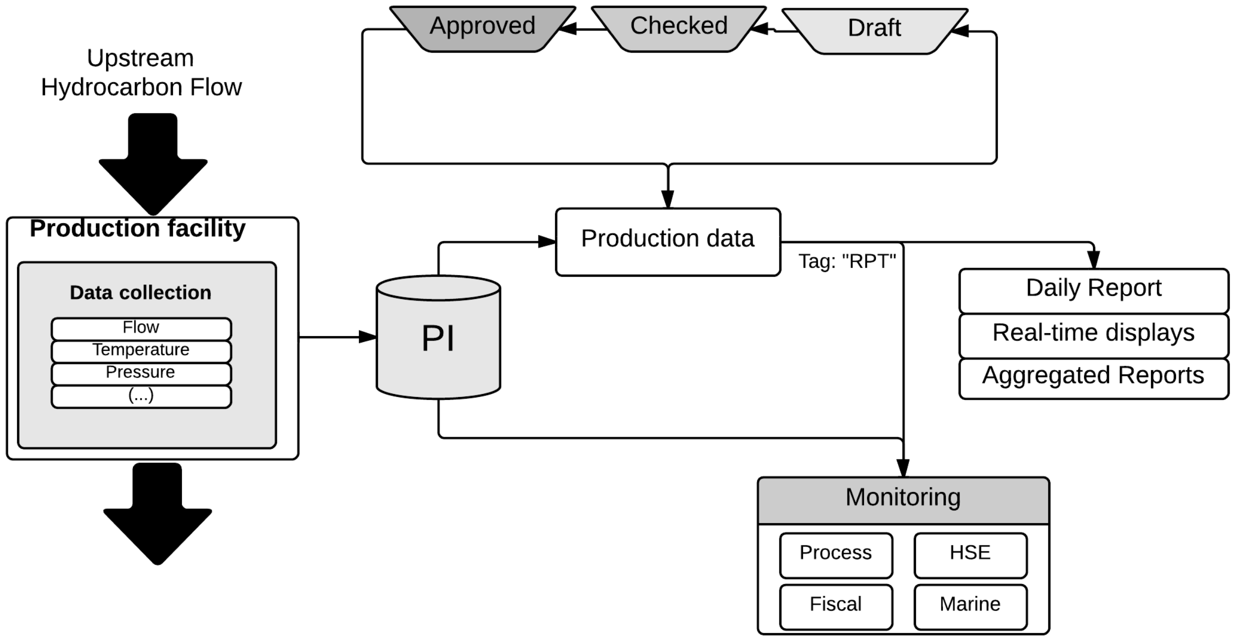


Figure 12: Flow of production data in reporting system

3.2.2 Plant Information system

The plant information system captures and stores dat. The company operates with different Plant Information Systems due to the units acquired from Sevan. The majority of FPSOs are installed with a PI from Osisoft and Amitec. The remaining FPSOs use a PI delivered from Siemens. Even though the systems have different providers, they are considered identical. They share the same interface, and fulfil the same regulatory requirements.

Access to data in PI may be done directly in PI-SQL client which fetches current values in the database and through an add-in tool that is used in excel. The add-in tool may collect data on specific tags real-time and historical. While PI is used as a database, the data must be collected from measuring and monitoring devices. These are maintained and controlled using the computerised maintenance system, STAR.

3.2.3 Daily report application

The Daily report application (DRA) is the main tool used in the production reporting. Data from PI is validated and then presented in reports generated by the system or manually by personnel. The daily report for the given unit covers all relevant information in the operation of the facility and vessel for one operational day:

- HSE
- Hydrocarbon production
- Well and reservoir
- Personnel
- Logistics
- Weather
- Activities

In order to assure that the data is of the highest accuracy and reliability, a control loop has been introduced. The daily reports have three statuses connected to where in the control loop the report is located, with rising data maturity. Raw data is defined as low maturity and the verified data is considered mature. A selection of daily reports are given in Appendix 5 and Appendix 6.

Status	**Description**	**Responsibility**
Draft	Raw data is retrieved from collection systems in the facility. The daily report currently has low data maturity and errors may occur. Operators oversee the document and input missing data.	Production, Maritime and Maintenance Operators
Check	Division supervisors verify raw data in the DRA. Occurring errors are corrected and all data is stored in PI parallel to the raw-data on a new tag "RPT". Data maturity is on a medium level.	Production, Maritime and Maintenance Supervisors
Approved	Installation manager controls the document and finalises it for issue. Data maturity is high.	Oil Installation Manager

Table 5: Daily Reports validation statuses

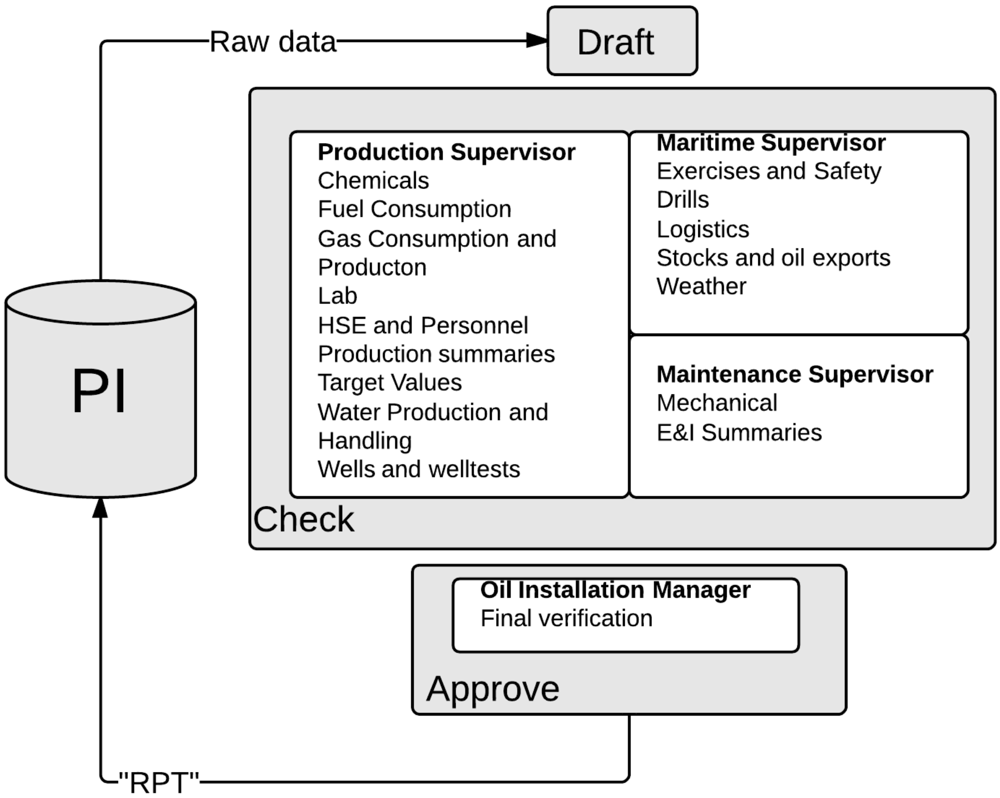


Figure 13: Data validation loop

The daily report is the main tool for presenting the performance on the units in Teekay Petrojarl Production. Together with key figures from production, such as volume dry oil produced and number of HSE-events, the DRA combines and processes data to that is the basis for performance measurement indicators. The DRA is a tool designated for users with knowledge and interest in specific operational performance of a unit. It is the basis for several meetings offshore and onshore.

3.3.3 Aggregated reports

The company also uses aggregated reports in their performance monitoring. Format and scope of both time and content vary. Monthly reports are commonly utilised, some units generate these manually by collecting data from either PI or the DRA and using presentations or text and table-based documents.

Other units use a semi-automatic report generator that collects the data and finalises it with minor input from the user. Many units include HSE, production and quality as topics for the report. Samples monthly reports are given in Appendix 7 and 8.

3.3.4 Information screen

An important platform for communication of the operational performance across the fleet is information screen. Real-time and historical key performance figures from the units are displayed on a web-based interactive site. Information that is presented is the following, rotating trough the units in Norway, United Kingdom and Brazil:

- Units
  - Staff count
  - Time of day
  - Weather on site
  - Produced volume (last five days, last 24 hours)
  - Production Utilisation Factor Field, today
- Fleet
  - Production Utilisation Factor Fleet, yesterday
  - Production Utilisation Factor Fleet, this month
  - Production Utilisation Factor Fleet, year to date
- Health, Safety and Environment
  - Total recordable injuries (Medical and Lost time)
  - HSE Incidents with High Potential
  - Quality incidents with High Potential

It may be accessed through intranet but is also displayed on information screens located in the offices and in some cases on the offshore units. This facilitates for transparency in operational track record for the units.

The information screen is the main tool of communicating the performance of the company in terms of operation of the units to the majority of the Teekay Petrojarl Organisation. It is also the only established platform for benchmarking or comparison between the units. A sample for an information screen is given in a screenshot in Appendix 9.

3.4 Loss Reporting and Indicators

3.4.1 Indicators

Key Performance Indicators are set for the company on an annual basis and reviewed periodically. Indicators are set on continuous processes and activities as well as projects and are either directly specified in the unit contract in the contracts or by the contractor according to criteria in the contract. The KPIs are defined in the company management system.

The KPIs that are used in Teekay Petrojarl have a weight on health, safety and environment (HSE). This can be seen as a result of a strong focus both internally and by regulatory authorities the past years on focusing to improve safety and to safeguard environment in operations. This does however create a slight imbalance in relation to the rest of the KPIs used in the company, which are within quality and production. These have three and two KPIs respectively.

It is important to note that the units also have developed own indicators that are used locally. One example is regularity, which is used on some units to measure past performance in production, but not defined as a key performance indicator in the management system. (Teekay Corporation, 2013c):

KPI	Description	Type
Lost Time Injuries (LTI)	Injuries causing lost time.	Cumulative
Medical Treatment Injuries	Injuries demanding medical treatment	Cumulative
Sick leave	Number of sick leave days	Cumulative
Near Misses	Number of near misses incidents	Cumulative
HSE Ideas	Number of HSE ideas from	Cumulative
First Aid Treatment	Number of first aid treatments	Cumulative
Other Environmental Emissions	Environment emissions not applicable to other categories	Cumulative
Spills to sea	Number of spills to sea	Cumulative

Table 6: Key Performance Indicators in Health, Safety and Environment

KPI	Description	Type
Planned Audits/Inspections performed	Number of planned audits and inspections performed	Cumulative
Overdue Nonconformities	Number of overdue nonconformities	Cumulative
Costumer Satisfaction	Satisfaction of client	Aggregated/Estimated value

Table 7: Key Performance Indicators in Quality

KPI	Description	Type
Production Utilisation Factor (PUF)	Production capacity and deliverability performance	Current value
Overall Equipment Effectiveness (OEE)	Availability, Quality and Production performance	Current value

Table 8: Key Performance Indicators in Production

The KPIs span across the entire breath of the operations, not merely production performance. The basis for the KPIs is generated done by collecting data from the units locally. For production performance the sources is data reported to PI. Presenting these through access on PI directly, through daily and aggregated reports and on the information dashboard.

The production performance KPIs Production Utilisation Factor and Overall Equipment Effectiveness will be the focus for the remainder of the thesis as the other indicators are not directly related to production. However, the KPIs related to HSE and quality do not exist in a vacuum and can be influenced by the same causes that influence PUF and OEE.

3.4.2 Production planning

There is no formalised or central strategy on how the target is to be set or handled on the various units, providing operational latitude. The heterogeneity of the units and contracts also cause targets to be set using different methods. Contracted volume, design capacity, well-production potential, planned production volume assuming no downtime and planned production volume can all be used on the different units.

Targets are set daily, monthly and annually and by the operator, normally outside contractor control. It is measured in bbls or Sm^3, depending on the field. Two methods in setting the target can be used: reservoir controlled or process controlled. The reservoir controlled is defined as the maximum production potential that the reservoir is able to deliver, while the process controlled target is the limit set by plant capacity, the maximum output of the FPSO.

In any event, the target is defined the Oil Production Potential, with a relationship towards production losses:

$$\text{Oil Production Potential} = \text{Actual Production} + \text{Production Losses}$$

The Oil Production Potential is divided in five groups, where planned stops are measured and combined in setting the target:

- Well and Subsea
- FPSO
- Revision Stop
- Export Stop
- Not planned activities

3.4.3 Production losses

As no proper definition of production loss is given in the literature, an effort to define it will be done in the following. When the production target, as the volume based quantity V_T, is set, as a reference value. When the reference value is stated a loss can. Let the following be the definition for production losses for the remainder of the thesis:

> Production loss: the deviation between planned volume (target) and the actual produced volume of a well, facility or installation, for a given period of time.

The losses are measured in dry oil volume figures and are a subjective quantification done by offshore staff. In a volume based context the definition yields the following relationship. For specific incidents causing losses calculation may be done by interpolating production between two data points, before and after the loss has started. If the loss is not measurable it is estimated. Given the planned production volume (target) V_{PT}, actual production volume V_A we can derive the resulting production loss V_L:

$$V_L = V_{PT} - V_A$$

Since a loss in production causes loss in revenue is important to distribute accountability of the loss. Some basic statements can be established from this.

- The loss is the responsibility, and hence the accountability, of the party that causes the loss. A loss cause may be a decision or action, or equipment, process or systems owned or operated by given party.
- The parties that may be accountable for a loss are the operator and contractor.

The loss of each stakeholder can be defined as follows: the total loss is the sum of losses accountable to contractor V_{LC} and operator V_{LO}

$$V_L = V_{LC} + V_{LO}$$

Consequently the contractor and operator loss may be found from the same relation:

$$V_{LC} = (V_P - V_A) + V_{LO}$$

$$V_{LO} = (V_P - V_A) + V_{LC}$$

3.4.4 Production Utilisation Factor

The Production Utilisation Factors (PUFs) are used on all units and are defined identically in the company. The PUFs are volume based planned-versus-actual lagging indicators that present performance of capacity and demand for a given time period in production. This means that they quantify the past performance of the facility based on reported data. It is defined as a ratio, with 100% as a no loss scenario. It can also be seen as production availability measure. There are three versions of the PUF´s, reflecting production performance of the field in total, the contractor and the operator. In this setting Teekay Petrojarl is the contractor on all fields, while the operator is the client.

Variable	Description
PUF_F	Production Utilisation Factor for Oilfield
PUF_C	Production Utilisation Factor for Contractor
PUF_O	Production Utilisation Factor for Operator
V_P	Volume of Dry Oil Production
V_{LC}	Volume of Lost Oil Production Accountable to Contractor
V_{LO}	Volume of Lost Oil Production Accountable to Operator

Table 9: Definitions and variables used in the Production Utilisation Factor

$$PUF_F = \frac{V_P}{V_P + V_{LC} + V_{LO}}$$

$$PUF_O = \frac{V_P + V_{LC}}{V_P + V_{LC} + V_{LO}}$$

$$PUF_C = \frac{V_P + V_{LO}}{V_P + V_{LC} + V_{LO}}$$

As seen from the formulas accountability of operator and contractor can be eliminated on the PUFs giving a performance indicator relative to one of the given stakeholders. A relationship between the three different PUF can be stated as follows.

$$100 - PUF_F = (100 - PUF_C) + (100 - PUF_O)$$

There are some time frame variations of the indicators, spanning from real-time to cumulative. The current PUF is based real-time data. The daily PUF is calculated on the total data for one day, from 00:00 until 23:59. Month To Date (MTD) and Year To Date (YTD) are the two final variations, and are based on total monthly and yearly data. In effect these are throughput availability indicators according to the Production Assurance framework since they are give mean actual relative to demand production.

These two the indicators are reset when a new month or year is entered. PUF are given a monthly target, which is the fraction between the Oil Production Potential Corrected Target and the Oil Production Potential Target, measured in percentage.

3.4.5 OEE and Regularity

The OEE is a lagging indicator used on the units as a metric to demonstrate total system performance in terms of availability, production performance and quality. It combines several measurements, and is therefore a significantly more developed measure than PUF. The OEE is included in the DRA, aggregated reports and on information screens. It is KPI and is therefore applied on all units as a central measure for performance.

$$\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Quality}$$

$$\text{Availability} = \frac{\text{Actual Production Hours}}{\text{Planned Production Hours}}$$

$$\text{Performance} = \frac{\text{Produced Volume} \times \text{Planned Production Hours}}{\text{Actual Production Hours} \times \text{Target Oil Production}}$$

$$\text{Quality} = \text{Manually estimated parameter in percent}$$

Regularity is an indicator used on some units to quantify performance in regards to scheduled downtime of the facility. It is not considered as a KPI in the company management system, and is therefore not implemented on the entire fleet. It is defined as follows:

$$\text{Regularity} = \frac{\text{Production Hours}}{\text{24 hours - Planned Outage}}$$

The company is currently developing a new metric that is called contract efficiency (CE). It measures operational performance on FPSOs relative to the contracts. The definition CE is revenue stream against contract potential. As the indicator is yet to be finally defined further elaboration on contract efficiency will not be given.

3.5 Petrojarl Varg and Petrojarl Foinaven

3.5.1 Rationale

In the following empirical data from operations will be used to illustrate how a Performance Monitoring System works in practice. The system itself generates a perspective of a unit's operational performance. To be able to assess the accuracy of the reporting system, a separate perspective may be developed, providing opportunity for comparison and analysis.

The scope is the operational performance of Petrojarl Varg (PJV) and Petrojarl Foinaven (PJF) in 2013. The selection of unit and time period was identified by examining daily reports, monthly reports and PI data on all units rom 2010 to 2014. The suite of documents used is listed in Appendix 1: Internal Documents from Teekay Petrojarl.

Some data has a clear meaning and does not need development to be useful, such as PUF and OEE, which as been copied directly from PI and plotted. Other data needs further treatment to be meaningful.

The data that has been developed or calculated by the author and is not in its original form as found in the source is given in the comments-column in Table 10: Sources for data used in case example.

Data	Source	Comment
Production deviation	PI	Manually developed
Dry Oil Production	PI	Original
Tags	PI	Manually developed
OEE	PI	Original
PUF	PI	Original
Reported losses	DRA	Manually developed
Loss categories	DRA	Manually developed

Table 10: Sources for data used in case example

To ensure a basis for comparison within the company and to be able to generalise the analysis results, some key requirements should be fulfilled: comparable production and monitoring systems, access to data, and a steady state of production. These particular vessels and the year 2013 were found as representable for the overall performance of the fleet. 2013 was a year with an operational performance with several elements worthy of further studies as both short and longer shutdowns and losses of large and small scale.

This ensures a broad exposure towards the objectives of the thesis. A larger time perspective will also be used when this is relevant.

The case will be structured through two stages. First, a reviewof the operational performance of the two FPSOs will be done, followed by a structured analysis according to the four work-processes: collection, validation, generation and presentation.

3.5.2 Review of performance

The two vessels were both on field during the whole of 2013. PJV had a stable production, disrupted by minor output reductions while PJF had a stable production for the majority of the year interrupted by long period where the facility was shut down and not producing any petroleum. As a reference the deviation between actual production and target (Figure 14, Figure 15) illustrates how well the units have been able to meet the expectations of the operator. This deviation is not used as a metric to reflect past performance in the company, but is calculated manually based on data collected from PI.

Five periods can be identified where there are large losses PJV. An otherwise minimal deviation from target indicates a good performance. On PJF the deviations are larger with numerous significant and several minor deviations. The unit seems based on this to have a poorer performance than PJV, but it can also signify that the unit has a higher resolution on the reported production and targets. Higher resolution gives a better data integrity. If this is true for PJF, then PJV had a lower reporting quality than PJF, as the resolution evidently is lower. This can be an expression of different reporting methodology.

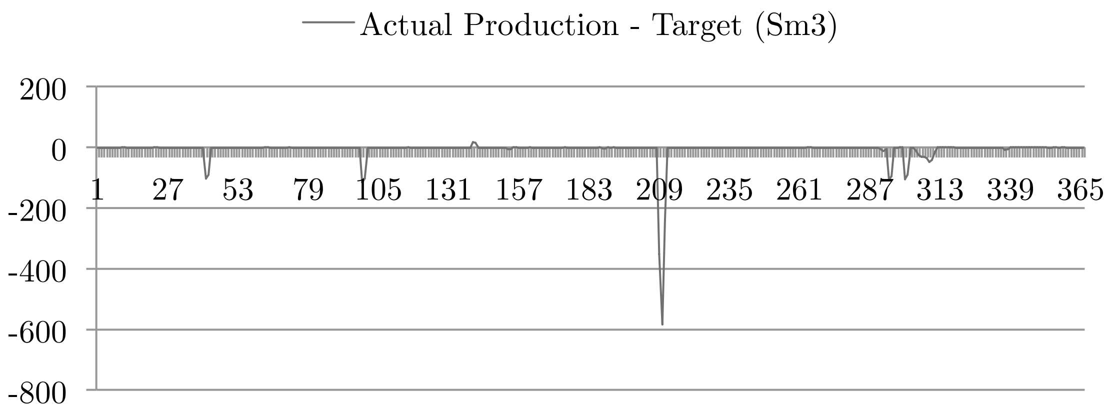


Figure 14: Production deviation, Petrojarl Varg 2013

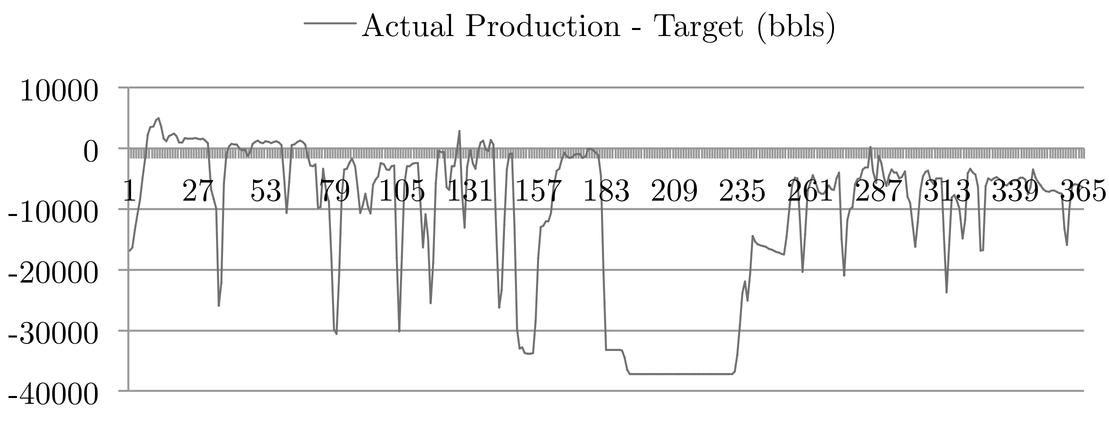


Figure 15: Production deviation, Petrojarl Foinaven 2013

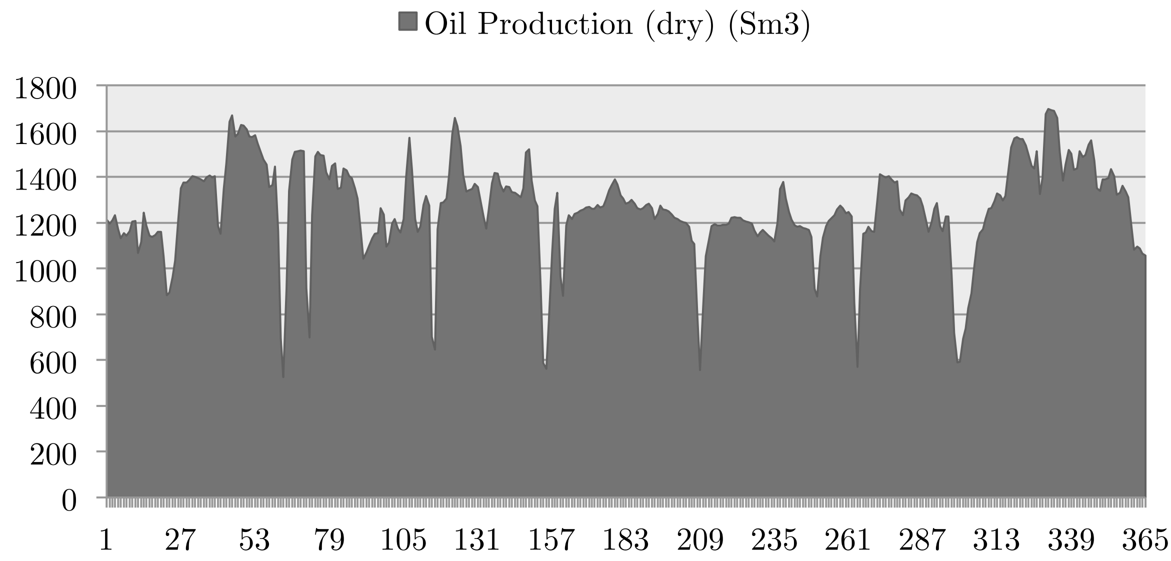


Figure 16: Dry Oil Production, Petrojarl Varg 2013

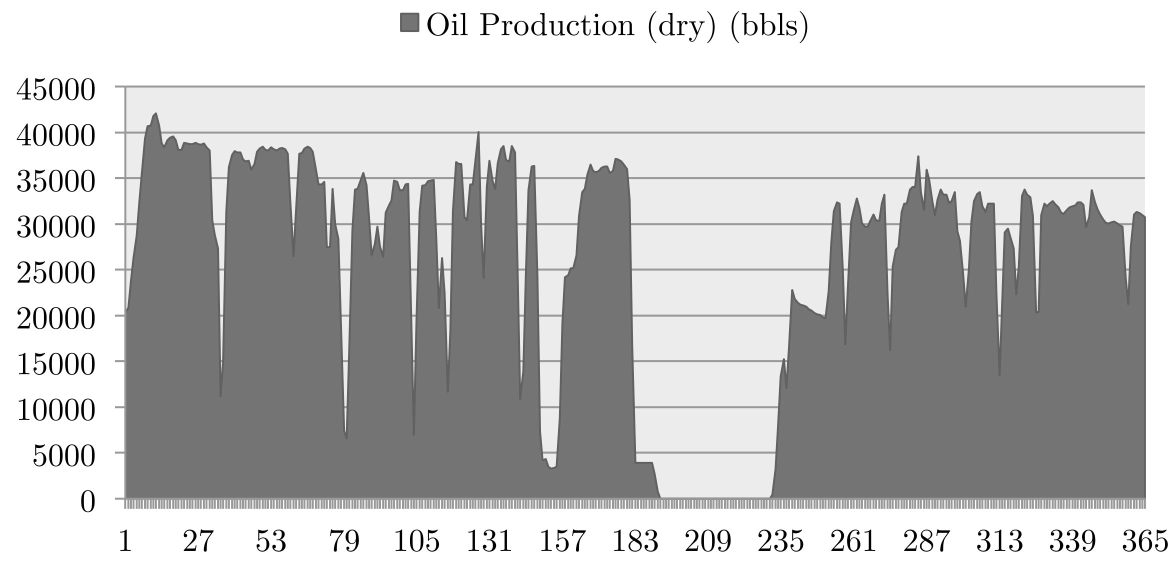


Figure 17: Dry Oil Production, Petrojarl Foinaven 2013

Reporting of production volume and production losses can give insight in how the units handle the reporting system itself. This is used in company performance analysis and a summary is given in Figure 16 and Figure 17.

PJV produced a total of 460.283 Sm^3 oil in 2013. The total production target, summarising all daily production targets for the period, was 462.495 Sm^3 oil. Together this is a daily planned oil production 1.267 Sm^3 and an actual production of 1.261 Sm^3. At stable production the output was between 1.100 Sm^3 and 1.500 Sm^3 oil daily.

PJF produced 9.468.300 bbls of oil in 2013. The total production target was 13.575.165 bbls. The deviation between planned and actual is 4.106.865 bbls. Given an oil price around $100 this is a significant loss of revenue. At stable production output varies between 30.000 bbls and 40.000 bbls daily.

Total	Operator	Contractor	Oil dry	Gas flared	Water injected
974	733	241	77.006 Sm^3	3.543.146 Sm^3	218.836 Sm^3

Table 11: Reported losses, Petrojarl Varg 2013

Total	Operator	Contractor	Oil dry	Gas flared	Water injected
142	42	78	96.766 bbls	22 MMscf	NA

Table 12: Reported losses, Petrojarl Foinaven 2013

Overview of losses for the units is given in Table 11 and Table 12. Loss category distribution is given in Figure 18 and Figure 19. Losses were reported every day in 2013, a total of 974 reported production losses. 75,3% of the losses was accountable to the operator and 24,7% to Teekay Petrojarl. On average there were 2,68 production losses every day, 2,01 and 0,66 losses accountable to the operator and contractor respectively.

The operator suffered from "choke back due to sand production" (as reported in the daily reports) continuously throughout the year causing large and recurring losses. One day was free of operator losses and 169 days had no contractor losses. In contractor losses elements defined as the FPSO-part of the system dominates. A clear majority of the losses was categorised within 3.4 equipment failure and corrective maintenance. Further category 3.1 planned maintenance and 3.3 process or operational problems also had significant contributions.

PJF had fewer losses than PJV, while there was a long period of shutdown from July through August. 142 production losses were registered. 29,5% of the losses was accountable to operator and 54,9% to Teekay Petrojarl. 15,5% of the losses was not assigned to any stakeholder. On average there were daily 0,39 reported losses, 0,11 accountable to operator and 0,21 to contractor. There were 265 days without reported production losses on the FPSO.

The operator had 320 days without losses, had 297 loss free days. Contractor losses on PJF were dominated by 3.4 equipment failure and 3.3 process or operational problems. Category 3.1 planned maintenance has a relatively small volume of reported losses compared to Petrojarl Varg.

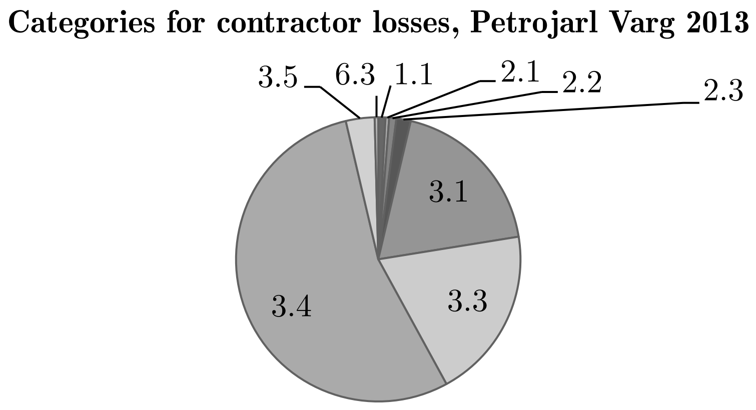


Figure 18: Contractor losses categories distribution, Petrojarl Varg 2013

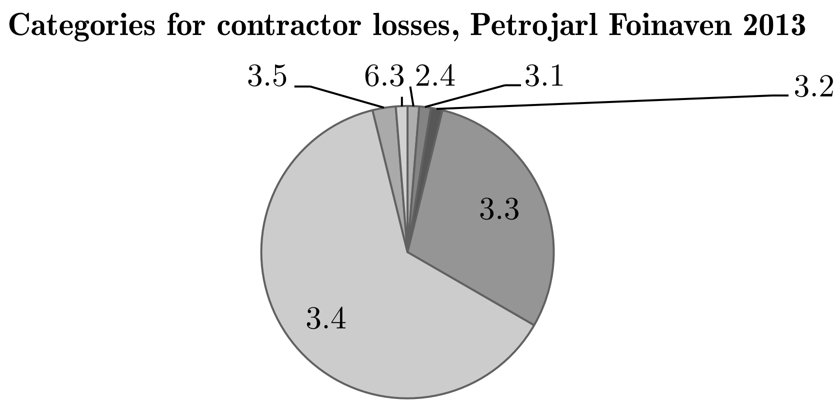


Figure 19: Contractor losses categories distribution, Petrojarl Foinaven 2013

Category	Group	Type of event
1.1	Reservoir	Reservoir limitations
2.1	Well and Subsea	Equipment failure and Corrective Maintenance
2.3	Well and Subsea	Planned Well Intervention to obtain higher oil production
2.4	Well and Subsea	Well Test and Logging
3.1	FPSO	Planned Maintenance
3.2	FPSO	Operational problems caused by modification projects
3.3	FPSO	Process or Operational problems
3.4	FPSO	Equipment failure and Corrective Maintenance
3.5	FPSO	Human Errors
6.3	Other	Weather and Waiting on Weather

Table 13: Loss categories with reported contractor losses

When reporting a loss, key information must be registered in the DRA. The date, time and duration of the loss must be entered along with unit, category and system for the loss. Importantly allocation to operator or contractor must be dealt with and registered. The shutdown level or type is noted, together with the cause tag or component, Synergi ID and supplemental comments. Estimations for losses in oil production, gas flaring and water injection are made. Work Order ID is noted on PJF.

Reporting losses correctly is important so analysis of operation can be done without unnecessary effort. Component or cause of loss is an important piece of information for improvement processes. Reoccurring events causing production losses may be reduced if the root cause may be identified and possibly eliminated using systematic analysis such as root cause analyses.

PJV has are three compressor trains: A, B and C. These contribute large share of the reported contractor losses. In 2013 there were many variations on how these were registered, as shown in Table 14. Some losses are registered with the component in the cause tag and component column while other have a descriptive text in the comment column where the component is revealed. There were differences on the name of the component itself, such as “Comp A”, “HP Compressor A”, “A Compressor”, all designating the came component.

Component	Count
Compressor A	10
Compressor B	21
Compressor C	52
HP Compressor A	10
HP Compressor B	40
HP Compressor C	18
Gas Compressor C	1

Table 14: Grouped count for reported losses on compressors, Petrojarl Varg 2013

The cause or component tag on PJF is primarily entered with tag number on a code format. Additional comments are seldom given. This enables for exact identification of components but makes it difficult to find the component or cause without searching through P&IDs. Difficult component nomenclature and varying component naming increase analysis complexity. Fixed IDs and tags that may be selected rather than free text when reporting the loss in the DRA may simplify this matter.

3.5.3 Collection

Collected data has several utilisations within the company, not merely production reporting, but also in HSE, maintenance and laboratory. This generates a database that is complex and large. When there is no centralised or general strategy as to how tags are developed and managed, the full potential of the collection of the reporting system may not be realised, due to lack of clarity.

The units use different tags as a result of previous history on the units and separate development. There are currently 1874 separate tags registered on in the PI on PJV. PI on PJF contains a total of 1680 tags. There are 17 different tags related to PUF on PJV and 16 tags on PJF.

All tags that are registered in the database are not actively used. This can indicate that there is slack in the number of tags than require. There seems to be some duplication of variables: *Target* and *Target copy* both are logged as daily values. Also the nomenclature may be an issue. Some tags are self-explaining but there is some uncertainty as to what some of the tags mean.

PUF	Today	MTD	YTD
mrpt Contractor		X	X
mrpt Contractor Target		X	X
mrpt Not planned		X	X
mrpt Planned		X	X
rpt Contractor	X	X	X
rpt Operator	X	X	X
rpt Field	X		
rpt MTD		X	
rpt YTD			X
rpt YTD Target			X
rpt Not Planned	X	X	X
rpt Planned	X	X	X
rpt Target	X		
rpt Target copy	X		
rpt Target Diff	X	X	
rpt Target Source	X		

Table 15: PUF tags in PI, Petrojarl Foinaven

PUF	Today	MTD	YTD
mrpt Contractor		X	X
mrpt Not Planned		X	X
mrpt Planned		X	X
rpt Contract	X	X	X
rpt Contractor	X	X	X
rpt Operator	X	X	
rpt Field	X		
rpt Today	X		
rpt MTD		X	
rpt YTD			X
rpt YTD Target			X
rpt Not planned	X	X	X
rpt Planned	X	X	X
rpt Target	X		
rpt Target copy	X		
rpt Target Diff	X	X	
rpt Target Source	X		

Table 16: PUF tags in PI, Petrojarl Varg

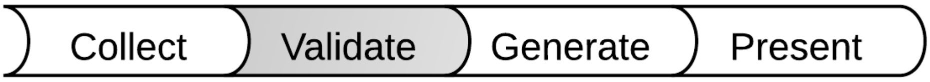
Oil Production	Today	MTD	YTD	Other
rpt -	X			X
rpt Acc Mth		X		
rpt Acc Yr	X		X	
rpt Average Mth	X	X	X	
rpt Comments				X
rpt Comments 2				X
rpt Comments 3				X
rpt Dry	X	X	X	
rpt Dry Acc		X	X	
rpt Dry Avg		X	X	
rpt Dry bbls Acc		X	X	
rpt Dry bbls Avg		X		
rpt Dry bbls Max		X		
rpt Dry bbls Possible Acc		X	X	
rpt Dry bbls Possible Avg		X		
rpt Dry bbls Possible Loss	X			
rpt Dry bbls Possible Loss Acc		X	X	
rpt Dry bbls Possible Loss Avg		X		
rpt Dry bbls Possible		X		
rpt Dry bbls Target Acc		X	X	
rpt Dry bbls Target Avg		X		
rpt Dry bbls Target Diff	X			
rpt Dry bbls Target Diff Acc Mtd		X		
rpt Dry bbls Target Diff Acc Ytd			X	
rpt Dry bbls Target Diff Avg		X		
rpt Dry Target	X		X	X
rpt Dry Target Acc		X	X	
rpt Dry Target Acc Mth		X		
rpt Dry Target Avg Yr			X	
rpt Dry Target Avg		X		
rpt Dry Target Avg Mth		X		
rpt Dry Target Avg Yr			X	
rpt Potential Corrected Target	X		X	
rpt Potential Corrected Target Source	X			
rpt Potential Target	X		X	
rpt Potential Target Source	X			
rpt Target	X			
rpt Target Acc Mth		X		
rpt Target Source	X			
rpt Target Yr			X	

Table 17: Oil Production tags in PI, Petrojarl Foinaven

Oil Production	Today	MTD	YTD	Other
rpt -	X			X
rpt Acc Mth		X		
rpt Acc Yr	X		X	
rpt Average Mth	X	X	X	
rpt Comemnts				X
rpt Dry	X	X	X	
rpt Dry bbls	X			
rpt Dry bbls Acc		X	X	
rpt Dry bbls Avg		X		
rpt Dry bbls Max	X	X	X	
rpt Dry bbls Possible Acc		X	X	
rpt Dry bbls Possible Avg		X		
rpt Dry bbls Possible Loss	X			
rpt Dry bbls Possible Loss Acc		X	X	
rpt Dry bbls Possible Loss Avg		X		
rpt Dry bbls Possible		X		
rpt Dry bbls Target	X			
rpt Dry bbls Target Acc		X	X	
rpt Dry bbls Target Avg		X		
rpt Dry bbls Target Diff	X			
rpt Dry bbls Target Diff Acc Mth		X		
rpt Dry bbls Target Diff Acc Yr			X	
rpt Dry bbls Target Diff Acc Avg		X		
rpt Dry Target	X			X
rpt Dry Target Acc		X	X	
rpt Dry Target Avg		X		
rpt Potential Corrected Target	X		X	X
rpt Potential Target	X		X	X
rpt Potential Wet Target	X			X
rpt Target	X			X
rpt Target Acc		X	X	
rpt Target Avg		X		

Table 18: Oil Production tags in PI, Petrojarl Varg

3.5.4 Validation



Maturity of daily reports is given by the status: draft, checked and approved. Data validation may be seen as a quality measure on the reporting itself. High maturity means that the data has been assured to be correct and reliable.

From 2010 to 2014 the validation of data on Petrojarl Varg has been sub-optimal the first half of this period. The reports for the years 2010 and 2011 largely were dominated by checked-statuses, with 364 checked in 2010 and one draft and 358 checked in 2011. In 2012 a development started in reversing this negative practice. Four reports had draft status, 92 checked and 266 approved.

By 2013 all daily reports were approved. In 2014 this trend continues, with all current daily reports having an approved-status. Petrojarl Foinaven has from 2010 to 2014 by and large had a good performance record in validation of data. A minor number of reports have a not-approved status. From 2010 to 2012 no reports had checked status, while there were three, three and two reports these years that had a draft-status. In 2013 a total of six reports had checked-status. For 2014 the performance continues with approved-statuses dominating.

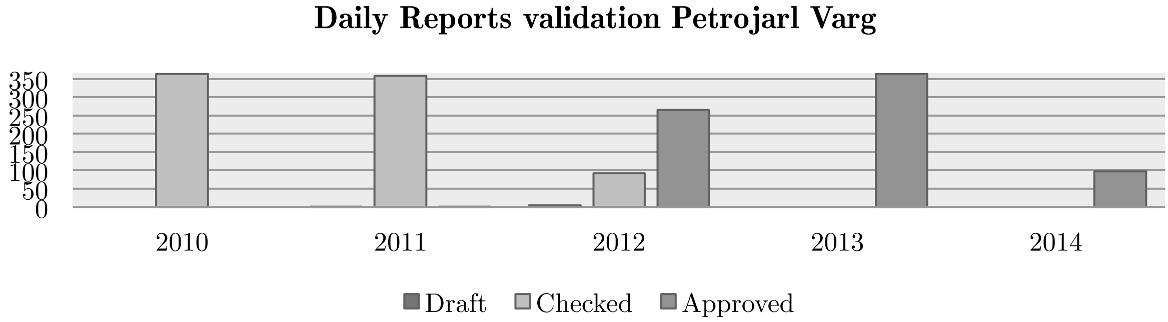


Figure 20: Daily reports validation, Petrojarl Varg

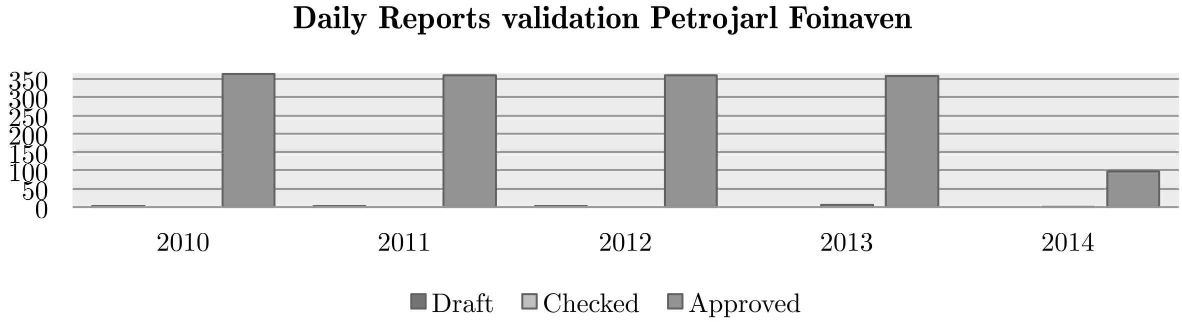
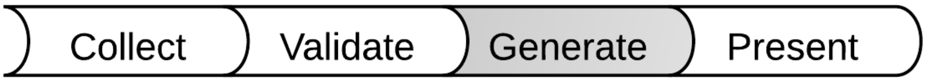


Figure 21: Daily reports validation, Petrojarl Foinaven

3.5.5 Generation



On PJV PUF-Contractor has a generally higher level than the PUF-Operator. Some abnormalities are seen where losses allocated to contractor are seen. The field-PUF combines all losses, and shows the overall performance. The PUF for field performance lies below both operator and contractor PUF.

The OEE is stable, with a few characteristic periods where the facility has been performance negative in terms of this indicator. No further information is however able to get about the cause, since it is an aggregated indicator.

For PJF the resolution is lower on PUF. This is to be expected according to the reported losses on the unit. The shutdown during the summer is not noticeable for the PUF contractor or operator, but is visible on the PUF field.

This means that no one is accountable for the loss, which is to be expected for a possible planned shutdown due to a major modification or repair. It is however peculiar that it is visible on the PUF field. The OEE is naturally affected by the shutdown.

An overview of the daily PUF values and OEE for both units is given in figures 22 to 27.

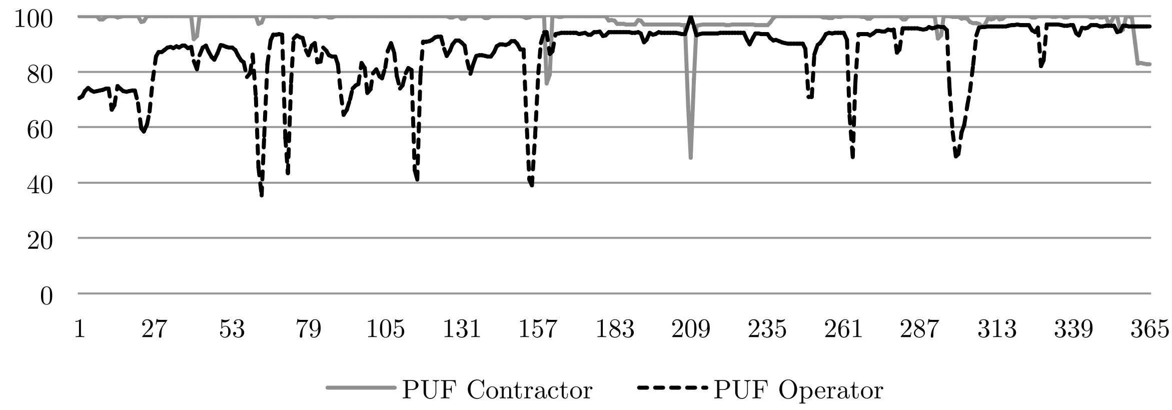


Figure 22: PUF Contractor and PUF Operator, Petrojarl Varg 2013

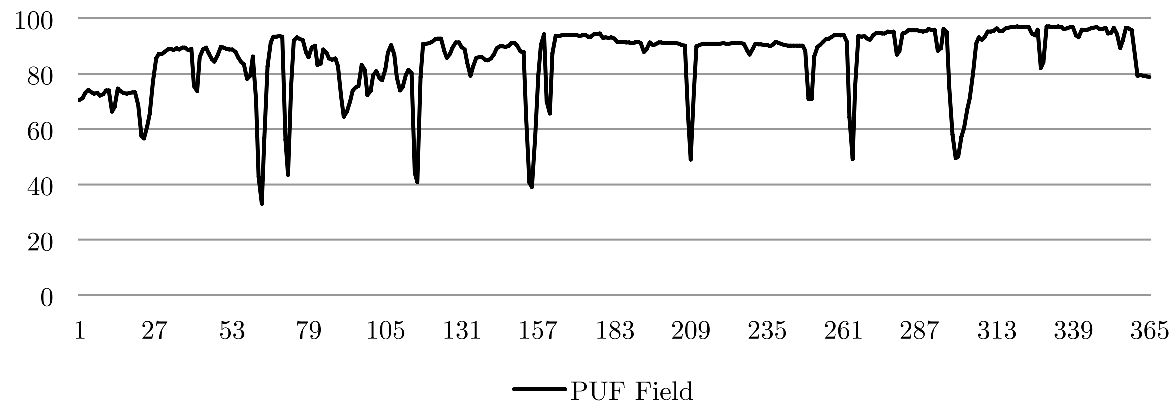


Figure 23: PUF Field, Petrojarl Varg 2013

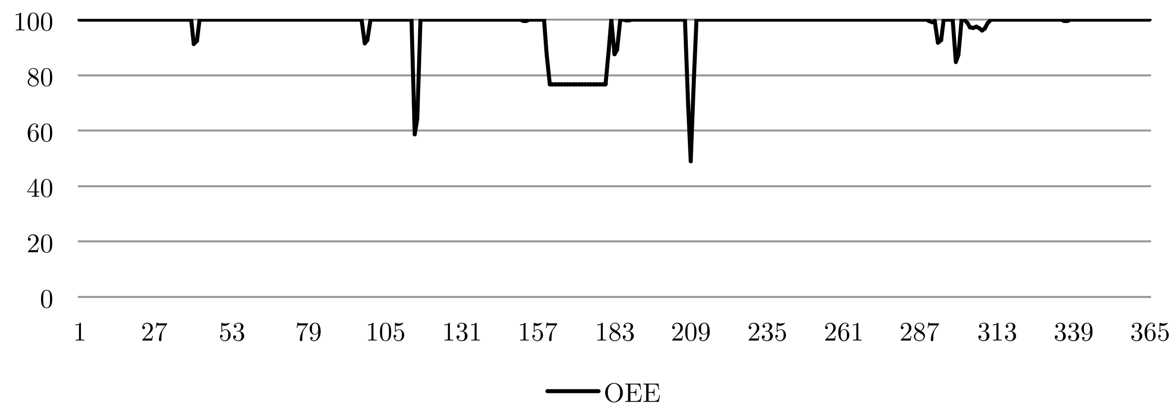


Figure 24: OEE, Petrojarl Varg 2013

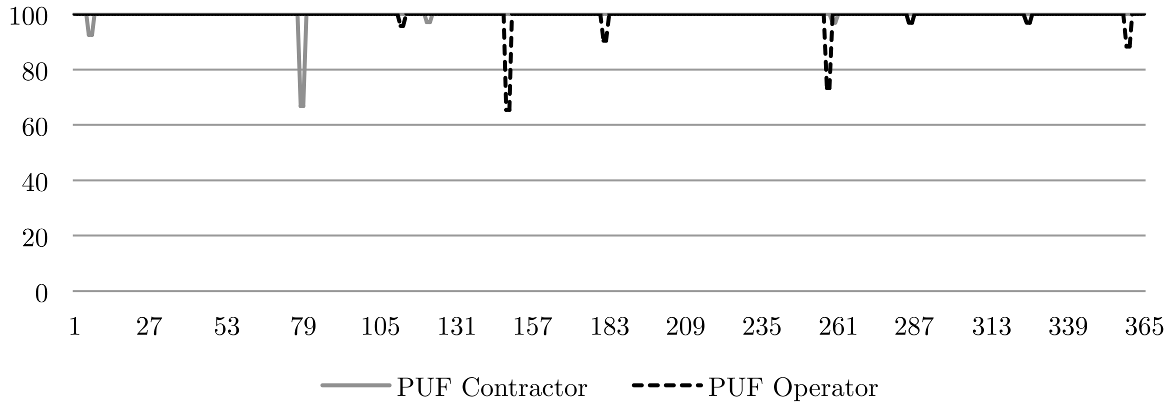


Figure 25: PUF Contractor and PUF Operator, Petrojarl Foinaven 2013

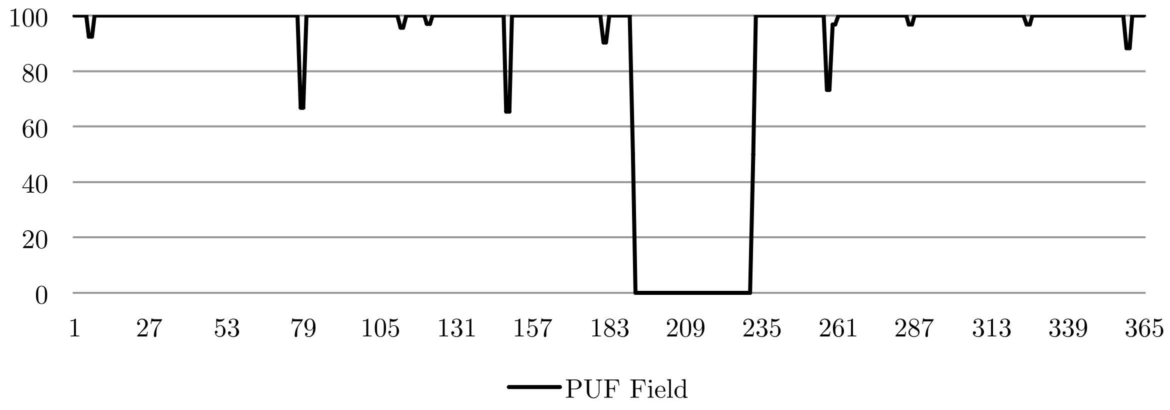


Figure 26: PUF Field, Petrojarl Foinaven 2013

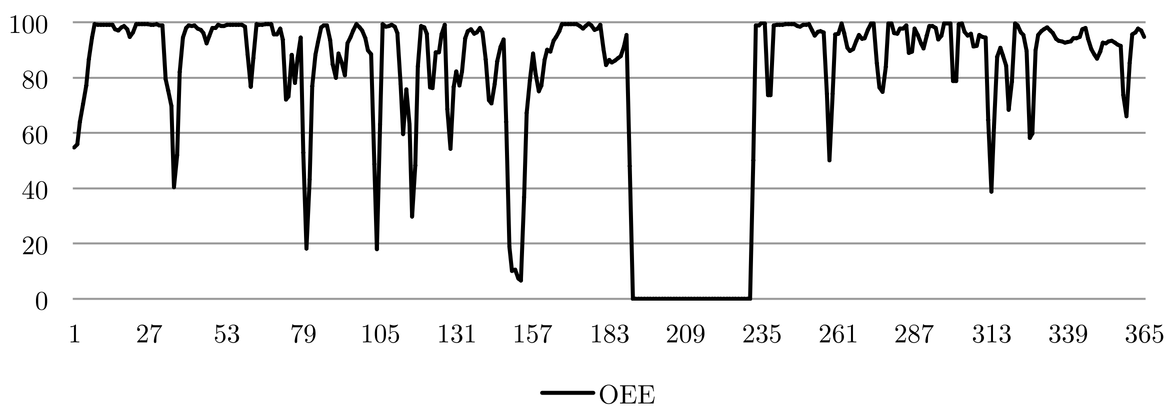


Figure 27: OEE, Petrojarl Foinaven 2013

3.5.6 Presentation

Daily reports have a short half-life because they follow the day-to-day performance. The reports may also be used to investigate certain trends in operation, as well as a input for aggregated reports. Samples of daily reports on the two units are given in Appendix 5 and Appendix 6.

The reports on both vessels have visible validation status. Also a additional comments may be used. PJV tends to not use this field unless it is especially important information while as for PJF it is commonly used to discuss technical issues. Activities, opportunities and vulnerabilities for the next 24 hours can be noted, frequently used on both units. The reports have graphical representations of oil production the past week and accumulated gas flaring and oil to sea. The HSE summaries are identical. The oil production summary showing targets and actual production is given. This is more extensive for PJF than for PJV. Water production, gas production and gas consumption summary is given, with variation as to what is presented.

Key effectiveness figures for the units are stated. These are measures of performance, and there is a specific difference in how these are reported. This is a summary of the KPIs and production statistics on both of the units Daily and MTD values are given. As to the specific figures that are presented, there is large difference. PJV presents the PUFs and losses given in volume for the system, reservoir, well and subsea, FPSO, revision stop, export and non-system.

PJF use these, in addition to field production OEE, regularity availability, production performance, quality oil produced and planned downtime. Production losses are summarised in the Shutdowns – Production downtime part of the report, with similar construction except PJF including work-orders on the loss reporting. PJV does not show OEE at all. This is a deviation from the management system requirements as it is a KPI.

The monthly reports are not established in the same format as the daily reports. The content and format varies. Samples for monthly reports for both units are given in Appendix 7 and Appendix 8. The monthly reports are aggregated reports on Petrojarl Varg. They are created semi-manually, and have a similar layout as some of the other units. It contains three sections: HSEQ, Production and Regularity and Asset integrity. In the HSEQ-section two main topics are covered, Environment and Quality assurance. The Production and Regularity sections contain oil production, water injection and regularity and production losses.

Finally, the Asset integrity section of the monthly report summarises key risks and challenges and maintenance management. The monthly reports of PJF are created manually, containing sections of Health and Safety, Environment, Water Injection, Oil production, Maintenance and Modification and Key Risks and Challenges. The report generally contains more information than the standard layout.

Chapter 4: Analysis

The criteria that were established in section 2.7 Criteria for a Performance Monitoring System had the objective to serve as a basis for design or assessment of such a system. In Chapter 3 Teekay Petrojarl was used as a case to exemplify how the practical application of performance monitoring can be done, with a description of how the company carried out the collection, the validation, the generation of information and presentation of performance in production. The sum of functions that were described was considered to be equivalent of a Performance Monitoring System, although such as system was not formally established.

The criteria can be used to assess the system in Teekay Petrojarl, as documented by the case and empirical example. Such an assessment gives insight as to how well the system performs relative to research and industry development within performance monitoring in the petroleum industry. It can reveal strengths and weaknesses with the system, and can show where resources must be prioritised to improve the systems fulfilment of objectives.

This is carried out in the following through subjective assessment by the author. The score is done on a low-medium-high scale, where the documented system from Chapter 3 has been evaluated for each criterion. The fulfilment of the criterion has been scored on a scale from zero to three. Three represents a high fulfilment of the criteria, two a medium, one a low and zero no fulfilment of criteria. Figure 28 shows the results of the analysis where the system used for performance monitoring in Teekay Petrojarl has assessed and scored for each criterion.

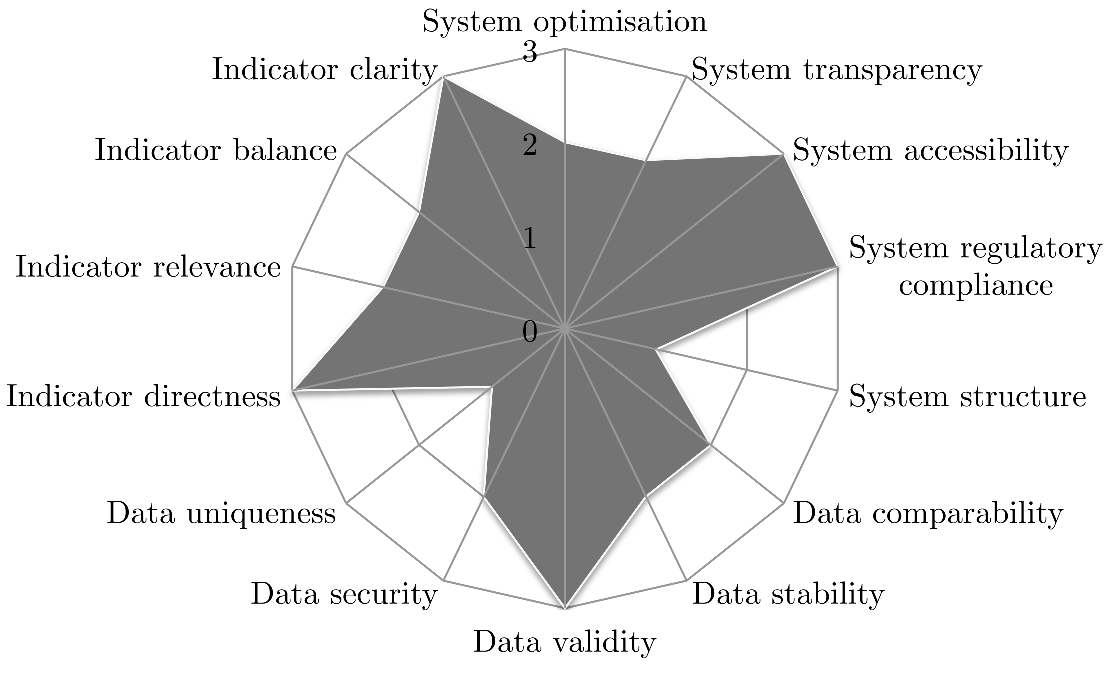


Figure 28: Analysis results of case criteria fulfilment

4.1 Reporting system

4.1.1 System optimisation

Criteria	Description	Score
System optimisation	The system shall contribute to maximising revenue and minimising losses through prevention of sub-optimal operations and incidents leading to losses. The system shall be connected to success critical areas of operations.	Medium

A system to monitor performance is established and utilised on all units in the company. Information from production is distributed widely. The company is contract oriented in its operations, meaning that satisfactory performance relative to the contracts is highly prioritised. Emphasis of this in the Performance Monitoring System in the as-is situation is not evident. With the introduction of contract efficiency as a metric the criteria can be further fulfilled.

An important ability for the system is to be an internal benchmarking tool, comparing unit performance across the fleet. This is done through the information screens, where the performance on several selected areas of interest is presented for each of the units. The reservoirs and fields are different on important variables, as are the facilities and contracts governing them. The company should evaluate if it is optimal to compare the units relative to each other directly, when the framework they operate in is different.

4.1.2 System transparency

Criteria	Description	Score
System transparency	The system, with its functions and processes, must be transparent.	Medium

No sources on user experiences of the system in question have been gathered in this study. However, some comments on the technical structure and status of the system can be made. There is low accessibility to written resources regarding system functionality and how to use software. If a problem arises and counsel is needed or a person is to develop an understanding of the system, written sources are scarce.

Some user manuals and procedures for operations exist for each unit and in management system documentation. The latter is primarily a management and quality assurance tool, not aimed specifically towards production and operations. The company has also lately been working in collecting the resources at dedicated intranet pages.

There is no common documentation for the reporting system, for data flow, usability or for the selected KPIs. More importantly there is no overall strategy on how the company wishes to use the data collected and information developed from operations

4.1.3 System accessibility

Criteria	Description	Score
System accessibility	It should be accessible with easy access to the contents. System should be readily available when needed by user and possible to export to desired use.	High

System access is access to the contents. This is done through PI, daily reports, information screen, and aggregated reports. The common method is either through browsing intranet pages or through the file folder system on company servers. Users that have viewer or editor rights may access it. Permission is given by an administrator, commonly a section, project or division manager. To view data in PI an excel add-in tool is used.

The user-friendliness of this solution can be questioned as it takes a fair amount of effort in excel to produce wanted data. The daily reports are accessed on company server directories. Therefore the aggregated reports could be an optimal solution. Information screen is displayed at the office, as well as on the online operations management portal.

4.1.4 System regulatory compliance

Criteria	Description	Score
System regulatory compliance	The design and use of the system shall fulfil regulatory requirements for formats, functions and structure.	High

Regulatory bodies evaluate the compliance of company systems through periodical and unscheduled audits. No significant discrepancies are noted in the filed of performance monitoring. The overall impression of is that the system fulfils the requirements posed by regulatory authorities.

4.1.5 System structure

Criteria	Description	Score
System structure	The system should utilise a structure where indicators combine to make out a Performance Management System. These should have an as-close-as-possible perspective to the actual performance.	Low

A formal structure as specified in the criterion does not exist. The company has a set of KPIs that are developed in several areas, such as HSE, quality and production, but there seems to be little strategic thinking behind how the entirety of the system should function. This is valid in relation to improvement, and decision-making processes.

Realisation of the full potential of the Performance Monitoring System can be establishing the processes of such as system in a Performance Management System structure.

4.2 Data

4.2.1 Data comparability

Criteria	Description	Score
Data comparability	The data collected must be of the same format or be able to convert to common format and unit, facilitating for efficient comparisons and streamlined archiving	Medium

The data is stored on accessible formats through standard software in the company. This allows for easy access. PI-data can be accessed directly through the SQL-database. An Excel add-in tool can also be used to access data. User friendliness of the two is not optimal. Daily reports are always stored on a portable document format, while the aggregated reports such as monthly and annual reports, have varying formats. The information screen has the same format for all FPSOs as it is one single screen rotating on the units.

Comparability is especially relevant when evaluating volume or time based quantities. While the majority of the formats are compatible and comparable with each other, the data itself may be of different units. This is evident on PJV where Sm^3 is the common measure of oil volume, while bbls is used on PJF. These are different because of the field variables. While the units easily can be converted, the exact conversion factors do rely on specific properties of the fluids in question. This has implications for the ability for the company to carry out benchmarking or comparisons between the units.

For manually entered data the format is mainly text-based. For the same components and causes losses are reported on different tags. Common tags for these would ease the process of generating statistics and therefore increase quality in the improvement processes.

4.2.2 Data stability

Criteria	Description	Score
Data stability	The data stream should have stability. Either it is a variable that is logged continuous value or if it is sampled at time intervals. Equipment and processes that is used for data sourcing should be reliable.	Medium

In the data examined in the case study there are no significant holes in the reported data. Production data exists for both units that have been evaluated, and there are no indications that data is missing on the primary sources. This is automatically generated data, and suggests that the solutions for automatic collection are working well.

Secondary information, additional to the primary directly reported, given by operators, such as assigning a component tag or a supplemental comment to a reported loss in the DRA, varies in format, if it is given at all. Supplemental information can in some cases be vital in identifying cause and improvements. Standardised cause or component tags would ease the method of creating stability in the data with regards to providing additional information, and better use of text-based input can give proper basis for analysis.

4.2.3 Data validity

Criteria	Description	Score
Data validity	The data should have a sufficient integrity so that statistic invalidity is avoided. The data shall be of sufficient volume and resolution. Successful verification of data must be in place.	High

The case example illustrates that the validity of the data collected is high. For units with a past poor level of validity trends indicate that focus is directed towards improving and developing the validity process. Based on this there is no significant basis to suggest that the validity of the data is unacceptable. However, other units may have other trends or statuses than the ones that are treated in this study.

4.2.4 Data security

Criteria	Description	Score
Data security	Data in the system should not be able to manipulate and access should be restricted to wanted users.	Medium

Access to daily reports, aggregated reports, information screen, and PI must be granted to a username. They can only be accessed from within company network or through a secure connection. Access is granted by ICT-support through management permission. Some information may be accessed through the intranet, which has a generic password common for all users, a negative factor when evaluating the criteria. Access to PI through the Excel add-in tool utilises a generic username for all viewers.

There is little opportunity to modify or manipulate the reported data in the system using the standard generic user name. Security is however also a question about access not merely editing. As for collection of data, no documentation of how the access is regulated apart from the OIM having overall responsibility for the reporting and validation, and the subdivision managers have specific responsibilities within their fields, has been found. If the units use generic login credentials to use the DRA and other tools, this opens for possibilities to modify or manipulate data, and would therefore be a negative factor.

4.2.5 Data uniqueness

Criteria	Description	Score
Data uniqueness	Duplication should be avoided and data should not overlap.	Low

In PI there is a large volume of data being reported on similar tags. This can suggest that there is some degree of duplication in the database. Many of the tags are not actively used. Some have not been used for several years the company may focus some effort on cleaning up the database. It must however also be appreciated that these tags contain historical data, needed both in regulatory requirements and for analytical purposes in the company.

4.3 Indicators

4.3.1 Indicator directness

Criteria	Description	Score
Indicator directness	Indicators should be calculated by using data as close as possible to the operations. Aggregated or modified data is not optimal to use in the calculation of indicators.	High

Literature on performance monitoring clearly states that the basis for metrics should be as close to the operations as possible. Indicators that are included as KPIs in Teekay Petrojarl are PUF and OEE. The PUF uses data relatively direct from production but relies on correctly reported losses. These values are interpolated or best-guesses. This means there can be a variation on the level of correctness of the PUF.

These are however a fairly good approximation, with few or none alternative methods of identifying the value. OEE is combined by several measured values and is therefore an aggregated indicator. Assuming availability and quality is reported properly the indicators in the company can be considered to be in accordance with the suggested best practice.

4.3.2 Indicator relevance

Criteria	Description	Score
Indicator relevance	Indicators must reflect success critical areas. They should provide valuable insight in that actual state of operations and be integrated into normal activities, giving an added value to the user.	Medium

The objective of operations is maximising revenue at minimal cost and the indicators should support this objective through providing insight and added value. Essentially this is done through facilitating for decisions through information on past performance. What information the indicators actually contain and what purpose serve in the company must then be evaluated. The indicators are well integrated into normal activities. This gives the indicators a suitable position in the operational management.

The PUFs give the performance in relation to losses on the field and for the operator and contractors. The indicator gives insight in how the unit is performing in relation to the production targets that are set for the given period. Increasing PUF will mean that the unit has been able to reduce the deviation between actual and planned production, suggesting reduced losses, increased production volume and thus increased revenue, a success critical area.

The indicator does however not contain more information than the production deviation, and provides limited insight beyond the historical ability to meet production targets. It is difficult to identify measures for improvement merely based on the PUF. Being the main indicator for performance measurement, the indicator should ideally be supplemented with additional information that may give a foundation for improvement processes.

A remark should be made on the fact that the MTD and YTD variations of PUF, and possible other indicators as well, are reset at the end of a period. They will be little representative as long spanned indicators in the start of the period. In the first month of a year the MTD and YTD will be identical. These will be gradually more valuable as information source as time lapses into the period.

The focus on contract obligations is also an important operational objective. The established indicators do not provide insight in this field apart from the losses that are communicated through the PUF. Performance relative to contract obligation may in the future be fulfilled through the indicator Contract Efficiency.

4.3.3 Indicator balance

Criteria	Description	Score
Indicator balance	There must be a balance in the number of indicators and what areas of operation they are applied to.	Medium

Variations on PUF exist according to stakeholder and time frame of measurement. A total of nine variations are possible covering field players and different time frames. This gives a good balance of indicators when studying production performance.

	Contractor	Operator	Field
Day	PUF_C	PUF_O	PUF_F
Month	$PUF_{C, MTD}$	$PUF_{O, MTD}$	$PUF_{F, MTD}$
Year	$PUF_{C, YTD}$	$PUF_{O, YTD}$	$PUF_{F, YTD}$

The OEE focuses on the availability, quality and performance of facility. The data it is based on is planned and actual production hours and volume together with quality. This provides perspective on the technical status and performance of the facility, an important aspect of operational activities. Yet, PUF already measures the performance in terms of oil production, and already contains some of the information in the OEE.

The question may be raised if the OEE then presents information that gives added value in performance monitoring. This may be illustrated by comparing PUF-contractor and OEE for a given time period. Since the equipment and components integrated in the OEE is of the contractor, and a main cause for contractor losses is shutdowns due to this equipment, there will be some correlation between these two. However, some losses are not due to equipment failure and similar, but other causes that are not included in this regularity perspective.

When viewing the other KPIs used in the company relative to the production oriented ones there is a clear majority of the indicators describing HSE. There are a total of eight HSE indicators, three for quality and two in production. The reason for this is evidently regulatory, as legislation requires a strong monitoring activity to be in place in this field.

It can be argued that there is an unbalance in terms of what is monitored when the company executes performance measurement of its units. Nevertheless it is important to note that this monitoring is intended for not only operations management in production but all other divisions in the company

4.3.4 Indicator clarity

Criteria	Description	Score
Indicator clarity	Indicators should be intuitively understood and be clearly defined, what is measured should be unambiguous and carried out within characteristic time periods.	High

The definition of PUF is defined in company documentation such as company internal notes on PUF calculation and DRA user manuals for each unit. The indicator is intuitive as it conveys the message "how well are we utilising our facility to meet the targets that are set for production". This serves well in promoting clarity for the indicator. As for the OEE the clarity is well defined, but the intuitiveness is harder to grasp. It is however a common indicator in the company and in the industry, and an understanding of what OEE represents have developed over time.

Chapter 5: Discussion

The literature review has broad and liberal perspective and collects sources from several fields of research as well as experiences from the industry. The theoretical framework is synthesised in set of criteria that can be used when designing or assessing a Performance Monitoring System.

Criteria for these systems in specific has not been found in the established literature and may therefore be a new contribution to the spectrum of recommendations that are posed towards stakeholders in the oil and gas industry. The argument of the thesis is that an application of the criteria can aid a producer of oil and gas in offshore petroleum industry to increase revenue through reduced losses and higher facility output.

Teekay Petrojarl is used as a case, where a set of subsystems, is considered to fulfil the objective of a Performance Monitoring System. It is described accordingly using a wide range of resources from the company. Empirical data from two production units is used to demonstrate the practical execution of performance monitoring in practice.

The criteria that are developed based on the literature review is used to assess the system, revealing the strengths, weaknesses and giving a basis to deduce improvement suggestions for the company.

The discussion is separated in three parts. First the criteria will be the focus: the contributions of the thesis and uncertainties with the framework discussed. This is followed by a discussion of the findings from the case analysis, also supplemented by uncertainties connected with the case. Finally, improvement suggestions for both the criteria framework and Teekay Petrojarl are given.

5.1 Criteria

5.1.1 Findings

A framework for assessing and designing a system to monitor performance in offshore oil and gas industry has been established. The framework is defined in section 2.7 Criteria for a Performance Monitoring System. This is through development of criterions assigned to important characteristics of such as system. The criteria take into account the most important aspects from a multidisciplinary literature review consisting of established theory, advances in research, industry experiences and legislative requirements.

The strength of the criteria is the broad span and integrative approach, combining several fields that can contribute positive to development of a system. The weakness is that it is dependent on subjective assessment, which is important to be aware of when it is used. It is a product of the literature review, which always can be extended and more comprehensive.

5.2.2 Uncertainties

The literature review and criteria developed in this thesis are bound to have restrictions. One particular example is that it does not consider the company to exist in a dynamic environment where the stakeholders affect each other. The literature review is today lacking in understanding the contractor as part of a dynamic environment with many different stakeholders.

A theoretical platform for discussing and elaborating on production losses is not found in the literature. Such a platform had therefore to be developed in the thesis by combining different research fields and already established theory in related areas.

A more extensive framework for production losses is possibly needed. It proved difficult to find scientific sources in this area. A clear definition and elaboration on production losses could serve as a basis for a master thesis on its own.

5.2 Case results

5.2.1 Findings

The criteria are used to assess the system, revealing strengths and weaknesses. The assessment reveals key areas where the score was particularly low: system structure and data uniqueness. The system structure criterion is found lacking in fulfilment because of the non-existence of an overall strategy. Such a policy should be in place to define processes, responsibilities and the products of a performance monitoring system.

Performance monitoring is characterised by being measurement effort to support management requirements of delivering KPI information. No processes where they actually are used are documented. A large volume of data being is produced without a clear intention. What was measured and how the information is utilised relative to success critical factors is found lacking.

With regards to management of data, there is a substantial effort that has to be done in systematisation of tags for reporting processes. An unstructured database does not serve as an optimal basis for analysis and improvement processes.

There seems to be a tendency, both in the literature and in the case, that oil and gas companies apply powerful and efficient ICT-tools where it is possible. This is clearly positive because it enables for calculations and analysis that previously was time consuming and expensive.

The tools needed can now be acquired and implemented fairly easy and at low costs. The result is that many different platforms exist in the same environment. Some have specific and unique functionalities, other are more general and some have duplicating functions with other software. The product is a messy landscape that is challenging to navigate in.

This can be considered as one of the reasons for the focus the industry has had on integrated operations the past decade. Harmonising the subsystems in a production infrastructure, whether it is the mechanical components or ICT tools, is vital for the systems to function in an optimal way. This is emphasised in the integrated operations mind-set. It seems also strongly relevant for Performance Monitoring Systems.

5.2.2 Uncertainties

The uncertainty of using a case should always be kept in mind when discussing results. Although excellent access to data was given from the company, manual retrieval from databases and manually working through daily and monthly reports was needed to obtain a necessary fundament for analysis. The methods cause possibility for errors in the empirical basis.

The usability of the systems that contains the data and information itself is a possible error source. Handling of the database by using wrong tags or retrieval method can produce wrong or erroneous variables. Creating statistics of validation of daily reports was done manually by counting the validation statuses of daily reports and keeping tally in a data sheet.

Same method was used on generating statistics on loss reporting, both on counting component contributions and counting operator and contractor losses. The retrieval process was always done multiple times and checked several times to minimise errors in the empirical basis.

Another source of uncertainties is the subjective endeavour where the system was assessment. The system was scored in terms of criteria fulfilment. This causes uncertainty and requires a critical approach to the results. There is a risk that the assessment includes bias or prejudice. Ideas and opinions were naturally created throughout the thesis process.

The challenge is to keep these ideas within a scientific framework and not colour them by subjectivity. A critical distance to the assessment is important, and to avoid not having a balanced case and analysis a critical distance has been sought.

Selection of units was done so that generalisation to the company and the industry would be feasible. This was carried out early in the thesis process by reviewing documentation available for the units. Needless to say there is a significant uncertainty caused by this. The statistical basis by having two of nine units does hardly provide a robust foundation to produce results that can be generalised.

All units should have optimally been studied with a longer time frame. This was not possible for the time set for the thesis. Despite this the findings may indicate trends and reveal strengths and weaknesses on the units that may have potential generalisation in the company. A critical distance should be by held the reader nevertheless.

5.3 Improvement suggestions

5.3.1 Criteria

To improve the framework the existing criteria should be expanded to also include a formal process. This process can be defined so that a complete tool aiding in design and evaluation may be created. A formalised process may aid to minimise the subjectivity inflicted when it is applied.

Extending the theoretical basis to also include industry research publications and revising the criteria after this would improve the framework. Petroleum industry players frequently publish their knowledge and experiences in conference papers and journals. A selection of these was covered in the preliminary project, but the depth of this study was limited at best.

Reviewing publications on the topic by industry players and summarising the experiences these companies have made can contribute to further develop the criteria for Performance Monitoring Systems.

5.3.2 Case

Measuring performance is in all fairness not success critical for a company to succeed. Neither does it generate revenue directly. It is commonly a parallel process to ordinary operation. This thesis argues that a company can increase profitability of its operations through a formalised system that monitors performance.

Not only is this a bold statement, it is also nearly impossible to falsify. The company that seeks to improve its performance must therefore be prepared to take risk when investing time and resources in improving such a system.

The most optimal way for the company to improve the Performance Monitoring System seems to be to initiate a process with sole objective to revise the system. The criteria in the thesis can be used to perform this but also requirements on other forms can be utilised. It is important that the project has a clearly defined aim to revise and develop the current one.

The initial step is to define the purpose and objective of the system. This should be done in accordance and understanding that other systems with equally important functions exists in the same environment. Functions that are to ensure that the Performance Monitoring System fulfils its purpose and objective must be stated in relation to this.

Success critical areas for the operation of the units must be defined and the indicators must be established in accordance with these. In the long term the company should seek to introduce a root-cause methodology that is integrated in the system The Performance Management System mind-set and Production Assurance framework should serve as guidance when creating the revised and formalised system.

A series of minor modifications and quick fixes can be given based on the analysis in this thesis, although a thorough process as mentioned above is advised. Given the uncertainty of the data material and analysis, it is considered that the above-mentioned process best contributes to improve the system. A conservative stance must therefore be taken when suggesting specific measures for improvement.

1. Collection

The units should have similar structure and tag utilisation in PI and in the daily reports. Tags should be identical if they contain the same information. This should at least be valid for the most important tags in production. Tags not in use should be deleted.

How loss reporting is carried out varies on the units. The company will be better served with a common practice on how losses are reported. This means what categories are used for the reporting. Standard nomenclature on components and equipment is advised.

2. Generation

The company should consider using a standardised format on the daily reports. Also the company should decide if monthly reports are to be a standard report. Ideally this should be issued automatically and on identical format for every unit, ensuring a basis for benchmarking the different units.

The MTD and YTD variations of PUF are reset on the start of a new measurement period. An alternative solution may be to have running averages calculated from one month and year prior to the day in question, giving maximum relevance within the time period they evidently are set to describe.

Another factors that influences on the indicators are periods where the facility is shut down or has a zero production output. This can cause noise in the statistical basis. The most critical issue at a facility varies between the units: it can be suboptimal performance or it can be reoccurring failures on components.

If the main problem is suboptimal performance periods with zero production output can be considered neglected from the material, as improvement processes will focus on fine-tuning of operations. If frequent failures are the problem zero-periods will be what actually reflects the success critical factors in the PUF.

A look into developing new indicators can be done, possibly using OPAE as a template. Regularity is used on some units. These have gathered experience in using them. Colleting these experiences and evaluate if it gives value added and is success critical, is suggested. If the experiences are positive the company should consider including regularity as a KPI.

4. Presentation

Bringing forth the causes for losses and suboptimal performance is as important as presenting past track record. One specific method of doing this is to generate more information on performance that can supplement PUF and OEE. Suggestions are statistics on loss categories, component failure contributions and revenue lost because of downtime.

The company should also consider extending the information screen to also include an in depth analysis for the specific unit. This can be displayed at this unit offshore and in the operations park onshore. Loss categories, component failure contributions and revenue lost can also be a part here.

Chapter 6: Conclusion

A literature review in research and developments relevant to Performance Monitoring Systems in offshore oil and gas production is carried out. Important contributions are found in Operations Management, Systems Engineering, Petroleum Production, from standardisation organisations, and in experiences from the industry. The literature review is synthesised in a novel set of criteria that can be used to design and assess a Performance Monitoring System. Each criterion is important to satisfy if the system is to fulfil its objective to improve operational performance and function as a tool for management to take correct decisions.

Results show that a holistic and integrated system is optimal for the system to fulfil its function and objective. Firm focus on internal and external stakeholder requirements must be held. When collecting data unnecessary noise must be eliminated, critical information must not be diluted. The Performance Monitoring System must also be in accordance with the company overall objective so that the decisions made using it is aligned with stakeholder interests.

Teekay Petrojarl is used as a case to illustrate how offshore oil and gas production companies execute performance monitoring. The criteria is utilised to analyse the case, revealing strengths, weaknesses and finding improvement measures that can increase quality and integrity of the system. To plan for excellence in future operations, an understanding of past performance must be developed. This means that the system dedicated to facilitating the understanding must be in accordance with needs and limitations of the persons that are going to operate it.

Analysis of the system shows that an overall strategy to allocate roles, responsibilities and to formalise processes in performance monitoring is missing. Purpose and utilisation of information on past performance is not established. This is recommended dealt with as soon as possible. Data management is also revealed as an issue. This is symptomatic for the industry, where a multitude of software and ICT-platforms create a complex landscape that is hard to orientate in. Continuing effort in integrating operations must be taken to utilise the full potential of digital technology and readily available data.

The case only provides a one-shot glimpse of a dynamic and ever changing environment. In addition, the literature study should be elaborated to increase the quality of each criterion. The analysis is product of a subjective assessment and should be read bearing this in mind, holding a critical distance.

The criteria should be further developed to also include a process that seeks to eliminate influence of subjectivity from the user. The theoretical framework should be elaborated to become more robust. As for Teekay Petrojarl a project should be initiated to establish a formal definition and structure of the Performance Monitoring System.

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Appendix 1: Internal documents from Teekay Petrojarl

The following provides as a list of the suite of documents retreived from Teekay Petrojarl Production AS that is subject to confidentiality and may not be reproduced.

General documentation

Title	Management System Journal (MSM)
Type	User Manual
Date	20.12.2013
Author	N/A
Description	Manual for the Management System applied in Teekay Petrojarl

Title	New PUF Calculations
Type	Company Internal Memo
Date	22. June 2012
Author	Jostein Vada
Description	Document describing new procedures to calculate Production Utilisation Factors

Title	PI Overview
Type	Company Internal Presentation
Date	17. October 2013
Author	André Gjelset
Description	Presentation describing the PI-system including infrastructure

User manuals

Title	Brukemanual for Petrojarl Varg v4.3.0
Type	User Manual
Date	26. August 2013
Author	N/A
Description	Instruction manual for daily report application on Petrojarl Varg

Title	Daily Operation Help
Type	User Manual
Date	21. December 2010
Author	N/A
Description	Instruction manual for daily report application on Petrojarl Piranema

Title	Daily Report Petrojarl Foinaven v.4.0.0
Type	User Manual

Date	N/A
Author	N/A
Description	Instruction manual for daily report application on Petrojarl Foinaven

Title	Daily Report PJO v2.1.0
Type	User Manual
Date	N/A
Author	N/A
Description	Instruction manual for daily report application on Petrojarl Cidade de Rio das Ostras

Title	Lab Report Help
Type	User Manual
Date	21. December 2010
Author	N/A
Description	Instruction manual for laboratory report on Petrojarl Piranema

Title	Registration Function Help
Type	User Manual
Date	21. December 2010
Author	N/A
Description	Instruction manual for registration functions in PIMAQ application on Petrojarl Piranema

Title	Valve Verification Help
Type	User Manual
Date	21. December 2010
Author	André Gjelset
Description	Instruction manual for valve verification in PIMAQ application on Petrojarl Piranema

Title	Petrojarl Foinaven Operations Manual: Part 3, Subsea & Productions Operation, Section 1: Equipment description, Section 2: Philosophies
Type	User Manual
Date	31.03.2011
Author	N/A
Description	Operations manual for FPSO Petrojarl Foinaven

Title	Petrojarl Varg Operations Manual: Part 3, Productions Operations, Section 2:

	System Description, Section 3: Operation Procedures
Type	User Manual
Date	31.03.2011
Author	N/A
Description	Operations manual for FPSO Petrojarl Foinaven

Title	Petrojarl Cidade de Rio Das Ostras Safety Case, Section 3: Facility Description, Section 4: Management System
Type	Documentation
Date	15.06.2011
Author	N/A
Description	Safety case with facility system description of Petrojarl Cidade de Rio Das Ostras

Daily reports

Title	Banff Field Daily Reports
Type	Daily Report
Date	1. January 2011 – 14. January 2012
Author	N/A
Description	All daily reports from Petrojarl Banfft

Title	Foinaven Field Daily Report
Type	Daily Report
Date	1. January 2010 – 14. April 2014
Author	N/A
Description	All daily reports from Foinaven Field

Title	FPSO Cidade de Itajai Daily Reports
Type	Daily Report
Date	30. April 2013 – 14. April 2014
Author	N/A
Description	All daily reports from Petrojarl Cidade de Itajai

Title	Hummingbird Spirit Daily Reports
Type	Daily Report
Date	15. May 2013 – 14. April 2014
Author	N/A
Description	All daily reports from Hummingbird Spirit

Title	Varg Field Daily Reports
Type	Daily Report
Date	1. January 2010 – 14. April 2014
Author	N/A
Description	All daily reports from Varg Field

Title	Voyageur Field Daily Reports
Type	Daily Report
Date	1. January 2013 – 14. April 2014
Author	N/A
Description	All daily reports from Voyageur Spirit

Title	Piranema Spirit Daily Reports
Type	Daily Report

Date	1. January 2013 – 14. April 2014
Author	N/A
Description	All daily reports from Piranema Spirit

Monthly reports

Title	Petrojarl Foinaven Monthly Reports
Type	User Manual
Date	01.2012 – 05.2014 (when available)
Author	N/A
Description	Monthly reports produced on Petrojarl Foinaven

Title	Petrojarl Varg Monthly Reports
Type	User Manual
Date	01.2012 – 05.2014 (when available)
Author	N/A
Description	Monthly reports produced on Petrojarl Varg

Appendix 2: Petrojarl Varg Technical Specifications

Petrojarl Varg is a ship-shaped FPSO that operates in Norwegian sector on the Varg field, NO licence block 15/15. The licence owners of the field are Talisman Energy Norge (operator), Petoro, and Det Norske. The field is situated at a depth of 84 meters. The unit has a contract until Q3 2016 with extension options.

The purpose of the FPSO is to:

- Receive and process crude oil
- Inject seawater to reservoir
- Inject produced gas to reservoir
- Operate and control subsea facilities
- Export stabilised crude oil via shuttle tankers

Figure 1: Courtesy of Teekay Petrojarl

Petrojarl Varg was launched as a new-build ship shaped Tentech 700 design FPSO in 1998. It is turret moored and accommodates 77 persons. In addition to the vessel itself the field also consists of a wellhead platform connected to the FPSO through flexible flow-lines and umbilical. The vessel is classified through DNV-GL as a "+1A1 Oil Production and Storage Vessel (N), POSMOOR ATA, CRANE, HELDK, ECO". The unit complies with Norwegian PSA regulations, as well as Norwegian Maritime Directorate Regulations for offshore units, IMO Mobile Offshore Drilling Unit (MODU) Code, SOLAS and NORSOK Standards.

Length	214,0	Meter
Breath	38,0	Meter
Draught	16	Meter
Displacement	100.021	tonnes
Launch	1998	year
Oil Storage	470.000	bbls
Crude production	57.000	Bopd
Produced water	57.000	Bopd
Water injection	100.000	Bwpd
Gas injection	53	mmscfd
Ground flare capacity	114	mmscfd
Risers/Umbilical	10	Total/in use

A summary of subsea and topside production facility components is given:

Subsea system

- Choke valve (remote operated) (subsea)
- X-mas tree (Subsea)
- Flexible jumper (subsea)
- Production header (subsea)
- Tubing (subsea)

Test separator system

- Test heater
- Test separator
- Test booster pump

Separator system

- Production heater
- 1^{st} Stage separator
- 2^{nd} Stage separator
- Interstage Oil heater (2)
- Electrostatic Coalescer
- Oil coolers

Low-pressure compression package

- Suction Cooler
- Suction Scrubber
- Booster compressor
- Booster condensate pump

High-pressure compression package (A/B/C)

- Compression suction scrubber
- High pressure compressor (4 stages)
- Compressor after-cooler

Sources:

Petrojarl Varg Operations Manual (internal document), 2011

http://www.teekayoffshore.com/Theme/TeekayOffshore/files/brochures/too_varg_brochure2.pdf

http://www.teekay.com/files/FactSheets/FPSO/Petrojarl%20Varg%20-%20digital.pdf

http://oljefakta.petro.no/innretning/petrojarl-varg

Appendix 3: Petrojarl Foinaven Technical Specifications

The Petrojarl Foinaven is a ship-shaped FPSO that operates in British sector on the Foinaven field (UK licence block 204). The field has three blocks and is owned by Britoil Plc. (Licence holder), BP Exploration Operating Company ltd., Marathon Petroleum Ltd and Marubeni Oil and Gas Ltd. The field depth is 390-600 meters, 125 miles west of Shetland.

Figure 1: Courtesy of Teekay Petrojarl

The purpose of the unit is to:

- Receive and process crude oil
- Inject seawater to reservoir
- Inject produced gas to reservoir
- Operate and control subsea facilities
- Export stabilised crude oil via shuttle tankers

The Petrojarl Foinaven was delivered in 1996 by Astano shipyard in Spain, designed by Golar-Nor Offshore. The container vessel "Anadyr" was modified joined with a purpose built section containing cargo storage and turret section, making it both a Newbuild and conversion project. It accommodates 70 people. The FPSO has been producing oil since November 1997, and has been on contract since 1994. It has a contract scope beyond 2021. It is classified by DNV-GL in with following class and notations "+ 1A1 Oil production and Storage Ship, HELDK, EO, F-AMC, POSMOOR ATA, DYNPOS AUT, COW, INERT_GAS, CRANE". The vessel complies with rules and regulation applied on the British continental shelf, SOLAS and MARPOL 73/78.

Length	250,2	Meter
Breath	34,0	Meter
Draught	12,8	Meter
Deadweight	432.769	tonnes
Launch	1996	year
Oil Storage	260.000	bbls
Crude production	140.000	Bopd
Produced water	120.000	Bopd
Water injection	165.000	Bwpd

Gas injection	100	mmscfd
Ground flare capacity	114	mmscfd
Risers/Umbilicals	15/12	Total/in use

Important subsea and topside facility components:

Subsea:

- Choke valve (remote operated) (subsea) (Xmas tree)
- X-mas tree (Subsea)
- Flexible jumper (subsea)
- Production header (subsea)
- Tubing (subsea)

Topside:

- Slug catcher
- Water circulation pump
- Test separator
    - Test separator heater
- Flexible hoses / swivel
- Separator train A & B
    - Heater 1: Heat exchangers (plate) x 2
    - Heater 2: Heat exchanger (tube)
    - Stage 1 separator
    - Stage 2 separator
    - Separator shutdown valves
    - Low pressure compression
    - Inlet diffuser
    - High pressure flare header
    - Hydro cyclone skid
- Separator train B

Sources:

Petrojarl Foinaven Operations Manual (internal document), 2011

http://www.teekay.com/Theme/TeekayCorp/files/doc_downloads/Petrojarl%20Foinaven%20Brochure_June%202011.pdf

http://www.teekay.com/files/FactSheets/FPSO/Petrojarl%20Foinaven%20-%20digital.pdf

Appendix 4: Production Loss Reporting Categories in Teekay Petrojarl

The following tables are an example of the production loss reporting categories used in Teekay Petrojarl. A loss is assigned one of these categories according to its cause and placement in the system. There is some variation in the formulation of the categories in specific, but the category titles and general content is the same across the fleet.

The categories used in this document are a combination of the production loss categories of Petrojarl Varg and Petrojarl Foinaven as they are defined in Brukermanual for Petrojarl Varg v4.3.0 (internal document) and Daily Report Petrojarl Foinaven v.4.0.0. (internal document).

Category	Type of event
A1	Reservoir uncertainties
A2	Planned reservoir interventions
A3	Unplanned reservoir interventions
A4	Well production testing
A5	Downhole well equipment failure
A6	Unplanned subsea well interventions
A7	Planned downhole well interventions
A8	Flow assurance (unplanned)
A9	Post-modification impact

Table 1: Production loss categories - Wells

Category	Type of event
B1	Subsea equipment failure
B2	Unplanned subsea intervention
B3	Planned subsea intervention
B4	Flow assurance (unplanned)
B5	Post-modification impact

Table 2: Production loss categories - Subsea installations

Category	Type of event
C1	Production facilities equipment failure
C2	Unplanned production facilities maintenance
C3	Planned production facility maintenance
C4	Flow assurance (unplanned)
C5	Post-modification impact

Table 3: Production loss categories - Production facilities

Category	Type of event
D1	Equipment failure and repair
D2	Preventive maintenance (planned)
D3	Process/operational problems
D4	Post-modification impact

Table 4: Production loss categories - Process and utilities

Category	Type of event
E1	Offloading
E2	Downstream restrictions
E3	Flow assurance

Table 5: Production loss categories - Export facilities

Category	Type of event
F1	Turnaround
F2	Modification

Table 6: Production loss categories - Turnaround and modification

Category	Type of event
G1	Bad weather
G2	Accidents or contingency requirements
G3	Labour conflicts
G4	Environmental policies
G5	Security
G6	Authority restrictions
G7	Product quality deviations

Table 7: Production loss categories - Other

Category	Type of event
H1	Project schedule delays
H2	Wells schedule delays
H3	Facilities schedule delays

Table 8: Production loss categories - Pre-production

Appendix 5: Daily Report Sample for Petrojarl Varg

TALISMAN ENERGY

Varg Field Daily Report - Page 1 of 4
Daily Report Summary
Report for 00:00hrs to 24:00hrs, 22 juni 2013
Version 4.3.4

TEEKAY PETROJARL

Health, Safety & Environment	Last 24h	MTD	YTD
Lost Time Incidents	0	0	0
Medical Treatment Injuries	0	0	2
Spills to Sea / Gas leakage	0	1	1
HSE - Accidents	0	3	16
HSE - Near Misses	3	5	28
HSE - Conditions	0	14	112
Quality Incidents incl. ESD / PSD	0	8	70
Total Number of Events	3	31	229
Cases with Auth. Notification	0	0	0
Active Monitoring Audits Performed	1	98	578

Days since last LTI:	Days since last oil spill	Perfect days:
366	1 868	NA

Oil Production (last 24h)		Actual	Target	
Oil Production Potential - Wet			1 348,2	Sm³
Oil Production - Wet	1)	1 268,6	1 268,2	Sm³
Oil Production - Wet		7 979,5	7 977,0	bbls
Oil Production - Dry		1 267,7	1 267,3	Sm³
Density - to storage		834,900		kg/Sm³
BS&W - to storage		0,068	<0,500	Vol %
RVP - to storage		8,70	<8,40	psi

Water Production (last 24h)		Actual		
Free Water Produced today	6)	2 663,5		Sm³
Overall Water Cut		67,7		%

Produced Water Handling (last 24h)	Actual	Target	
Produced Water Overboard	2 690,5		Sm³
Produced Water to Slops	0,0		Sm³
Produced Water from Slop - Overboard	0,0		Sm³
Water Jetting	27,0		Sm³
Drain water overboard	0,0		Sm³
Quality Oil-in-Water overboard	2,2	< 17,0	mg/l
Quality Oil-in-Drain water overboard	0,0	< 20,0	mg/l

Water Injection (last 24h)		Actual	Target	
Water Injection (down riser)	7)	7 974,2	9 720,0	Sm³
Mean Oxygen Content		0,3	< 5,0	ppb

Gas Production (last 24h)		Actual	
Gas Production from formation	3)	846 007,4	Sm³
Average GOR today		666,9	Sm³/Sm³

Gas Consumption (last 24h)		Actual	Target	
Gas Flared	2)	0,0	< 17 000,0	Sm³
Gas Injected (ex.Gaslift)		799 069,5		Sm³
Gaslift		72 965,0	< 0,0	Sm³
Fuel Gas used	4)	46 937,9		Sm³

Fuel - Diesel Oil (last 24h)		Actual	Target	
Diesel Consumed - CO2 Tax	5)	10,3	< 16,5	m³
Diesel Consumed - NON CO2 Tax		0,0		m³

Key Effectiveness figures (last 24h)	Day	MTD	Target	
PUF Field	94,1	82,0		%
PUF Contractor	100,0	98,0		%
PUF Operator	94,1	84,0		%
Reservoir Losses	80	2 050		Sm³
Well & Subsea Losses	0	1 391		Sm³
FPSO Losses	0	2 092		Sm³
Revision Stop Losses	0	0		Sm³
Export Losses	0	0		Sm³
Non System Losses	0	0		Sm³

OIM	Operator - Oil Company Rep.
Alf H. Hansen	Morten Krogh

Daily Report Status & Comments:

☐ Draft ☐ Checked ■ Approved

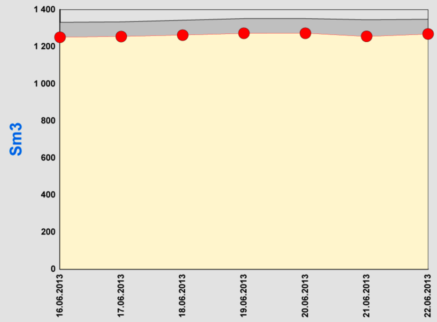
Comments to this report:

Next 24hrs:

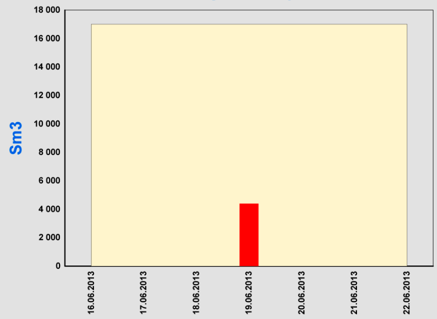
Activities: Hot work in turret area
Opportunities: Stable production
Vulnerabilities: A10 sand production

Exercises & Safety Drills:	Today	Month to date
Safety Drills:	0	3
Comments:		

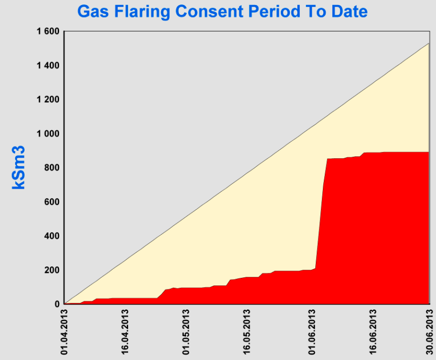
Oil Production 7 last days



Gas flaring last 7 days



Gas Flaring Consent Period To Date



Varg Field Daily Report - Page 2 of 4
Production, Well & Chemical Injection Status Report

Report for 00:00hrs to 24:00hrs, 22 juni 2013

Well Tests

Well On Test	Duration (hours)	End Time (HH:MM)	Choke %	Gaslift Rate (Sm^3)	Oil Rate (Sm^3)	Gas Rate (Sm^3)	GOR Sm^3/Sm	Water Rate (m^3)	Water Cut (%)	WHP (Barg)	WHT (DegC)

Well Status- and Well Allocation Summary @ 24:00

Well	Type	Status	Hours On-Line HH:MM	Choke (%)	Annulus A (Barg)	Annulus B (Barg)	WHP (Barg)	WHT (DegC)	Est.Oil Prod. (Sm^3)	Est.Wtr. Prod. (Sm^3)	Est.Gas Prod. (Sm^3)	Water Cut Vol %	GOR Sm^3/Sm^3	Gas Lift (Sm^3)	Gas Inj. (Sm^3)
A-01	Prod	Closed	00:00	0,0	92,0	0,00	98,0	18,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0
A-03	Prod	Open	24:00	11,0	0,0	56,0	36,9	30,0	0,0	0,0	0,0	0,0	0,0	34 763,0	0,0
A-05	Prod	Test	24:00	11,0	184,5	52,00	38,0	104,5	0,0	0,0	0,0	0,0	0,0	38 202,0	0,0
A-06	WaterInj	Open	24:00	27,0	24,0	-1,70	232,9	21,0	0,0	0,0	0,0	0,0	0,0		0,0
A-07	GasInj	Open	24:00	33,0	18,0	16,00	216,4	17,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0
A-08	Prod	Open	24:00	38,0	81,8	45,50	85,2	90,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
A-09	Not Avail	Closed	00:00	0,0	77,3	12,00	77,2	20,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0
A-10	Prod	Open	24:00	11,0	84,0	20,00	88,0	102,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0
A-11	Not Avail	Closed	00:00	0,0	-999,0	0,00	-999,0	16,7	0,0	0,0	0,0	0,0	0,0		0,0
A-12	Prod	Test	24:00	5,0	66,0	4,00	40,0	36,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0
A-13	WaterInj	Open	24:00	14,0	193,0	2,80	194,6	21,0	0,0	0,0	0,0	0,0	0,0		0,0
A-14	WaterInj	Open	24:00	20,0	10,5	2,20	28,8	25,4	0,0	0,0	0,0	0,0	0,0		0,0
A-15	Prod	Closed	00:00	0,0	105,4	24,00	104,3	18,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0
A-16	WaterInj	Closed	00:00	0,0	5,1	4,00	256,3	21,0	0,0	0,0	0,0	0,0	0,0		0,0
Total									0,0	0,0	0,0			72 965,0	0,0

Chemicals

Storage Tank	Product Name	Product Code	Inj. Rate ml/min	Conc. ppm	Filled	Consumed	Comment
42_40_12_TA001	Corrosion inhibitor	KI-384	39,0	30,0	0,0	0,0	To 1. Stage separator
42_60_12_TA001	Scaleinhibitor	EC6562A	153,0	80,0	2 500,0	0,0	Wellhead
42_40_13_TA001	Corrosion inhibitor	KI-384	19,0	0,0	0,0	0,0	To test separator.
42_30_11_TA001	Oxygen Scavenger	OR-13	90,0	0,0	0,0	0,0	

Comments Wells

Test separator: A05, A-12 : Oil 485 Sm3 and Water 911 Sm3.

Comments Chemicals

Free chloride: 0,64
A-01 Downhole inj 0,00 (ltr/h) Scale injection
A-03 Downhole inj. 0,26 (ltr/h)
A-05 Downhole inj 2.01 (ltr/h)
A-08 Downhole inj 3,22 (ltr/h)
A-10 Downhole inj 3,35 (ltr/h)
A-12 Downhole inj. 0,01 (ltr/h), A-15 Topside inj. 0,01 (ltr/h)

Shutdowns - Production Downtime

Date&Time Start	Durat (hr)	Unit	Losses by: Cat	Syst	C/O	Est losses Oil Dry	Gas Flared	Water Inj.	Shutdown type/level	Cause Tag or Component	Synergi	Comments
22.06.2013 00:00	24,00	A	1.1	A	O	80				A-10		Choked back due to sand production
22.06.2013 07:45	16,00	B	3.4	E	C			1 746		WI pump 13		Out of service, troubleshooting ongoing

Varg Field Daily Report - Page 3 of 4
Personell, Logistics, Stocks, Weather & Activities Report
Report for 00:00hrs to 24:00hrs, 22 juni 2013

Personnel @24:00	Varg A	Varg A @PJV	PJV	Total
TKPJ Personnel	0	0	45	45
TKPJ Contractors	0	0	21	21
Catering Contractors	0	0	7	7
Others	0	0	0	0
Day Visitors	0	0	0	0
Operators	0	0	0	0
Operator Contractors	0	0	3	3
Total POB	0	0	76	76
Total POB Operator			3	
Beds Available			1	

Helicopter Operations

Helicopter ID	Arrived	Departed	Comments

Marine Operations - Vessels

Vessel Name	Arrived	Departed	Comments
Esvagt Dee			Standby Vessel

Next Offloading Window	ETA FPSO	ETA Refinery	Comments
TBN	30.6-02.07		390,000 bbls +/- 5%

Stocks

Crude Oil Stock	
Crude Oil to Stock today (m^3)	1 268,6
Crude in Storage (m^3)	50 514,7
Crude in Storage (bbls)	317 737,5
Crude Storage Available (m^3)	19 166,3
Crude Storage of target (%)	72,5

Diesel	m^3
Consumption Last 24hrs	10,3
Diesel in Stock	905,5
Slops	m^3
Slop to Stock Last 24hrs	0,0
Slop in Stock	188,3

Heli Fuel	Litres
Consumption Last 24hrs	0,0
Heli Fuel in Stock	3 700,0
Fresh Water	m^3
Consumption Last 24hrs	27,3
Fresh Water in Stock	778,4

Product Export Oil Shipped - This Batch / Offloading

Cargo No.:		
Start Loading		
End Loading		
Loading Grs. Volume	0,0	Sm3

Oil Export Quality - This Batch / Offloading

Density	0,0	kg/Sm3
RVP	0,00	psi
BS&W	0,000	Vol %
Salt	0,0	mg/l

Weather and Draught

Waves Last 24hrs		
Max Sign Wave Height	1,7	m
Maximum Wave Height	3,2	m
Significant Wave Period	6,2	sec
Heave, Surge & Sway last 24hrs		
Maximum Heave (10 min)	1,1	m
Maximum Surge (10 min)	1,0	m
Maximum Sway (10 min)	0,7	m
Draught		
Draught Fwd.	13,2	m

Wind (10 min)		
Avg W speed @ 24hrs	6,9	m/s
Avg W Dir @ 24hrs	166,0	deg
Max Gust W Sp Last 24hrs	15,1	m/s
Air Temperature, Air Pressure & Visibility		
Air Temperature	12,0	deg C
Air Press at Helideck	995,9	hPa
Visibility	10,0	km
Draught Aft	13,6	m

PJV Operations Summary

Stable production

07:45 Stopped WI 13 due to trobleshooting.
08:38 Stopped vacuum booster pump due to change of oil/filter.
08:55 Started vacuum booster pump.
19:59 Adjusted O2 scavanger --> 90 ml/m.
21:45 Started jetting degasser and 1 stage sep.
23:04 Jetting completed on 1 stage sep.

Varg A Operations Summary

Synergi / Safecard Summary

No	Summary
4010798	Defect safty function on crane 1.
4010797	Emergency light failed during function test..
4010805	Leakage on cooling medium system.

Non Conformance

Status	No	Summary

Marine Summary

Surface treatment/Painting on tank deck and process deck.
Painting on forcastle.
Scaffolding in process.
Rig pull in equipment for GE riser.
Build habitat, gas export, turret.

E&I Summary

Pulling cables for gas export.
PM flodlights
Modify levelgauge in ballasttanks.
Repair lights aft.
Install aircondition in crane 3.
Check chlorine pump for fw.

Mechanical Summary

Remove and install clamps for pipes on tankdeck.
Various work orders in PMS.
Troubleshoot fuel gas motor 3.
Install inter lock on 4 valves on test seperator.
Install air condition in crane 3.
Visual inspection camshaft on motor # 3.
Overhaule W I- pump 13.
Disconnect hydraulic panel on anchor winch.

Main Equipment Down

Water injection pump nr 13 due to troubleshooting.

Varg Field Daily Report - Page 4 of 4
Insentive & Accumulation Report

Report for 00:00hrs to 24:00hrs, 22 juni 2013

Flaring	Day - Last 24 Hours	Month - Average	Month - Accumulated	Year - Accumulated	
Flaring - Actual.	0,0	31 509,0	693 205,3	2 056 924,9	Sm^3
Flaring TKPJ	0,0	3 847,6	84 646,9	448 469,1	Sm^3
Flaring Operator	0,0	27 661,7	608 558,5	1 600 409,2	Sm^3

Diesel	Day - Last 24 Hours	Month - Average	Month - Accumulated	Year - Accumulated	
Diesel consumed - Actual	10,3	17,9	394,6	2 595,3	m^3
Diesel TKPJ	10,3	17,9	394,6	2 440,5	m^3
Diesel Operator	0,0	0,0	0,0	154,8	m^3

Fuel Gas	Day - Last 24 Hours	Month - Average	Month - Accumulated	Year - Accumulated	
Fuel Gas Consumption	46 937,9	34 634,6	761 962,2	6 432 565,0	Sm^3

Production	Day - Last 24 Hours	Month - Average	Month - Accumulated	Year - Accumulated	
Target - Oil Production	1 347,7	1 369,4	30 125,8	272 850,0	Sm^3
Oil Produced - Actual	1 268,6	1 119,0	24 618,3	221 072,2	Sm^3
Diff. Oil Production 8)	0,4	-0,4	-9,6	-378,1	Sm^3

Water Injection					
Water Injection (Down riser)	7 974,2	6 737,1	148 215,9	828 774,9	Sm^3
Water Injection Target	9 720,0	7 154,8	157 406,1	947 211,3	Sm^3
Water Injection Utilisation Factor Contractor	-	-	-	-	%

Injection Wells	Last 24 Hours	Target day	Last week acc	Target week	Month - Accumulated	Year - Accumulated	
A-06	2 075,8	2 400,0	16 769,4	18 018,8	34 815,9	34 816,8	Sm^3
A-07	0,0	0,0	0,0	0,0	0,0	409 000,7	Sm^3
A-13	1 422,2	1 320,0	11 345,1	11 868,2	18 644,5	18 811,8	Sm^3
A-14	4 476,2	6 000,0	37 692,7	39 991,8	70 203,8	339 412,4	Sm^3
A-16	0,0	0,0	0,0	0,0	24 551,7	26 733,1	Sm^3

Comments to this Report

1)
2)
3)
4)
5)
6) Jetting 1 stage sep.
7) WI pump13 in test modus and troubleshooting ongoing.
8)

Appendix 6: Daily Report Sample for Petrojarl Foinaven

Foinaven Field Daily Report - Page 1 of 3
Daily Report Summary
Report for 00:00hrs to 24:00hrs, 17 September 2013 Version 4.0.2

TEEKAY PETROJARL

Health, Safety & Environment	Last 24h	MTD	YTD
Lost Time Injuries	0	0	0
Medical Treatment Injuries	0	0	1
Spills to Sea / Gas Leakage	0	0	0
HSE - Accidents	0	3	15
HSE - Near Misses	0	0	16
HSE - Conditions	0	0	6
Quality Events inkl. ESD / PSD	0	0	9
Total Number of Events	0	3	47
Cases with Auth. Notification	0	0	0
Active Monitoring Audits Performed	3	16	432

Days since last LTI:	Days since last oil spill	Perfect days:
393	146	258

Oil Production (last 24h)	Actual	Target	
Oil Production - Wet	30,370		bbls
Oil Production - Dry	30,191	*24,500*	bbls
Scale/Corrosion Inhibitor (subsea)	54	*< 60.00*	ppm
BS&W - to storage	0.590	*< 1.000*	Vol %

Water Production (last 24h)	Actual	Target	
Water Production	80,120		bbls
Overall Water Cut	73.0		%

Produced Water Handling (last 24h)	Actual	Target	
Produced Water Overboard	79,941		bbls
Oil-in-Water overboard	35.70	*< 30*	ppm
Monthly OIW Average	31.40		ppm
Produced Water to Slops	0		bbls
Oil in Produced Water & Spills YTD	17.7	*< 20.0*	tonnes
Oil-in-Water ReInjected	0.00		ppm

Water Injection (last 24h)	Actual	Target	
Water Injection (down riser)	8,057	*0*	bbls
Produced Water ReInjected	0		bbls
Mean Oxygen Content	0.60	*< 10.00*	ppb
Mean WI Pump Discharge Pressure	35.89	*0.00*	barg

Gas Production (last 24h)	Actual	Target	
Gas Production from formation	23.28		MMscf
Field GOR	771	*789*	scf/bbl

Gas Consumption (last 24h)	Actual	Target	
Gas Export 06:00 - 06:00	8.70		MMscf
Gas Export 24:00 - 24:00	10.40		MMscf
Mean Water Content	0.59	*< 1.70*	lb/MMscf
Mean H2S Level	32.60	*< 3.30*	ppm
Gas Flared (less inerts)	4.61	*1.70*	MMscf
Flared over consent for period	-177.02		MMscf
Gas to subsea (down riser)	39.40		MMscf
Gaslift	23.82		MMscf
Fuel Gas used	2.53		MMscf

Fuel - Diesel Oil (last 24h)	Actual	Target	
Diesel Consumed - NON CO2 Tax	54	*< 18*	m^3

Key Effectiveness figures (last 24h)	Day	MTD	Target	
Field Production OEE	99.4	92.5		%
Regularity Availability	100.0	100.0		%
Production Performance	100.0	93.3		%
Quality Oil Produced	99.4	99.1		%
Planned Downtime	0.0	0.0		hrs
PUF Field	93.8	96.00		%
PUF Contractor	93.8	100.00		%
PUF Operator	100.0	97.00		%
Reservoir Losses	0	0		bbls
Well & Subsea Losses	0	0		bbls
FPSO Losses	2,000	22,000		bbls
Revision Stop Losses	0	0		bbls
Export Losses	0	0		bbls
Non System Losses	0	0		bbls

OIM	Operator - Oil Company Rep.
Svein Arntsberg	Sean Frost

Daily Report Status & Comments:

☐ Draft ☐ Checked ■ Approved

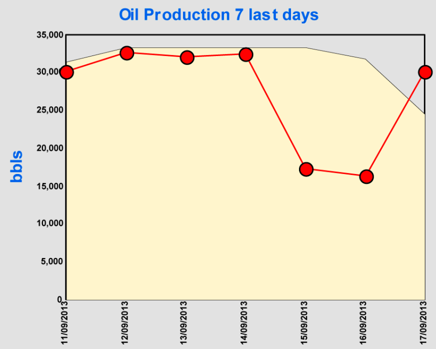
Comments to this report:

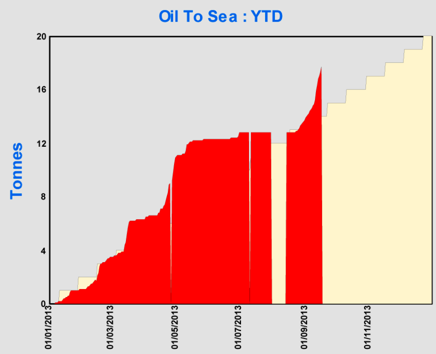
Target met: Rates from COT dips
1/2A Comp: Lo suction flowX2.New software uploaded & Unit i/c. WI stillo/c: Flowmeter problem.

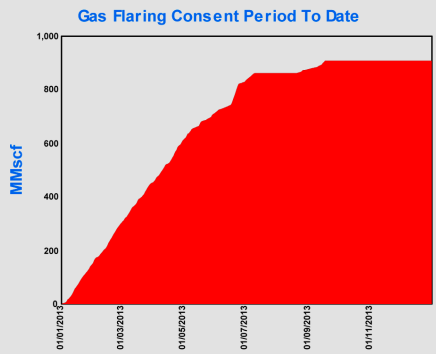
Next 24hrs:

Activities	GDE1D.PortBoiler.WI Standby flowmeter.
Opportunities	Complete Test Repairs. Thruster test run.
Vulnerabilities	Water detected in Thruster. Standby Wi flowmeter.

Exercises & Safety Drills:	Today	Month to date
Safety Drills:	0	3
Comments:		







Foinaven Field Daily Report - Page 2 of 3
Production & Well Status Report
Report for 00:00hrs to 24:00hrs, 17 September 2013

Well Status- and Well Allocation Summary @ 24:00

Producers

Well	Status	Riser	Hrs on-line (HH:MM)	Choke (%)	Est.Wtr.Cut (Vol %)	Est GOR (scf/bbls)	Gas Lift (MMscf)	Alloc Gas rate (MMscf)	Alloc Wtr rate (bbls)	Oil Prod. (bbls)
P11	P	R5	24:00	30	53.6	400	0.46	0.3	1,078	677
P12 (T35)	S/I		00:00	0	27.4	250	0.00	0.0	0	0
P13	P	R5	21:04	20	74.6	300	0.25	0.4	5,284	1,306
P15	P	R14	20:51	26	82.0	700	1.67	0.8	7,912	1,260
P16	P	R7	24:00	10	30.7	5,000	0.00	8.2	1,063	1,741
P17	P	R14	21:34	50	49.3	1,500	3.04	4.7	4,424	3,301
P18	S/I		00:00	4	84.3	800	0.00	0.0	0	0
P19	P	R7	21:55	38	25.7	2,000	1.74	2.8	715	1,501
P110 (T25)	P	R14	19:51	51	59.5	600	2.35	1.0	3,401	1,680
P111	P	R5	24:00	56	25.0	200	1.45	0.9	2,132	4,642
P21	P	R15	24:00	100	67.1	300	3.71	1.1	10,601	3,772
P22	S/I		00:00	32	77.0	250	0.00	0.0	0	0
P23	S/I		00:00	61	96.3	340	0.00	0.0	0	0
P24	S/I		00:00	30	78.2	150	0.00	0.0	0	0
P25	S/I		00:00	0	73.9	350	0.00	0.0	0	0
P26	S/I		00:00	0	80.0	2,600	0.00	0.0	0	0
P27	P	R2	24:00	69	84.3	175	0.00	0.7	29,340	3,965
P28	S/I		00:00	21	64.1	357	0.00	0.0	0	0
P29	P	R2	22:22	51	73.6	412	3.50	0.7	6,923	1,802
P210	S/I		00:00	50	94.6	500	0.00	0.0	0	0
P211	S/I		00:00	0	66.9	250	0.00	0.0	0	0
P212	S/I		00:00	0	6.8	1,100	0.00	0.0	0	0
P213 (CU)			00:00	0	0.0	0	0.00	0.0	0	0
P41 (EF)	P	R6	24:00	58	83.5	700	3.36	0.3	3,372	484
P42 (EF)	P	R6	24:00	60	40.9	400	2.29	1.5	3,874	4,062
P43 (EF)	S/I		00:00	20	90.0	896	0.00	0.0	0	0
Totals							23.82	23.30	80,120	30,191

Water Injectors

Well	Status	Hrs on-line HH:MM	Choke %	Tree Inj Press. (bara)	Wtr Inj Rate (bbls)
W11	S/I	00:00	100	231	0
W12	S/I	00:00	5	90	0
W13	S/I	00:00	20	104	0
W14	S/I	00:00	0	53	0
W (P14)	S/I	00:00	50	5	0
W15	S/I	04:13	11	70	5,011
W16	S/I	00:00	10	59	0
W17	S/I	00:00	15	59	0
W18	S/I	04:10	16	102	154
W19	S/I	00:00	0	61	0
W110	S/I	04:18	26	38	204
W22	S/I	00:39	28	138	0
W23	S/I	00:00	0	59	0
W24	S/I	00:00	29	64	0
W25	S/I	00:00	41	0	0
W26	S/I	00:00	0	59	0
W41 (EF)	S/I	04:03	23	128	1,998
W42 (EF)	S/I	04:02	21	122	690
Totals					8,057

Comments Wells

Comments Chemicals

Gas Export & Gas Injectors

Well	Status	Hrs on-line HH:MM	Choke %	Tree Inj Press. (bara)	Gas Inj Rate (MMscf)
Export 24:00	Export	20:07	2	171	10.40
G31	S/I	00:00	1	0	0.00
P12	Inj	17:50	0	0	5.20
Totals					15.60

Scale/Corrosion Inhibitor

Scale/Corrosion Inhibitor (DC -1)	54	ppm
Scale/Corrosion Inhibitor (DC -2)	55	ppm
Scale/Corrosion Inhibitor (Subsea excl. EF)	54	ppm

Shutdowns - Production Downtime

Date&Time Start	Durat (hr)	Losses by: Cat	Syst	C/O	Est losses Oil Dry (bbls)	Gas Flared (MMscf)	Shutdown type/level	Cause Tag or Component	Synergi	Work Order	Comments
17.09.2013 06:30	0.50	3.4	F	C	500	1	G3/431	FAXX10911L			
17.09.2013 11:55	1.40	3.4	F	C	1,500	3	G3/431	FAXX10911L			
17.09.2013 11:03		3.4	E	C			G9/354	2PIT1311L			

Foinaven Field Daily Report - Page 3 of 3
Personell, Logistics, Stocks, Weather & Activities Report
Report for 00:00hrs to 24:00hrs, 17 September 2013

Personnel

Personnel	
Total POB at field @ 24:00:	
Teekay Petrojarl	43
Operator	3
Catering	6
Operator Contractor	2
Teekay Petrojarl Contractor	15
Other	0
Day Visits	0
Total POB at PJ Foinaven	69
Beds Available:	20

Helicopter Operations

Helicopter ID	Arrived	Departed	Comments

Marine Operations - Vessels

Vessel Name	Arrived	Departed	Comments
Subsea Viking	23:17		

Next Offloading Window	ETA FPSO	ETA Flotta	Comments
Petroatlantic	18.09.13 11:00		

Stocks

Crude Oil Stock	
Crude oil to stock today (bbls)	30,191
Crude in Storage (m^3)	12,400
Crude in Storage (bbls)	77,907
Crude Storage Available (m^3)	23,600
Crude Storage of target (%)	34

Diesel	m^3
Consumption L24h	54
Diesel in Stock	1,845
Slops	**m^3**
Slop to Stock L24h	20
Slop in Stock	610

Heli Fuel	Litres
Consumption L24h	0
Heli Fuel in Stock	9,865
Fresh Water	**m^3**
Consumption L24h	0
Fresh Water in Stock	659

Methanol	liters
Consumption L24h	288
Methanol in Stock	7,000
HW 540	**liters**
Consumption L24h	900
HW 540 in Stock	12,400
Petrocare	**liters**
Consumption L24h	1,500
Petrocare in Stock	41,000

Product Export Oil Shipped - This Batch / Offloading

Cargo No.:		
Start Loading		
End Loading		
Loading Grs. Volume	0.0	Sm3

Oil Export Quality - This Batch / Offloading

Density	0.0	kg/Sm3
RVP	0.0	psi
BS&W	0.0	Vol %
Salt	0.0	mg/l

Weather and Draft

Waves Last 24hrs		
Max Sign Wave Height	2.6	m
Maximum Wave Height	4.2	m
Significant Wave Period	0.0	sec
Heave, Pitch & Roll last 24hrs		
Maximum Heave (10 min)	5.5	m
Maximum Pitch (10 min)	1.4	deg
Maximum Roll (10 min)	2.7	deg
Draught		
Draught Fwd.	11.3	m

Wind (10 min)		
Avg W speed @ 24hrs	3.8	m/s
Avg W Dir @ 24hrs	255.0	deg
Max Gust W Sp Last 24hrs	4.9	m/s
Air Temperature, Air Pressure & Visibility		
Air Temperature	6.2	deg C
Air Press at Helideck	1,032.3	hPa
Visibility	10.0	km
Draught Aft	13.0	m

Operations Summary

Star maintenance,
Addressing synergi/safecard actions
Cont. with circulation/filtration of 1+2B-comp. lub. oil,
WI stand by pump started. Tripped again and trouble shooting min flow transmitter. Ongoing trips and restarts.
Trouble shooting B coal oil flow meter completed. Online.
1&2A trip. Restarted. Tripped again and mod made on low flow flow in the UCP. Restarted.
All wells on start up after Comp stop.
HP FG comp started B after comp stoppage.
Glycol pump B PSV1607B removed for recert.

Standing active process alarms =

Marine Summary

PM's
General Housekeeping
Synergi & safecards actions
Various Scaffolding, boiler
sea fastening
Prep backload
lift in eng room

E&I Summary

Star Maintenance.
FT 703A
Trace earth fault on 230 V distribution systems.
Troubleshoot on Engine 1C, Fuel Gas System
Safe Card Actions
Test of Truster Control
Troubleshooting of Software for Compressor 1&2A
Troubleshooting on FT 1303 WI St.By Pump

Synergi / Safecard Summary

No	Summary

Mechanical Summary

STAR Maintenance
Commissioning of aft Thruster
Safe cards
Preparation of port boiler for inspection/repair
Start major overhaul of engine 1D
Overhauling PSV´s
Housekeeping

HSE Comments

1 PtW audits, 0 Active monitoring, 0 ORR. 2 Safe cards.

Non Conformance

Status	No	Summary
Active	18807	Major NC W14 Dispensation for long-term shut-in
Temporary	-2701	Minor NC 400 Not recording safecards in synergi
Temporary	-7744	Minor NC: Overdue planned maintenance tasks 2013
Temporary	-1504	Minor NC: Deviation against Offloading C/L aft thruster OS

Main Equipment Down

B PWRI booster pump
P21 & P25 PCV's
Discharge header methanol pump
R11
Erosion probes on manifold deck
Sludge pumps A + B in engine rooom
1/2 B Compressor
1D engine Damaged bearing on one time gear wheel.
Aft thruster
Fuel gas compressor A

Appendix 7: Monthly Report Sample for Petrojarl Varg

Petrojarl Varg – Varg field Operations

June, 2013

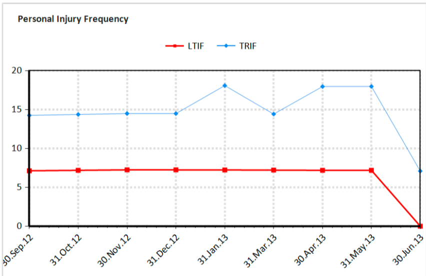
Status:	**Approved**
Approved By:	RAAS
Approved Date:	14-08-2013

Section 1: HSEQ

Health & Safety

Days since Last LTI **374**

	Units	MTD	YTD
Lost Time Incidents		0.00	0.00
Medical Treatmens Injuries		0.00	2.00
Spills to Sea / Gas Leakages		2.00	2.00
Authority Notifications		0.00	0.00
Number of High Potential Incidents			
HSE program - Planned Progress	[%]		
HSE program - Actual Progress	[%]		



Comments

4007463 Fremmedlegeme på høyre øye Debris on the eye

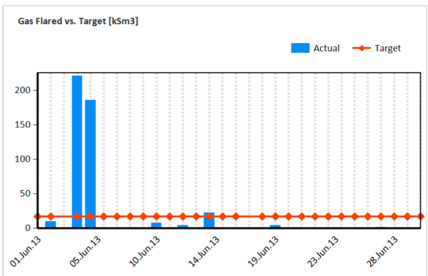
4009557 Person traff skarp kant med hode

4010510: Liten gasslekkasje i stem på blokkventil – Varg A

4010494: Ubetydelig lekkasje fra stem på blokkventil i turret

Environment - Emission to Air

	Units	MTD	Daily Avg.	PTD
Actual Flared Gas	[kSm3]	695.3	23.18	894.2
Consent Flared Gas	[kSm3]	510.0	1 547	
Remaining to meet Consent	[kSm3]	-185.29	-6.18	1 018
Diesel consumed	[m3]	522.3	17.41	2 723
Fuel Gas Used	[kSm3]	1 109	36.97	6 780
Actual CO2 from Flared Gas	[Tonnes]	2 593	86.45	7 680
Actual CO2 from Diesel	[Tonnes]	1 407	46.91	7 337
Actual CO2 from Fuel Gas	[Tonnes]	3 181	106.0	19 444
Actual CO2 - total	[Tonnes]	7 182	239.4	34 461



Petrojarl Varg – Varg field Operations

June, 2013

Status: **Approved**

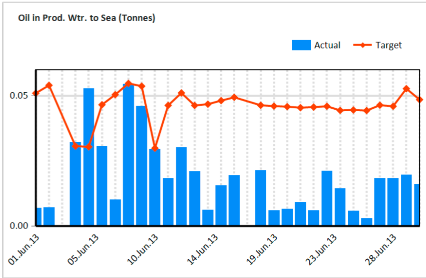
Approved By: RAAS

Approved Date: 14-08-2013

Environment - Discharge to Sea

Days since last Oil spill **1876**

	Units	MTD	YTD
Actual Quality Oil in Water Overboard	[Mg/l]	7.90	16.20
Target Quality Oil in Water Overboard	[Mg/l]	17.00	17.00
Oil in Water Overboard	[ton]	0.60	6.54



QA

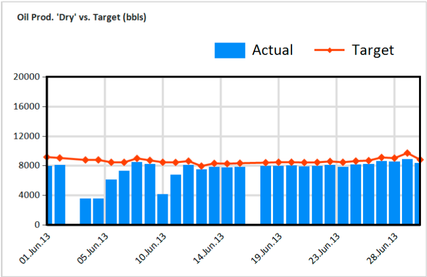
	Units	Value
Audits and Inspection Program Status		
No. Of Open Synergi Actions (All)		23.00
No. Of Overdue Synergi Actions - Priority 1		0.00
No. Of Overdue Synergi Actions - Priority 2		11.00

Petrojarl Varg – Varg field Operations	Status:	Approved
June, 2013	Approved By:	RAAS
	Approved Date:	14-08-2013

Section 2: Production and Regularity

Oil Producion "Dry Volume"

	Units	MTD	Daily Avg.	YTD
Actual Oil Produced	[bbls]	221 405	7 380	1 455 760
Target Oil Production	[bbls]	260 706	8 690	1 787 442
Actual Oil Produced	[Sm3]	35 201	1 173	231 448
Target Oil Production	[Sm3]	41 448	1 382	284 172



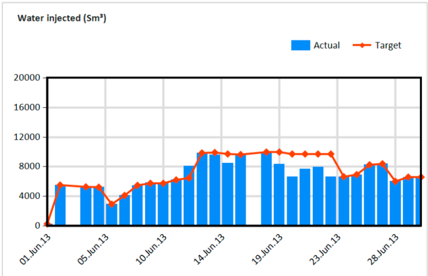
Water Injection

Injected Water

	Units	MTD	Daily Avg.	YTD
Actual Water Injection	[Sm3]	202 209	6 740	882 768
Target Water Injection	[Sm3]	214 187	7 140	1 003 990
Required to Meet Target	[Sm3]	12 271	409.0	121 517

Re-Injected Produced Water

	Units	MTD	Daily Avg.	YTD
Produced Water Disch. to Sea	[Sm3]	80 730	2 691	425 504



Regularity & Production Losses

	Units	MTD	YTD
Actual Prod. Utiliz. Factor (PUF) Contractor	[%]	98.44	99.56
Target Prod. Utiliz. Factor (PUF) Contractor	[%]		
Actual Production Losses – Planned	[%]	2.65	4.09
Actual Production Losses – Not Planned	[%]	12.24	14.03

This month recorded causes of production DownTime & Losses

	Units	MTD	YTD
Actual Production Losses - Planned	[Sm3]	1 125	11 687
Actual Production Losses - Not Planned	[Sm3]	5 122	40 005

	Units	MTD	YTD
OEE *1)	[%]	83.64	96.68
Availability – Regularity	[%]	83.67	96.87
Performance – Production	[%]	99.97	99.82
Quality – Oil to Storage	[%]	100.0	100.0

*1) OEE calculation is based on P&I plan target.

Section 3: Asset Integrity

Key Risks & Challenges

Severe corrosion in ballast tank

Discussions wrt contract - outstanding invoices

Opportunities

Maintenance Management

	Units	MTD	YTD
Backlog: PM – Safety Critical & All Disc	[mhrs]		
Backlog: CM – Safety Critical & All Disc.	[mhrs]		
Backlog: PM – All Priorities & All Disc.	[mhrs]		
Backlog: CM – All Priorities & All Disc.	[mhrs]		
Backlog: Proj. – All Priorities & All Disc.	[mhrs]		
CM/CM+PM	[mhrs/mhrs]		

Note: Cut-off dates for the values is the last day of each month.

Appendix 8: Monthly Report Sample for Petrojarl Foinaven

Petrojarl Foinaven – Foinaven field Operations - January 2013

Health & Safety

Note Report Updated Manually No Automatic Updates From COMPIS

Days Since Last LTI: **118**

	Units	MTD	YTD
Lost Time Incidents		0	1
Medical Treatment Injuries		0	0
Spills to Sea / Gas Leakages		1	8
Cases with Authority Notification		0	5
HSE program – Planned Progress	[%]	0	0
HSE program – Actual Progress	[%]	0	0

Comments:
Safety:

RUE 02/13 - 06.01, Synergy 4007069, *Quality- Condition.* *Petronordic inside 500m zone. Failure at the 110 v backup system during loading ops. Stopped loading and out safety zone for troubleshooting, resume ops after 1 hr.*
RUE 03/13 - 06.01, Synergy 4007075, *Quality- Condition, Failure of newly installed 3B comp after cooler.*
RUE 04/13 – 08.01, Synergy 4007120, *HSE Near Miss. Helicopter had to re-position due to wind change . Investigation still on-going onshore.*
RUE 05/13 - 11.01, Synergy 4007199, *HSE Accident MTI ,Small laceration to arm in galley.*
RUE 06/13 - 15.01, Synergy 4007307, *Quality condition, Having to re-program overpressure protection for new well flowing. (R11 /R15)*
RUE 07/13 – 23.01, Synergy 4007499, *HSE Accident . Subsea Viking ROV leaked 200ml oil from a quick coupling.*
RUE 08/13 - 28.01, Synergy 4007630, *Quality condition, Foinaven compressor control upgrade project #23020. Level 1 Investigation root and causes of why the software was not fit for purpose. External investigation.*

HSE incident near miss / Conditions: 4

We had 10 safety critical 1, priority 1 jobs outstanding by end of the month. Ref. Risk assessment 13/13

Safe card for November:: 189 cards. Total 189 cards in for the year. Drills, Table tops, muster and safety meetings in accordance with the plan.

Environment – Emission To Air

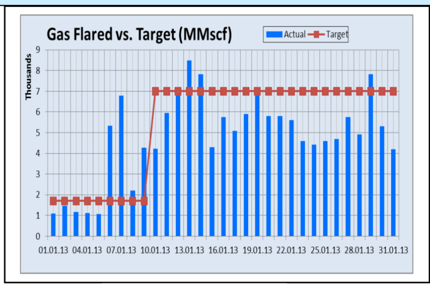
	Units	MTD	Daily Avg.	PTD
Actual Flared Gas	[MMscf]	149,470	4.822	
Consent Flared Gas	[MMscf]	169,300		
Remaining to meet Consent	[MMscf]	19,830		

Comments:

Total Flaring For Month Was 149,47 mmscf
Average Daily Flare 4,822 mmscf

Temporary Flare Consent Of 7mmscf/day allocated By BP Due To Riser DC1 Wells Available and only A Train Compression in Service.

Note! Periodic allowance is based on annual at UK sector and quarterly at Norwegian sector.



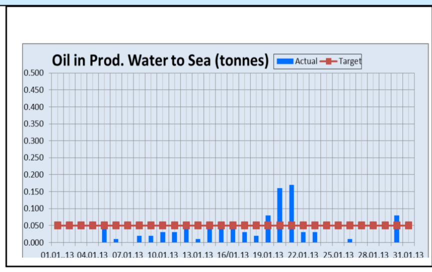
Petrojarl Foinaven – Foinaven field Operations - January 2013

Environment – Discharge To Sea

	Units	MTD	Daily Avg.	YTD
Actual Quality Oil in Water Overboard	[ppm]		22.4	
Target Quality Oil in Water Overboard	[ppm]	0	30	
Actual Oil in Produced Water	[tonnes]	1		
Consent Oil in Produced Water.	[tonnes]	1.5		
Days since last Oil spill		26		

Comments:

OIW Target 30 ppm
OIW Actual Average For Month 22.4 ppm



Water Injection

Injected Water

	Units	MTD	Daily Avg.	YTD
Actual Water Injection	[bbls]	848958	27386	
Target Water Injection	[bbls]	1277118	42571	
Required to meet Target	[bbls]			

Re-Injected Produced Water

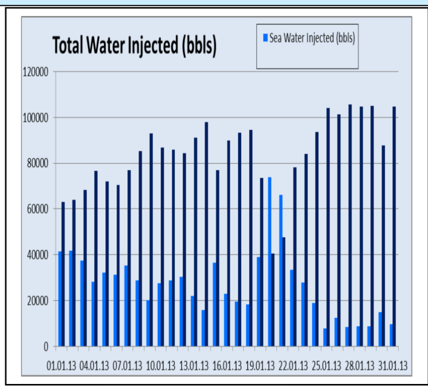
	Units	MTD	Daily Avg.	YTD
Actual Re-Injected Produced Water	[bbls]	2602320	83,946	
Target Re-Injected Produced Water	[bbls]	2891248	93266	
Produced Water discharged to sea	[bbls]	288928	9,320	
Regularity of Re-Injected produced Water	[%]			

Comments:

Water Injection System Steady For Month.

PWRI System Throughput Under Investigation Under Design Rates.

Note! Target is based on 100% Re-Injection of Produced Water.



Petrojarl Foinaven – Foinaven field Operations - January 2013

Oil Production "Dry Volume"

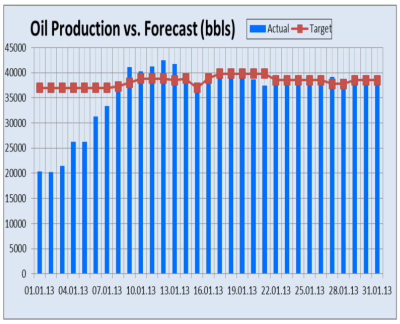
	Units	MTD	Daily Avg.	YTD
Actual Oil Produced	[bbls]	1,121977	36,193	
Target Oil Production *1	[bbls]	1,186,500	38,274	
Actual Oil Produced	[Sm3]			
Target Oil Production *1)	[Sm3]			

*1) *Based on weekly/monthly figures from P&I Plan*

Comments:

Target oil production for the month was 1,186500bbls. Total oil production for the month ended 1,121977 bbls, which equates to **94.56** % of target.

Riser 14 & DC 1 Wells Brought On Line on 05/01/13
Production Steady Increase Over Month Due To DC1 back on line.
Production Restriction Due to Flaring & Gas Lift Restriction as Only One Compression Train Available.



	Units	MTD	YTD
Actual Production Utilization Factor (PUF)	[%]	100	
Target Production Utilization Factor (PUF)	[%]	100	0,0
Actual Production Losses – Planned	[%]		0,0
Actual Production Losses – Not Planned	[%]		

YTD

YTD

This month recorded causes of production DownTime & Losses:

	Units	MTD	YTD
Actual Production Losses – Planned	[bbls]	0	0
Actual Production Losses – Not Planned	[bbls]		

	Units	MTD
OEE *1)	[%]	87.4
Availability – Regularity	[%]	88.0
Performance – Production	[%]	99.3
Quality – Oil to Storage	[%]	

*1) *OEE calculation is based on P&I plan target.*

Petrojarl Foinaven – Foinaven field Operations - January 2013

PM & CM Maintenance and Modification Projects

	Units	MTD	Daily Avg.	YTD
Backlog: PM – All Priorities & All Disc.	[mhrs]			
Backlog: CM – All Priorities & All Disc.	[mhrs]			
Backlog: PM – Safety Critical & All Disc.	[mhrs]			
Backlog: CM – Safety Critical & All Disc.	[mhrs]	0		
Backlog: Proj. – All Priorities & All Disc.	[mhrs]	0		

Note: Cut-off dates for the values are the last day of each month.

Activity Highlights:

Davits installed for Ist Stage Heaters.
3B Cooler Removed & sent Ashore For Repair.
PWRI Booster Pump A Seal Changed Out.
Roxar Visit To Change Out Corrosion / Erosion Probes & Bacterial Samples.
DA Biociding & Process Vessel Sand Washing Carried Out.

E/I:
Modifying Control System for 1C&1D engine.
Lighting Repairs
Heat Trace Maintenance.

Marine:
4 Batch OffLoads to MT Ptrolantiv
7 Batch Offloads to Petronordic
SWIRE Inspection on Helifuel System
Metering Stream Strainers Cleaned.
Port Lifeboat Davit Repaired
Changed Scavenge Coolers .
Repaired Scale Inhibitor Pump.

Rep. & Maintenance – All Priorities – All Disciplines

Rep. & Maint. – Safety Critical Equipm. - All Disc.

Key Risks & Challenges

1A-2B Motor has to be changed out due to Winding Problems. (Change Out In Progress / Motor Dismantling Ongoing)
3 B Discharge Aftercooler to be Changed Out (Cooler Removed & Sent for Repair
ESD Valves on 3 B compressor are Passing and will require change out. (This Planned Work To Be Carried Out During a Shutdown Period)

Opportunities

Installation of 1B-2B New Motor & 3 B Aftercooler & Bring B Train Compression Back on Line.

Increase Production Throughput When B train Compression Available.
Install & Commission New Chemical Injection Skid

Appendix 9: Information Screen Sample