ENG450
Engineering Internship
Final Report

Woodside Energy Ltd.
Cossack Pioneer Facility Engineering Team

"A report submitted to the School of Engineering and Energy, Murdoch University in partial fulfilment of the requirements for the degree of Bachelor of Engineering"

Author: Julian Holmes
Student No: 30581389
Year: 2008

Academic Supervisor:
Professor Parisa A. Bahri

Industry Supervisor:
Douglas Hamilton

Abstract

Cossack Pioneer is a floating production storage and offloading vessel located 112 km North West of Karratha. This report details the work performed during a 16 week internship with Woodside Energy Ltd working in the Cossack Pioneer Facility Engineering Team. This Perth based team provides engineering support to the production facility. The report incorporates a description of the facility and topsides process and discusses the systems used for process control.

The earlier work performed during the internship focussed on small engineering design and control system modifications for the instrumentation and control group within the facility engineering team. Partway through the internship focus changed and the challenging role of Facility Control Engineer for Cossack Pioneer was assumed during the absence of the facility Senior Control Engineer. The report provides discussion of learning outcomes acheived and experience gained during the internship.

Acknowledgements

Table of Contents

List of Figures

NOTE: Figures have been excluded from electronic version for copyright reasons.

List of Abbreviations

Acronym	Definition
C&E	Cause and Effect Chart
CCS	Cargo Control System (Allen Bradley PLC5)
CSS	Combined Safety System (Triconex triple redundant PLC system covering emergency shutdown and fire and gas protection functions)
DCS	Distributed Control System (Honeywell TDC3000) - used interchangeably with PCS in this context.
FET	Facility Engineering Team
FPSO	Floating Production Storage and Offloading facility
GWA	Goodwyn Alpha – a north west shelf gas processing platform
HAZOP	Hazard and Operability analysis
IHR	Incident Hazard Report
IPF	Instrumented Protective Function
KGP	Karratha Gas Plant
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
NRA	North Rankin Alpha – a north west shelf gas processing platform
NWSV	North West Shelf Venture
ODME	Oil Discharge Monitoring Equipment
P&ID	Piping and Instrumentation Diagram (Drawing)
PAS	Production Accounting System
PCS	Process Control System (Honeywell TDC3000) – used interchangeably with DCS in this context.
PFW	Produced Formation Water
PLC	Programmable Logic Controller
RMO	Recurring Maintenance Order
RTM	Riser Turret Mooring – Cossack FPSO mooring/connection point
SAP	Systems, Applications and Products (in Data Processing). SAP is a German based software company specialising in business workflow management.
SIL	Safety Integrity Level
STC	Simple Technical Change
TCMS	Technical Change Management System – a component of the SAP system
TIC	Technical Integrity Custodian
TOP	Temporary Operating Procedure

1. Introduction

Murdoch School of Engineering and Energy offers a 16 week internship program as an alternative to a traditional final year engineering thesis. The full time engineering internship is intended to provide professional experience in the student's discipline area to achieve the required educational outcomes of the engineering degree [1][2].

This report details the work performed and experience gained during the internship undertaken with Woodside's Cossack Pioneer facility engineering team. With the primary role of the facility engineering team being to keep the facility producing safely, much of the future work revolves around addressing equipment failures and process vulnerabilities, making future work requirements difficult to predict. The earlier work performed during the internship focussed on small engineering design and control system modifications working under the guidance of the Senior Control Engineer. Partway through the internship focus changed and the challenging role of Control Engineer for Cossack Pioneer was assumed during the absence of the facility Senior Control Engineer. Internship progress has deviated substantially from the original plan [11] due in part to the change of role for the latter part of the internship.

The report is structured to provide a logical progression through the background information, work performed and outcomes acheived during the internship. This includes:

- A brief introduction to Woodside, the FPSO facility "Cossack Pioneer", and description of Cossack Pioneer's topsides process and utilities.
- An overview of the Cossack Pioneer control systems.
- Overview of the internship role and some of Woodside's internal processes relating to it.
- Presentation of the main tasks undertaken during the internship and the methodologies applied in solving them.
- Evaluation of the internship outcomes and issues arising from it.
- Discussion of outstanding and future work.
- Summary of the main findings and conclusions reached during the internship.

2. Background

This section provides an overview of the company, facility and a description of the process, utilities and control systems on the facility with which I've been involved during the internship.

2.1 Company Overview

Woodside Energy Ltd. is Australia's largest oil and gas exploration and production company, founded in 1953, and named after the small town in the Gippsland region of Victoria. Woodside has its head office in Perth and offices in other locations supporting Woodside's regional operations nationally and internationally. The company employs over 3000 staff globally [4].

Woodside is the operator and part owner of the North West Shelf Venture (NWSV) which includes the North Rankin (NRA) and Goodwyn (GWA) platforms, Floating Production, Storage and Offloading (FPSO) Vessel "Cossack Pioneer" and shore based LNG processing plant with 5 LNG processing trains. The North West Shelf Venture is Australia's largest resource development project located on the North West shelf off the Western Australian coast near Karratha. It is a joint venture between Woodside, BP, Shell, Chevron, BHP Petroleum and Japan Australia LNG (MIMI) operated by Woodside for the production and supply of domestic (pipeline) gas, oil, LNG and LPG to the Australian and international markets [4].

Aside from the NWSV, Woodside operates/owns a range of other oil and gas producing assets. Other Australian facilities operated and part owned by Woodside include:

- Enfield, North of Exmouth producing oil via the FPSO vessel "Nganhurra."
- The Laminaria-Corallina project in the Timor Sea producing oil via the FPSO "Northern Endeavour."
- Otway project, producing gas from the Thylacine and Geographe gas fields south of Victoria at the processing plant near Port Campbell.
- Vincent, North West of Exmouth producing oil via the FPSO vessel "Maersk Ngujima-Yin".

Woodside also has a range of projects currently in the construction phase, including:
- Karratha gas plant upgrade including a second LNG berth and fifth LNG processing train.

- Perseus over Goodwyn Project, North Rankin B (NRB) and the Angel Project boosting the capacity of the North West Shelf Venture.
- Pluto Project – currently Australia's second largest resource project, due for completion in 2010. The development includes an offshore platform and onshore LNG processing train with planned capacity to support tie-ins from adjoining gas fields.

Woodside has a range of potential projects in the assessment / selection stage and undertakes an extensive exploration program which targets an international exploration portfolio in both proven hydrocarbon areas and frontier (higher risk) areas. The company is focussed on actively expanding its LNG capability to achieve its goal of becoming a significant player in the rapidly expanding global LNG market. Woodside has a strong safety focus and is committed to investment in alternative energy technologies, sustainable development and the broader community [4].

2.2 Cossack Pioneer Facility Overview

The "Cossack Pioneer" (CP), a floating production, storage and offloading facility (FPSO) commissioned in late 1995 is the sole oil producing asset within the North West Shelf Venture. The FPSO is a converted oil tanker (formerly the Chevron London) shortened, modified and retrofitted with the necessary process equipment and utilities to fulfil its oil and gas production role. It is located approximately 112km north west of Karratha and 30 km east of the North Rankin Alpha (NRA) platform on the North West Shelf. Figure 2.1 shows the location of Cossack Pioneer in relation to the other NWSV facilities.

Processing facilities on board the FPSO separate the production fluids into gas, oil and water. Gas is exported via a subsea pipeline to the North Rankin gas platform before being transferred to the onshore LNG processing facility at Karratha. Produced gas is also used for "gas-lift / kick-off' to initiate well flow and boost the production rate of some of the wells. Oil, once stabilised (dewatered, degassed and cooled) is stored in the onboard cargo tanks (capacity 1.15 million barrels) for subsequent offloading via a flexible line to bulk tankers moored astern. Figure 2.3 shows Cossack Pioneer during an offloading operation with an oil tanker moored astern. Daily oil production capacity is 140,000 barrels with current daily production reaching around 80,000 barrels. Process equipment onboard treats produced water to an acceptable quality for discharge overboard.

Figure excluded for copyright reasons

Figure 2.1 – Cossack Pioneer Location Map [3]

The Cossack Pioneer is moored to a riser turret mooring (RTM) in approximately 80m water depth. The RTM connects the FPSO via flexible flowlines and a series of subsea manifolds to 12 production wells on the Wanaea, Cossack, Lambert and Hermes Oil/Gas reservoirs. The subsea field layout is shown in Figure 2.4. The RTM provides the swivel connection which allows the vessel to pivot about the fixed mooring as required. Figure 2.2 shows Cossack Pioneer with the RTM in the foreground.

The FPSO has the capability to disconnect from the mooring and sail away should the need arise for maintenance or due to extreme weather conditions (e.g. cyclones). The vessel has a core crew of 29 and accommodation for up to 80 people [3]. Cossack Pioneer's 'vital statistics' are summarised in Table 2.1.

Figure excluded for copyright reasons

Figure 2.2 – Cossack Pioneer FPSO showing the Riser Turret Mooring (RTM) in foreground [4].

Table 2.1 – Cossack Pioneer Information Summary [3], [4].

Table 2.1 Cossack Pioneer Information	
Length/Breadth/Draft	267m / 52m / 16m
Accommodation Capacity	80 Maximum (Core Crew: 29)
Commissioned	November 1995
Water depth	80 meters
Producing Fields (discovered)	Wanaea (1989), Cossack (1990), Lambert (1996), Hermes (1996)
No. of Wells	12
Daily Production Capacity	140,000 barrels of oil per day
Oil Storage Capacity	1.15 million barrels

Figure excluded for copyright reasons

Figure 2.3 – Cossack Pioneer FPSO during offloading (Oil tanker moored astern) [4]

Figure excluded for copyright reasons

Figure 2.4 – Cossack Pioneer Subsea Field Layout [3]

2.3 Process Description

To be able to make a valuable contribution to the facility engineering team and in order to fulfil the requirements of the Instrumentation & Control engineering roles, it was essential to have a good understanding of the function of each part of the topsides process and utility systems on Cossack Pioneer. This section (Process Description) and the subsequent section (Utilities Overview) provide a summary of the essential topsides systems in use on Cossack Pioneer based on information gained during my reading and research on this topic. Whilst some written information was available on the general topsides process, particularly a brief overview provided in the "Cossack Pioneer Safety Case" [3], much of my knowledge of the general topsides process and utilities was derived through conversations with various members of the facility engineering team.

The purpose of the topsides process equipment on Cossack Pioneer is to separate the production fluids into oil, water and gas components. This section provides an overview of the essential process equipment and supporting utilities on the FPSO. A simplified (basic) process flow scheme is illustrated in Figure 2.5. A more detailed process schematic is included in Appendix 1.

Figure excluded for copyright reasons

Figure 2.5 – Cossack Pioneer Basic Process Flow Scheme [3]

2.3.1 Separation

With reference to the "Cossack Pioneer Process Schematic" (Appendix 1), well production fluids are transferred to the separation stage via primary / secondary production headers and the test header. The production fluids are separated through three stages, designated high pressure (HP), intermediate pressure (IP) and low pressure (LP). Four separator vessels are used including one each of the HP, IP and LP vessels designated V501 – V503 respectively. A second HP separator (V504 - Test Separator) is provided for use in well testing and reservoir monitoring. All separators are flooded weir type horizontal vessels with anti-motion baffles [3].

Oil is heated between the IP and LP stages using steam driven heat exchangers (E503A/B). Oil exiting the final stage (LP) separator is transferred via rundown pumps (P501A/B/C) and coolers (E504A/B) to the cargo storage tanks [3].

2.3.2 Produced Water Handling

Water extracted from the production fluids via the HP, IP, LP and Test separators is further processed using hydrocyclones (S501/S502/S503) to remove any emulsified oil. The water is then degassed (V513) before being passed to the Oil Detection and Monitoring Equipment (ODME). There are two ODME devices available to monitor the level of oil in water present in the treated process formation water (PFW). If the treated water meets the required environmental standards for oil in water (<30mg/L), the produced water is discharged overboard. Where the standard is not met, the water is automatically diverted to the slops tank for further treatment.

2.3.3 Gas Recycle

Gas taken off from the IP and LP separators is recycled to the gas export suction manifold and recompressed to a suitable pressure using the Recycle Compressor (K501). The recycle compressor is a two stage centrifugal type incorporating pre-cooler (E502) and inter-stage cooler (E501) fed from the tempered water system. The LP stage of the compressor takes gas from the LP separator, The IP stage suction combines gas from the LP stage and gas taken from the IP separator. The recycle compressor is driven by an electric HV motor (KM501) [3].

2.3.4 Gas Export

Separated gas is pressurised for export via the gas export pipeline to NRA using two export compression trains (K503A/B). Each export compression train consists of a two stage centrifugal compressor. Each stage of the compressor incorporates suction coolers (E505A/B, E506A/B) and liquid knock-out vessels (V508A/B, V509A/B). Both

stages of the export compressor(s) are housed in a single casing driven by fixed speed electric HV motors (KM503A/B) [3]. First stage suction gas is derived from the combination of HP separator gas and IP recycle compressor discharge.

Each of the export compression trains can be run independently to facilitate continued process operation (at reduced production rates) during periodic maintenance on individual trains.

2.3.5 Dehydration

Gas taken from the discharge side of the second stage of each export compressor train is combined and treated in the dehydration unit prior to export. The four stage dehydration system is designed to remove free water and water vapour from the gas stream. Gas is first passed through the feed separator (V510) to remove free (liquid phase) water, then passed through liquid-gas coalescer (V21) to further remove water and hydrocarbon liquids. The gas is then passed through the molecular sieve vessels (V514A/B) to further remove water vapour from the stream. Finally the gas is passed through the dry gas filter (S510) to remove any remaining particulate matter.

The molecular sieve beds require periodic regeneration to reactivate the filter media which becomes water saturated after extended use. Regeneration of the molecular sieves is achieved by back flowing dried heated gas through the sieve beds at regular intervals. Heating of this regeneration gas is achieved using the steam heater (E508) and electric heater (E509). The majority of treated gas discharged from the dehydration system is routed directly to the export gas header for transport via subsea pipeline to NRA then to the onshore gas processing plant. A small portion of the treated gas is retained for gas-lift purposes.

2.3.6 Gas Lift

The purpose of the gas lift system is to provide gas kick-off (well start-up) and gas-lift to increase well production rate. Gas-lift is the process by which compressed gas is introduced to the well bore to reduce the hydrostatic pressure of the well fluid column. The reduced column pressure results in increased flow rates.

The gas pressure required for effective gas lift is higher than the export gas pressure. A reciprocating type compressor (K505) is used to attain the gas pressure required for gas lift. Gas introduced to the gas lift system is first passed through the liquid knock out drum (V511), then compressed in gas lift compressor (K505) and cooled through tempered water fed cooler (E512) before being routed to the gas lift header on the RTM. Gas flow is controlled by remote adjustment of subsea choke valves. Gas lift is

currently only used for Cossack Well CK4, although the capability exists to use gas lift for other subsea wells as required [3].

2.3.7 Fuel Gas System

The fuel gas system on Cossack Pioneer provides conditioned gas of the required specification for the gas turbine generators (Solar Taurus 60's), boilers and flare purges and pilots.

Fuel gas is drawn off from the suction manifold of the first stage export compressor, cooled using tempered water fed heat exchanger (E510) then passed through the liquid knock-out drum (V507). High pressure (HP) fuel gas is supplied to the Gas Turbines via filter/separators (V519A/B) and fuel gas coalescer (A312) to remove water and hydrocarbon liquids. A pressure regulated take off from the HP fuel gas header is used to provide low pressure (LP) fuel gas for the boilers and flare pilot/purges [3].

2.3.8 Flare System

The flare system utilises separate LP and HP flare systems with a combined flare tip [3]. The flare system provides a means to dispose of waste gas and hydrocarbon liquids taken from various stages of the topsides process. It also provides the means to blow down (empty) the entire process pipework of flammable inventories should the need arise in emergency or planned shutdown situations.

The LP flare vessel (V516) receives hydrocarbon waste liquids from the closed drains system and gas from the LP flare header. The LP flare header is fed from numerous control valves on the facility including most separation and knock-out vessels. The HP flare knock-out drum (V517) receives gas from the wet HP flare header and the cold HP flare header. Wet HP gas is derived from purge valves upstream of the separation stage. Cold HP flare gas is derived from purge valves downstream of the dehydration stage. Output from the HP and LP flare knock-out vessels is routed to the common flare tip for combustion [3].

Excessive use of flaring leads to significant energy wastage and increase carbon emissions. It is a regulatory requirement and stated aim of the facility to keep flaring levels to the absolute minimum required to support safe operation of the facility.

2.4 Utilities Description

Utility systems on Cossack Pioneer provide the necessary material and energy requirements for the ship systems and process. This section provides a summary and brief description of the essential utilities onboard the FPSO.

2.4.1 Water

There are multiple water users on Cossack each having different quality requirements. Process cooling water requirements include a combination of tempered water and seawater. There is also the requirement for fresh water on the facility for various parts of the process as well as for human consumption.

Fresh Water

Fresh water is generated on Cossack Pioneer using two flash evaporators and a reverse osmosis unit. This distilled water, termed 'Process fresh water' is used for wash down, system flushing and maintenance purposes (e.g. tempered water make up). Process fresh water is not fit for human consumption.

Potable water used for hotel services (human consumption) is distilled water that has been passed through a sterilising unit [3].

Tempered Water

Tempered water is fresh water maintained in a closed system used for process cooling. It has the facility for the injection of chemicals to inhibit build up of scale and corrosion in the process heat exchangers. Tempered water is cooled via two sea water fed heat exchangers (E515A/B). Tempered water makeup is supplied via a connection from the process fresh water supplies as required. The tempered water system includes a monitoring device which detects the presence of hydrocarbons in the water. Presence of hydrocarbons potentially indicates a leak in one of the process heat exchangers.

Sea Water

Sea water is used extensively on the FPSO for cooling purposes. Uses include direct cooling for various process coolers, cooling for the tempered water system and cooling and scrubbing of the boiler flu gas for the inert gas system.

2.4.2 Instrument and Service Air

Instrument and Service air for the facility is provided via three air compressors. The compressed air is passed through refrigerated driers and filters [3]. Instrument air is used for pneumatic control functions on the process and power plant as well as feed air

for the nitrogen generation system. Service air is used for pneumatic tools and lifting devices [3].

2.4.3 Diesel Fuel

Diesel fuel is required as a backup fuel when fuel gas is unavailable (e.g. during process start-up). Both the boilers and the gas turbines are capable of dual fuel operation. Diesel is also used for the auxiliary and emergency generators and emergency fire pumps [3].

Diesel is delivered from supply boats and distributed to dedicated storage tanks via a debugging unit and purifier [3].

2.4.4 Boilers

Steam for the facility is generated by two dual fuel boilers (Port and Starboard). Each unit has a capacity for 60,000 kg/hr when gas fired or 75,000 kg/hr when diesel fuelled. The boilers are setup to supply steam at the following operating pressures [3]:

- Superheated steam at 6250 kPa
- De-superheated steam at 6000 kPa
- Low pressure steam at 1200 kPa
- Exhaust steam at 370 kPa

The main consumers of steam on the facility include:

- Steam turbine generators
- Ship propulsion steam turbines
- Process heat exchangers (heaters)

2.4.5 Inert Gas System

The inert gas system makes use of the boiler combustion gas to create an inert atmosphere for the cargo storage tanks. The boiler flu gas having been completely combusted is low in oxygen. The flu gas is passed through a cooler and scrubber and results in clean, cooled, low oxygen content inert gas. A monitoring system is in place in the inert gas system to ensure that the O_2 level never exceeds 5%. Maintaining O_2 levels in the cargo storage areas below 5% ensures there is never a combustible gas mixture present.

2.4.6 Nitrogen Generation System

Cossack Pioneer uses nitrogen for inert gas service to reduce risk of ignition in the following areas:

- Export compressors (K503A/B) shaft seal purge/seal gas
- Recycle Compressor (K501) shaft seal purge/seal gas
- Port & Starboard boiler fuel gas burner purge system
- Process systems N_2 purge general service for system isolations and purging for service access.

The nitrogen demand is supplied from a self-contained nitrogen generating unit. This system is a "Permea Prism Alpha Membrane Separation" unit. It uses the membrane separation principle to generate high purity nitrogen from feed air. The generation system supplies nitrogen to a storage receiver from which it is drawn off as needed.

2.4.7 Power Generation and Distribution

High voltage (6.6 kV) is generated by five 4.1 MW Gas Turbine Generators (Solar Taurus 60) and two 5 MW Steam Turbine Generators. These devices are connected to a high voltage (HV) switchboard. Step-down transformers from the HV switchboard supply four low voltage (440 V) LV switchboards: Ship Systems, Facilities, Non-essential and Emergency Systems. The Ship Systems switchboard is also supplied by two 760 kW diesel generators for use when the FPSO is in marine mode. The emergency switchboard is supported by a 350 kW emergency diesel generator for use in the event of failure of the HV generators. A dual battery backed uninterruptible power supply system (UPS) provides emergency power for vital systems [3].

Available supply voltages on the facility include:

- 6.6 kV 3-phase, 60 Hz AC
- 440 V 3-phase, 60 Hz AC
- 220 V 3-phase or single phase, 60 Hz AC
- 24 V DC

2.4.8 Cargo handling

The cargo handling system collectively describes the series of pumps, valves and instrumentation used to manage inventories stored in the various tanks on board. The cargo system is managed using a single PLC called the Cargo Control System (CCS). The CCS is responsible for low level control tasks relating to oil decanting and offloading, ballast water transfer to maintain ships trim and stability, and slops tank settling and decanting operations for the treatment of oil contaminated water.

3. Cossack Pioneer Control Systems

Cossack Pioneer Control Systems can be broadly divided into the following four categories:

1. Process Control System (PCS) – this is the Honeywell TDC3000 distributed control system (DCS) which provides operator control of the facility and the human machine interface (HMI) for monitoring and controlling the status of other control systems.

2. Combined Safety System (CSS) – this is independent safety control system responsible for all emergency shutdown (ESD), process shutdown (PSD) and fire and gas detection functions. It is physically implemented using two Triconex triple redundant PLCs.

3. Subsea Control System (SCS) – an independent electro-hydraulic system for remotely controlling subsea manifold valves and instrumentation.

4. Package Controllers – PLCs residing on local package responsible for the control of an individual unit, termed a unit control panel (UCP) or a PLC responsible for a range of devices in a specific area.

Each of these categories and the relationship between them is described in more detail in the following sections.

3.1 Control of Process and Ship's Systems

The central control room (CCR) located in the accommodation module is the primary control point for the facility and is continuously manned. Control of wells, processing facilities, cargo control system and process monitoring is all performed from the CCR. The central equipment room (CER) located immediately below the CCR houses most of the control equipment (I/O cabinets, marshalling cabinets and PCS servers).
The machinery control room (MCR), located in the engine room is used for monitoring of all marine equipment and power generating machinery. The SCS is controlled by the master control system (MCS) which is located in the CER [3].

3.2 Process Control System (PCS)

The PCS performs the control of the process facilities, has a monitoring role over the other control systems and provides the operator console human machine interface (HMI) for complete monitoring / control of the plant. The PCS hardware used on

Cossack Pioneer is a Honeywell TDC3000 Distributed Control System (DCS). In the context of this facility, the terms PCS and DCS are used interchangeably.

The Honeywell TDC3000 DCS uses a three tiered network infrastructure to provide flexibility whilst securing essential control functionality at lower levels. The three tiers comprise:

1. Universal Control Network (UCN) – This lowest level is the secure path for process I/O connections to the TDC3000 system.
2. Local Control Network (LCN) – the middle tier network provides the communication interface between TDC3000 components that comprise the DCS.
3. Plant Control Network (Intranet) – Provides the interface for client applications to access the TDC3000 system.

Figure 2.6 shows the arrangement of the TDC3000 network hierarchy and the modules that connect at each network tier.

Figure excluded for copyright reasons

Figure 2.6 – Honeywell TDC3000 Network Hierarchy [15]

The TDC3000 modules relevant to the Cossack Pioneer DCS configuration include:

- High-Performance Process Manager (HPM) – Provides flexible I/O functions for data monitoring and control. The HPM resides on the UCN and takes a range of plug-in I/O cards to support connections to various field devices. The most

common (and simplest) cards used are Analog I/O for connection to field transmitters and control valves using 4-20mA signaling and Digital I/O for switching field devices and reading the status of on/off switches.

- Network Interface Module (NIM) – Connects the UCN to the LCN. In this case the NIM provides connectivity to the LCN for the HPM (field I/O devices).

- Global User Station (GUS) – Provides the operator console HMI for plant monitoring and control. The facility has multiple GUS stations spread across the various control rooms on the vessel.

- Process Historian Database (PHD) – This device is a server that connects to the LCN and collects operations and process data to be made available for diagnostic, monitoring and accounting purposes.

- Application Module (AM) – Allows for the implementation of more advanced calculations and control strategies. The AM is able to communicate with any device on the LCN and performs calculations and control strategies defined using a scripting language called 'Control Logic' (CL) [15].

- Highway Gateway (HG) – this device provides for connectivity to the LCN for other control devices using the "Data Highway" communication protocol. For Cossack Pioneer, the HG interface provides for interconnectivity between the Combined Safety System (Triconex PLCs) and various package controller PLCs around the facility (mostly Allen Bradley PLCs).

As the PCS is able to interface to all the other control systems on the facility, the operator HMI console is able to merge the interfaces of various control systems onboard. The central control room (CCR) on Cossack has 6 GUS stations available for monitoring and control of all the facility control systems.

The PCS is configured to permit remote connection to the system from the Perth office. Engineering level changes to the PCS configuration are generally performed by the facility control engineer from the Perth office by remote connection.

3.3 Combined Safety System (CSS)

The CSS performs the emergency shutdown (ESD), process shutdown and fire and gas (F&G) detection and control functions for the facility. It is physically implemented on two separate Triconex triple redundant safety PLCs located in the equipment room in the rigid arm at the bow of the FPSO. The two systems are:

- CPESD (Cossack Pioneer Emergency Shutdown) – responsible for safe shutdown of the facility under normal and emergency situations. CPESD has direct control of all critical SDVs (shutdown valves), XDVs (diverter valves) and

BDVs (blowdown valves) and initiates shutdown of the facility under detected abnormal operating conditions and in response to external shutdown requests (e.g. from a PCS request or manually operated ESD pushbutton)

- CPFNG (Fire and Gas Control System) is responsible for the detection, monitoring and control of fire and gas events within the facility. Detection of these events is achieved through a series of smoke, detectors, flame detectors, gas detectors, fusible loops and other fire and gas detection apparatus. The FNG system is responsible for deploying fire control systems (e.g. deluge system and Innergen and CO_2 fire suppression systems) and initiating alarming and process isolation in the event of gas detected.

The Triconex triple modular redundant (TMR) safety PLC is used extensively within Woodside for this safety system application. It has a reputation for high reliability through its redundant architecture employing three separate processors and a two out of three (2oo3) voting system. The system is designed to allow hot swapping of various hardware (plug in cards) and code changes can be implemented while the system is live. The redundant systems are transparent to the end user providing a high level of reliability without increasing complexity to the user of the system [14].

Operation and monitoring of the F&G PLC is performed via two dedicated PCS HMI consoles in the CCR. The ESD PLC operator interface is merged with the PCS main consoles accessible from six operator workstations (GUS's) in the CCR.

The interface between the CSS and the PCS provides capture and monitoring of alarms, collection of alarm data to the PHD server and facilitates control of facility shutdown functions.

3.4 Subsea Control System (SCS)

The SCS is an electro-hydraulic system used for remotely controlling the subsea valves and instrumentation. The SCS functions independently from the other facility control systems under normal operation. Hydraulic power to the SCS is provided by the production hydraulic power unit (PHPU). The entire subsea hydraulic control system is fail safe in the sense that it can be completely shutdown by depressurising the PHPU.

As with the CSS, the operator interface for the SCS is integrated into the PCS console in the CCR. The master control system (MCS) located in the CER provides the interface between the SCS and both the combined safety system and the PCS.

The SCS has an interface to the CSS to facilitate automatic shutdown of the subsea production system should the need arise, and process shutdown in the event of SCS failure.

The interface to the PCS is used to relay subsea data used for operational reporting and accounting purposes.

3.5 Package Controllers

This section collectively refers to all the other controllers used on the facility and includes PLCs residing on local package responsible for the control of an individual unit, termed unit control panel (UCP) or a PLC responsible for a range of devices in a specific area. The package controllers generally have an interface to the PCS which provides for collection and monitoring of process data and to provide override and package shutdown capabilities to the operators from the CCR.

Package controllers used on Cossack Pioneer include:

- Cargo Control System (CCS) – an Allen Bradley PLC5 performs all the monitoring and control functions required for cargo handling, ballasting and water discharge monitoring.

- Alarm Monitoring System (AMS) – provides alarm status information to the CCR and MCR on engine room machinery equipment including the status of ship's systems and utilities (e.g. power generation, instrument air, cooling water).

- Mooring Connect/Disconnect Control System (MCDCS) – performs control and monitoring functions required for the connection and disconnection of the FPSO from the riser column.

- Nitrogen UCP – The unit control panel PLC (Allen Bradley SLC500) for controlling the nitrogen generation system.

- Dehydration System UCP – an Allen Bradley SLC500 used to control the process gas dehydration system including molecular sieve regeneration.

- Utilities Monitoring and Control System (UMCS) – an Allen Bradley PLC5 used for control of the Inert gas system, Steam load shedding system, Utility motor control and valve fault alarms.

- Boiler Management System (BMS) – a Triconex PLC used for control of port and starboard boilers.

- CCC – The compressor anti-surge controller provided by Compressor Controls Corporation to allow optimal performance of the export and recycle compressor whilst preventing compressor surge.

Internship Role

The internship assignment at Woodside involved placement in the Cossack Pioneer Facility Engineering Team (FET). Two distinct roles were performed during the internship with approximately half the internship period spent in each role.

The first part comprised an Instrumentation & Control Engineering support role working directly under Senior Control Engineer (Al. Tarawne). Areas of responsibility included all instrumentation and control systems onboard Cossack Pioneer. These included the Honeywell TDC3000 DCS, Combined Safety System (Triconex PLCs), and package controllers consisting mostly of Allen Bradley PLCs with a small number of Modicon PLC systems. Instrumentation included the full range of pressure, temperature and flow measurement devices as well as fire and gas detection apparatus and intrinsically safe (IS) barrier devices. The wide variety of tasks performed during this time provided the opportunity to gain familiarity with the various control systems on the facility.

The role performed during the second half of the internship was that of Facility Control Engineer (with support from other facilities' control engineers) during the Senior Control Engineer's extended leave. This position whilst very challenging, provided me with an excellent opportunity to gain experience in a control engineering operations role. Every system encountered was unfamiliar and there were some steep learning curves to overcome during some of the tasks attempted. The role included many small administrative and support tasks that have not been detailed in this report. Focus has been concentrated on the more comprehensive tasks with significant engineering learning outcomes.

The following sections serve to describe the function of the facility engineering team and some of the internal processes used within Woodside that relate directly to my internship role.

3.6 CP Facility Engineering Team

The Cossack Pioneer Facility Engineering Team comprises a team of 12 engineers headed by facility engineering team leader (FETL). The team included four mechanical, four electrical, instrumentation and control engineers, a marine/structural engineer and reliability/risk engineer.

The facility engineering team is responsible for providing shore based engineering support for the FPSO. Its area of responsibility includes the entire vessel including marine systems, utilities and the entire topsides process equipment up to an including

the RTM. The team is also supported as required by a separate subsea engineering team responsible for the maintenance of subsea wells, manifolds and pipelines. Offshore, a core crew of 30 includes a maintenance team comprising electrical/instrument, mechanical and marine technicians for carrying out modifications and routine maintenance and an operations team charged with operating the FPSO production facility. A Perth based campaign and major maintenance team is responsible for carrying out scheduled and major maintenance requirements for the facility.

The facility engineering team is responsible for working closely with these other teams to ensure the safe and efficient operation of the facility.

Typical tasks of the FET include implementation of work orders (WO's), recurring maintenance orders (RMO's), temporary operating procedures (TOP's) and simple technical design changes (STC's) to address the emerging maintenance/repair requirements and optimise operation of the facility. Some of the work involves condition monitoring of equipment for pre-emptive maintenance to reduce production down time and shutdown planning to make efficient use of scheduled down time. The majority of the team's tasks revolve around reactive work to address equipment failures and vulnerabilities making forward planning a difficult task. Team members often need to make regular visits to the facility to oversee modifications / repair work and fulfil their engineering support role.

3.7 Technical Change Management System (TCMS)

Woodside's operating assets undergo continual technical revision to meet ongoing maintenance, performance, safety, environmental and regulatory requirements. Any changes made can have potentially catastrophic consequences in terms of health/safety, environmental or financial impact if not managed properly to ensure the suitability and compatibility of the modification with existing systems. To this end, Woodside uses a formalised process for the management of technical change to ensure that all the necessary checks and double checks are in place and that any changes are properly documented.

The Technical Change Management System (TCMS) is part of the SAP (Workflow management software) used within Woodside. TCMS provides formalised methods to raise technical queries (for noted issues), notifications (to initiate the formal process of checking and approving technical changes) and work orders (for implementing the change). Even the simplest of changes, termed a Simple Technical Change (STC) requires concurrence from two discipline engineers (the initiator and the Technical Integrity Custodian (TIC)), approval from the engineering team leader, operations manager and the offshore facility superintendant.

Whilst this process does introduce a significant administrative burden particularly for the implementation of simple modifications, the system is necessary to prevent small mistakes causing big problems and adversely affecting the facility.

3.8 Operational Reliability Improvement Process (ORIP)

Woodside's Production Group uses a common process for recording, analysing and following up on unwanted events/conditions in order to analyse and improve the operational reliability of its plant/facilities. This process, called the Operational Reliability Improvement Process (ORIP) is a structured approach to record, analyse and mitigate unwanted events/conditions [16]. They may be characterised as those that impact on the business in the areas of [16]:

- production loss, deferment and downtime;
- integrity and reliability;
- damage to reputation; and
- increased expenditure

ORIP provides the company with a common process for recording, analysing and following up on unwanted events/conditions. It has five clearly defined stages [16]:

1. Identify the unwanted event/conditions
2. Assess and rank those event/conditions
3. Select and analyse to determine the cause of the problem / issue / event
4. Decide best course of action and act / implement
5. Review the results from actions – analyse and improve

The ORIP process forms a key role within the facility engineering team in maintaining the reliability of the facility. Weekly ORIP meetings are held to review actions in attempt to actively reduce the likelihood of unwanted events/conditions. This process is driven by the facility reliability engineer with the support of the facility engineering team. A substantial part of the facility control engineer role was involved with addressing actions arising from the ORIP process.

4. Internship Main Tasks

The internship position was an operations role with the main focus on functioning as part of a multidisciplinary engineering team tasked with keeping an asset producing as much as possible as safely as possible. Much of the work involved in the role was reactive specifying engineering modifications in response to emerging needs through equipment failures, changing process conditions and identified risks and vulnerabilities with the facility as they were identified. As such, many of the tasks performed were short term and of a small scale, which did not warrant inclusion in this report. Examples of tasks in this category include:

- Facilitating regular remote access to the PCS by Honeywell technicians for routine maintenance tasks.
- Attending and contributing to weekly and monthly facility meetings and representing the Cossack facility in monthly discipline (Instrument/Control) meetings.
- Creating work orders for the testing and replacement of faulty equipment (valves, transmitters, switches).
- Action tracking and reporting of progress on outstanding modification tasks in the technical change management system (TCMS).

This section details the projects of significance which had demonstrable learning outcomes in line with one or more of the stated internship objectives [2]. For each task, an overview of the equipment involved, definition of the problem requiring attention, summary of work performed and an assessment of the current project status and learning outcomes is provided.

4.1 Cossack Critical Meter Tag Identification

4.1.1 Background

This task was part of a larger project run by the Maintenance Improvement Group to establish a process to maintain the reliability, integrity and accuracy of instruments which contribute to the fiscal metering used within Woodside's Production Accounting System (PAS). PAS data is critical to the operation of the various assets making up the North West Shelf Venture to ensure reliable representation of production from each well and each facility to enable revenue allocation between venture partners and for other accounting reasons.

The aim was to identify the physical instruments associated with the critical meter tags used within PAS and relate these back to the identifiers within SAP (Woodside's business workflow management software) to facilitate automated procedures for maintenance, calibration and testing of PAS critical instruments. The actual devices upon which the production data depends were identified by SAP functional location to ensure that sufficiently rigorous maintenance and calibration procedures are in place.

4.1.2 Task Definition

PAS points were initially provided by the Maintenance Improvement Group as a list of critical meter tags. Each of these points corresponds to an output provided by the DCS (Honeywell TDC3000). Each of these DCS outputs represents either a scaled version of a physical metering instrument (pressure, temperature, flow etc) or a calculated value based on inputs from multiple devices.

In the Cossack Pioneer case, the majority of the subsea flow and hours producing meter points were calculated values. No flow transmitters are installed on the individual wells, hence flow data is provided based on a combination of information from temperature, pressure and position indicators combined with parameters such as gas to oil ratio (GOR) and water cut which are based on established well test data. Hours producing information is calculated based on the status of the master, wing and choke valves for each well.

The PAS system requires details of oil, gas and water flow rates from each well, hence these meter values are provided as 'virtual meters' based on these calculated values. In some cases, these virtual points were based on input from up to ten physical instruments. The physical instrument tags are the tags which identify the devices in P&ID and C&E drawings. The physical instrument tags can be directly related back to the functional location in SAP. The general procedure for identifying the SAP functional location from each PAS meter point included:

a) Identify the tag detail by looking it up in the Honeywell TDC3000 DCS documentation system (DOC3000). DOC3000 provides a complete offline version of the DCS configuration. This allows users to determine configuration and programming details of the TDC3000 system without affecting the online control system. The point detail can be used to identify the nature of the point (single instrument or composite). For the case of composite points, the relevant

control logic (CL) file was consulted to trace back to the individual instruments contributing to the composite signal.

b) Identify the corresponding physical device(s) that generate the signal(s) provided to the DCS. This was done by locating the instrument on the P&IDs and determining the physical instrument tag(s).

c) Find the functional location (FLOC) which identifies the device(s) in SAP. This was achieved by searching within SAP by the physical tag number.

4.1.3 Current Status

The majority of this task was completed in the first few weeks of the internship and the findings, along with a report of the procedures used to obtain the data were presented to the Maintenance improvement group for their further action. The 175 PAS meter points were traced back to a list of over 500 physical instruments. The intent of the task was to identify any critical metering instruments which did not have adequate automated testing and maintenance procedures in place. The meter tag audit exercise achieved the desired outcome by identifying a substantial number of tags that weren't adequately captured within the SAP system. As a result a separate project was initiated by the maintenance improvement group to populate the SAP database with the missing information.

4.1.4 Learning Outcomes

Whilst the task involved considerable repetition, a number of useful learning outcomes were achieved. The exercise of tracing points back to physical meters required consulting the majority of the P&IDs for Cossack. Before the instruments could be identified, a good understanding of the process and the symbols, terminology and tagging conventions used was required. Considerable time was spent gaining a good understanding of the Cossack facility and the P&ID symbols and tagging conventions. The task also required accessing configuration information from the Honeywell TDC300 DCS. A sound understanding of the fundamentals of the Honeywell DCS was achieved through this exercise.

4.2 Solar Turbines Taurus 60 Gas Turbine Training Course

This 5 day training course "Solar Turbines Taurus 60 Generator Operation and Routine Maintenance" run during week 3 of the internship provided a comprehensive coverage of the various aspects of the Gas Turbine Generating Units used on Cossack. It wasn't a project per say, but did provide valuable insight into the function of the power generation equipment on the facility. Topics covered in the course included:

- General Package functions and description
- Turbine Engine
- Starting System
- Lube Oil System
- Dual Fuel System (Gas / Liquid)
- Electrical System
- Control System (Allen Bradley PLCs)
- Generator & Support System

Solar Turbines is a division of Caterpillar specialising in the manufacture and support of gas turbine generating units. Cossack Pioneer uses 5 Taurus 60 Generating Turbines (GTs) to supply the electrical power requirements of the facility. The generators supply power at 6600V, 60Hz for the high power equipment (HV compressor motors). Step down transformers also provide for utility supplies at 440V and 220V and 24VDC.

From a control perspective the training course provided an excellent coverage of the Turbotronic control system for the Solar Turbines. This system is implemented on Allen Bradley PLCs. The main control loops involved in achieving tight control of the turbine performance were discussed. For Cossack Pioneer, the unit control panel (UCP) for each turbine and the load management system (LMS) are all implemented on Allen Bradley PLC5 systems.

4.3 Nitrogen Generation System Modifications

4.3.1 Background

Cossack Pioneer uses nitrogen for inert gas service to reduce risk of ignition in the following areas:

- Export compressor (K503A & B) shaft seal purge/seal gas

- Recycle Compressor (K501) shaft seal purge/seal gas
- Port & Starboard boiler fuel gas burner purge system
- Process systems N_2 purge general service for system isolations and purging for service access.

The nitrogen demand is supplied from a self-contained nitrogen generating unit. This system is a "Permea Prism Alpha Membrane Separation" unit. Permea Maritime Protection is an engineering and manufacturing company specialising in gas processing systems for marine applications [9].

Nitrogen generation is based on the principle of membrane gas separation. The "PRISM membranes" used in the unit are formed into hollow fibres to maximise surface area. Compressed air is fed into the bore side of a hollow fibre bundle enclosed within a pressure vessel. The arrangement is geometrically similar to a shell and tube heat exchanger. As the air passes through the inside of the bore, O_2, CO_2 and H_2O (vapour) permeate faster than nitrogen to the low pressure side of the fibre membrane. The bore high pressure side air is depleted of the faster gases and enriched in nitrogen. The critical factors determining the purity and flow rate of produced nitrogen include the differential pressure across the membranes (driving force); the exposure time gases are exposed to the membrane surface and the total surface area of the membrane. Membrane surface area is fixed for the given system, thus in practice the nitrogen purity and production rate are controlled by varying the feed air pressure and flow rate. The separation process is continuous and doesn't require consumable replenishment, with the exception of power [9].

When the system is first started, it produces off spec nitrogen (high O_2) for a short period until the normal operating pressures and flow rates are reached. The control system for the unit is configured to automatically vent the off spec nitrogen to atmosphere and redirect flow to the N_2 receiver once the required purity levels are attained. Purity of the nitrogen is determined by measuring the O_2 content as a percentage. This is achieved using a galvanic type O_2 sensor with the analyser mounted in the unit's front panel.

The unit on Cossack is configured to shutdown once the N_2 receiver pressure has reached its rated level. The unit restarts when the receiver pressure drops to a specified level. During each of these 'cycling' operations, the off spec nitrogen produced at start-up is vented.

The original unit control system for the nitrogen package was implemented on a GE Fanuc 90/30 PLC. A recent upgrade project (July 2007) has replaced the original PLC with an Allen Bradley SLC500 PLC due to parts availability / obsolescence issues with the original controller. The logic in the new controller was configured as an exact replica of the original device logic. The unit control system includes an interface to the Honeywell TDC300 DCS for alarming and package shutdown functions.

4.3.2 Problem Definition

A number of issues with the nitrogen generation system requiring engineering solutions were identified:

i)   The capacity of the system was found to be barely adequate for the application. A recent leak in the purge/seal gas system to the export compressor highlighted the issue that only a small additional draw on the nitrogen system is required before the unit is unable to maintain adequate pressure in the nitrogen receiver and a process shutdown results. The nitrogen generator is a critical utility to the topsides process and a suitable solution was required to address supply capacity issues.

ii) An incident occurred where the engine room operator noted the O_2 content display was reading low (0.3%). It was confirmed that the O_2 reading was faulty when it was found not to deviate during a cycle of the N2 generator system. System cycle should cause a brief high O_2 alarm (>5%) until the excess O_2 is displaced. During this phase the N_2 monitoring unit diverts out of specification N_2 to atmosphere. When O_2 content falls below 5% the vent to atmosphere closes and N_2 is redirected to the accumulator. Typically the cycle process takes less than a minute. Normal operating level for O_2 content in N_2 quality is approx 3.5%, max allowable O_2 content in N_2 system is 5%. There is high potential for this issue to recur as the normal failure mode for galvanic oxygen sensors is low reading [9]. A longer term solution to address this problem is required. The issue has been identified as having potential for health & safety consequences, hence has been raised as a first priority item for urgent attention.

The consequence of the erroneous low O_2 analyser reading is that out of spec (high oxygen content) N_2 is allowed to be passed to the N_2 receiver from which it is used for inert purge/seal gas. Hazards from this condition include:

- High O_2 in N_2 sealing gas on K503A, K503B & K501 (export and recycle compressors). High O_2 (greater than 5%) in presence of an ignition source increases the possibility of ignition or explosion.

- High O_2 in N_2 purge gas for port and starboard boilers (greater than 5%) in presence of an ignition source raises the probability of ignition or explosion.

Due to the incident noted in (ii), a temporary operating procedure (TOP) has been put in place which requires regular manual checks of the O_2 analyser reading using a portable O_2 analyser. The fixed analyser has to be recalibrated whenever a variation is noted. The calibration system of the nitrogen generator has not been designed to support easy calibration of the O_2 sensors. A solution was required that permits rapid switching of the oxygen sensors to a calibration source of known O_2 content for calibration purposes.

4.3.3 Proposed Solution

The solutions proposed to address the issues raised were:

i)   The nitrogen generation system is capable of running at different purity levels. 97% purity can be achieved with a nitrogen production rate of 70 sm^3/hr (current setting), or at 95% at rate 140sm^3/hr. A separate study and risk assessment by the facility process engineer identified that the lower purity nitrogen (95%) is adequate for the inert gas service requirements on Cossack. The system is to be reconfigured to run at the lower purity level with increased capacity. This is achieved by changing the alarm and trip levels in the O_2 analyser [9]. A secondary requirement identified was the need to re-range the nitrogen receiver flow transmitter in the DCS input to match the full scale range of the flow transmitter.

ii) The proposal for improving the reliability / integrity of the oxygen sensing system includes the following:
- Inclusion of a second O_2 sensor and analyser into the package to provide redundancy.
- Inclusion of support for the second O_2 analyser in the unit control system (PLC) logic. A high O_2 reading on either analyser should trigger an off spec nitrogen vent.

- Inclusion of the facility for low O_2 level alarms to indicate possible faulty sensor(s).
- Inclusion of additional sanity checks on the O_2 analysers to monitor the discrepancy between the O_2 readings from each device and raise alarms if required.
- The unit control PLC is a low I/O count unit having only digital inputs/outputs. Hence the inclusion of sanity checks for comparison of reading from the two analysers must be implemented within the DCS.

iii) The proposal for improving the useability of the calibration functions on the nitrogen panel involves duplicating the system employed on another oxygen analyser onboard; the Inert Gas System. This system employs a valve which allows the selection of instrument air (known O_2 concentration 21%) or Nitrogen from an N_2 quad (storage vessel) to flow through the analyser sampling system during calibration. Implementation of a similar system for the N_2 generation unit will relieve the need for manual connection of a portable gas source to the sample line during calibration and improve the efficiency of the calibration process.

4.3.4 Work Required

The scope of work for this project requires changes to:

- Documentation – P&IDs, Functional Logic Diagrams, Termination Drawings and C&E charts need to be marked up for the hardware changes to the package
- Hardware – new equipment (O_2 analysers, cabling, instrument tubing and regulators) require fitting, terminating and commissioning.
- Software – both the unit controller (PLC) and the Honeywell DCS require programming changes to support the new hardware and sensor sanity checks and alarms.
- Work-Pack – Detailing the changes required, how they are to be performed and test procedures for commissioning

The Honeywell DCS in particular is a complicated system for an inexperienced engineer. Substantial time during this project was spent acquiring the requisite system knowledge in order to make the necessary logic changes.
PLC code changes were made using the RSLogix500 ladder logic programming software. Once the documentation and software changes have been specified, a work order needs to be raised in Woodside's workflow management software (SAP) to get the physical changes implemented.

4.3.5 Current Status

All hardware change requirements for the original oxygen analyser duplication scope have been determined and the relevant drawings marked up with the changes. The code for logic changes in both the PLC and the DCS have been completed, but not yet implemented. One of the complications preventing implementation of these changes is the fact that the nitrogen generator is a critical piece of kit for production. If the nitrogen generator stops, the entire process must be shutdown. Hence this work which requires isolation of the N_2 system must wait for a shutdown opportunity to be completed. Shutdowns generally occur only during cyclone disconnects and the planned annual September shutdown. The requirement for reconfiguration of the nitrogen flow transmitter in the DCS has been completed and control bulletin confirming the changes posted.

The original design for the duplicate oxygen analyser sample tubing involved extension of the series connected sample tubing to include the second analyser. It turned out that the series connection shown on the P&ID is not a reflection of the system as built and the two existing analysers are actually T'd off downstream of a pressure regulator in the sample line which is not shown on the P&ID. A modification is required to specify the inclusion of a second regulator to support the new analyser. This modification has yet to be included in the work pack.

4.3.6 Learning Outcomes

This project has provided the opportunity to gain a good understanding of another package within the facility. The job has required changes to both hardware and software, meaning that many aspects of engineering design process have been applied for both control and instrumentation aspects. Both the unit control PLC (an Allen Bradley SLC500) and the Honeywell TDC3000 DCS required logic modifications, or configuration changes. This required considerable reading and research to gain an adequate understanding of the function and programming procedures for both systems. The exercise has also provided exposure to Woodside's internal management of technical change procedures through the TCMS application in SAP.

4.4 ODME Valve Control Logic Modifications

4.4.1 ODME Description

The ODME (Oil Discharge Monitoring Equipment) forms a critical role in ensuring that discharged water meets strict environmental standards. The ODME measures the level

of oil in the produced water in units of mg/L and raises an alarm when the oil in water level exceeds 30 mg/L. Produced formation water (PFW) is analysed on Cossack using an on line Sigrist analyser. Sigrist is a leading manufacturer of process photometers. Sigrist oil trace analysers are based on the fluorescence effect. Most mineral oils radiate visible light (fluorescence) when excited by UV light. Oil in water levels can be determined by measuring the level of fluorescence. PFW oil measurement is also backed up by a portable Horiba monitor which measures oil levels in a fixed sample based on the solvent extraction/infrared absorptiometry method.

The discharge of water overboard is controlled by a series of valves; the overboard valve, which allows water discharge overboard when open and the recycle valve which allows the water to be diverted to the 'slops' tank for further treatment before discharging. A separate VAF Oilcon is used to monitor OIW content of water discharged intermittently from the slops tank after a period of settling [6][7][8].

4.4.2 Problem Definition

It had been observed that during the changeover from discharge overboard to slops diversion, significant quantities of hydrogen sulphide gas (H_2S) have been observed to be vented to atmosphere via the overboard valve. In one instance this caused 3 fixed gas detectors around turbine flat and aft deck to indicate gas concentrations until vapour escape was stopped [12]. Due to the potential safety impact, a first priority item was raised from an IHR alerting of vapour (H_2S) from port slop tank migrating to atmosphere. The area where the hydrogen sulphide gas was released is near manned areas as well as the gas turbine generating units. Presence of gas in this area has potential for injury as well as potential for causing a process trip and hence deferment.

In the process of diversion from discharge overboard to the slops tank when the ODME raised a high oil alarm, current valve control logic simultaneously closes the overboard valve and opens the recycle valve. During the changeover there is some time where both valves are allowed to be partially open. This partially open situation allows under some circumstances a path for the H_2S gas to migrate from the slops tank to atmosphere via the recycle and overboard valves.

4.4.3 Work Required

Changes were required to the valve interlock logic to prevent both valves from being substantially open at the same time. There are two pumps which can be employed to drive the overboard/slops water flow. One is a centrifugal type 'produced water pump', the other is a positive displacement 'stripping pump'. The valve interlock logic must also prevent both valves from being simultaneously closed to prevent pump damage

due to shut in head causing over pressure. The compromise solution requires the closing valve to be 95% closed (5% open) before the opening valve is allowed to start opening. Assuming both valves have similar opening/closing times, this will result in an overlap where both valves are open 2.5% - a much reduced level whilst still preventing the water flow path from being shut in.

The valves in question are controlled by the Cargo Control System (CCS), an Allen Bradley PLC 5/80. CCS programming changes are made using the Allen Bradley programming software for the PLC 5, RSLogix5. The CCS also has an interface to the PCS/DCS, a Honeywell TDC3000. The CCS controls the valve position and monitors the ODME alarm state when the ODME system is in 'auto'. There is the facility from the PCS operator panel to switch the ODME system to manual. Under this condition, the CCS merely controls the low level functions of the valve hydraulic control (open/close) in response to PCS requests. The proposed interlock logic should not interfere with the unrestricted control of the valves from the PCS when in manual mode. The scope of the task includes:

- Review of the existing valve control logic to confirm existing operation and identify the code rungs requiring modifications for the logic changes.
- Modification of the PLC code to incorporate the additional interlock preventing valve opening until the 'other' valve is 95% closed whilst still allowing unconstrained operation in 'manual mode'.
- Review of the impact of modifications on other functionality within the CCS (open/close timeouts etc).
- Creation of Simple Technical Change (STC) notification and Work order to facilitate the formal approval processes for the proposed changes.
- Creation of a work-pack to define the procedure required for the core crew instrument/electrical technicians (Inlecs) to perform the changes.
- Review of successful completion of the changes and closeout.

4.4.4 Current Status

Changes to the PLC code have been completed, STC notification has been created, work order has been approved and the logic changes have been implemented in the PLC. In the testing phase there was initially some misunderstanding with offshore technicians of the intended operation of the valve interlock logic. It was reported as not working as required when the ODME system was in manual. The valve interlock logic is explicitly disabled within the PLC code to allow full individual control of each valve whilst in manual mode. Clarification on these issues was provided to the offshore core crew. This job has now been closed out following confirmation from offshore that the solution provided does address the issue and the new logic functions as intended.

4.4.5 Learning Outcomes

This job, whilst involving relatively simple changes to the PLC logic, has provided a number of useful learning outcomes:

- Experience programming the Allen Bradley PLC5 system.
- Familiarity with the ODME systems.
- Appreciation of Woodside's internal processes for simple technical changes (STCs) and management of change processes.

4.5 SDV Closure Timing

4.5.1 Background

This job pertains to the requirement under established performance standards for Cossack Pioneer to test on a regular basis the functionality of the various shutdown valves (SDVs) around the facility used for shutdown and process isolation during intentional shutdown and emergency events. Continued functionality of the SDVs is critical to the safety and integrity of the facility. There is a specific performance standard relating to SDVs which details minimum performance requirements in terms of leakage rates when fully closed and maximum closure times for the valves [13]. There are various maintenance and testing procedures in place to ensure regular testing of these valves and compliance with the performance standard. The current reporting functionality that has been setup for analysis of valve performance allows checking of the state of the valves before and after a shutdown event (to verify successful closure of the valves) but doesn't provide specific closure timing information. This project addresses the need for the closure timing information in order to demonstrate compliance with the performance standard.

4.5.2 Problem Definition

Each SDV has 3 electrical connections to the valve; an open limit switch indication, closed limit switch indication and the connection to the valve actuator to control the valve state (open/closed). In the existing configuration, the majority of SDVs have their actuator and closed limit switch connections physically wired to the emergency shutdown (ESD) system (a Triconex triple redundant PLC) whilst the open limit switch is physically connected to a DCS input. The ESD system is able to initiate SDV closure and confirm successful closure by monitoring the closed limit switch status. The open

limit switch status is provided to the DCS for indication purposes. The closed limit switch status information is forwarded to the DCS via a serial connection from the ESD Triconex PLC. It is the DCS that is used to provide closure timing information via the Honeywell process historian database (PHD) system. Accurate timing information can only be provided for physical hardwired inputs to the DCS, not the status flags inputs that are used to transfer the SDV closed status to the DCS. In order to facilitate closure time reporting from the DCS, various changes are required to enable the capture of relevant timing information.

4.5.3 Work Required

The work required to achieve the goal of providing an on demand SDV closure timing report can be divided into the following steps:

i) Re-establish full functionality of the PHD server. This task is not strictly part of the job, but became an essential prerequisite. It became evident that whilst the PHD server on Cossack was collecting existing process history information, it could not be accessed remotely to make the necessary changes for valve closure information. A full reboot was required and reconfiguration of the remote access software "Dameware" to restore functionality. It sounds simple, but the process took over two weeks and the involvement of myself, Woodside IT and Honeywell support personnel to resolve the issue.

ii) DCS point modifications to support full status capture and journaling of the open and closed limit switches for each SDV. The DCS point configuration changes are made via remote connection to one of the Honeywell Global Universal Station (GUS) terminals in the Cossack central control room (CCR). Before this work can be performed, work orders need to be raised and approved with detail of the changes to be implemented and a work permit in place to authorise the remote connection work. Some of the SDV point configuration parameters (for the riser emergency SDVs) could only be modified during a process shutdown. The configuration changes required deactivating the relevant point, making the changes and then reactivating. The process of deactivating the RESDVs triggers an immediate process shutdown. The changes to these critical valves configuration were performed during the planned shutdown opportunity in mid September.

iii) Physical connection of closed limit switch indications to DCS inputs. The closed limit switch cabling is currently run through intrinsically safe (IS) isolation devices. The isolation devices used have a single input and two outputs for each point. This task requires the connection of the second output to a spare

input in the DCS. The main preliminary work involved specifying the relevant points in the ESD system marshalling cabinet and identifying spare inputs in the DCS field termination assembly (FTA) for all the connections. A work order and associated work pack is required to perform the cabling work offshore. This work also requires a shutdown opportunity to implement the changes.

iv) Creation of the SDV closure timing report template. The report is run using an Excel template with macros that extract the necessary data from the PHD server. The task of creating the report template has been delegated to Honeywell personnel due to the specialist knowledge of the PHD system required for this task. My role in this item was to provide Honeywell with the necessary background information, facilitate their access to the system and ensure the report template created meets the requirements.

4.5.4 Current Status

Full functionality of the PHD server has been restored and DCS point configuration changes have been completed. A draft report template has been completed by Honeywell pending completion of the required cabling work offshore (shutdown opportunity). A few of the SDVs already have full connection to the DCS which allows for testing of the report functionality. A work order is in place for the field termination work to be completed.

Tasks required for completion:

- Verification of the draft closure timing report.
- Completion of the field termination work by offshore core crew (work order is in the system).

4.5.5 Learning Outcomes

The main learning outcomes from this task included:

- Exposure to the engineering (configuration) interface of the Honeywell TDC3000 DCS.
- Understanding of the interface between the DCS and the Triconex ESD system
- Further exposure to Woodside's internal technical change management system (TCMS).
- Collaboration with Honeywell personnel and Woodside IT.

4.6 Cossack Pioneer SIL Study

The Cossack Pioneer Safety Integrity Level (SIL) study is a recurring requirement for the facility. Woodside standards and regulatory requirements dictate the need to perform the SIL study every 5 years to capture any changes that may affect the integrity of Instrumented Protective Functions (IPF's) on the facility. Cossack's SIL study review is a technical integrity (TI) task that is due to be completed as soon as possible.

4.6.1 Background

The SIL study focuses on the adequacy of safeguards to mitigate hazards. It complements a HAZOP study which concentrates on the identification and risk ranking of hazards. The SIL study involves the determination of the safety integrity level (SIL) for each safety instrumented function (SIF) in a safety instrumented system (SIS) and depends on [10]:

- Corporate tolerable risk standards. In Woodside these standards are defined and quantified in the "Corporate Risk Matrix".
- Overall risk from unprotected hazards that can occur.
- The risk reduction provided by all non SIS protection layers

The SIL study is best applied at the front end engineering design (FEED) stage of a new project, as a supplement to the HAZOP. It is also extensively used during a plant's life cycle to determine if improvements are needed and provide guidance to the form of improvement.

The SIL rating is a measure of safety system performance in terms of the probability of failure on demand (PFD). For convenience the SIL ratings are divided into 4 categories (1- 4) with 4 being the highest integrity level (largest risk reduction factor).

4.6.2 Work Required

The tasks required to get the SIL study for Cossack in action include:

1. Securing the time commitment from the required participants in the study:
   - SIL facilitator who has the necessary SIL facilitation qualifications
   - Process Engineer
   - Instrumentation & Control Engineer
   - Experienced Operator from the facility
   - Safety/Risk Engineer

- Scribe (records details and updates the SIF database)
- Package Vendors (as required)

2. Track down previous HAZOP/SIL studies and Safeguarding Narrative documentation for reference during the study.

3. Populate the SIL study SIF database. The software used within Woodside is Shell's "SIFpro" software designed for use in SIL studies. A substantial amount of pre-work is required before the study commencement to enter all information relevant to each SIF on Cossack.

4. Schedule the meeting time(s).

5. Post-work: Review outcomes of the study and document.

4.6.3 Current Status

The SIL study (proposed by Woodside's Instrumentation & Control Technical Authority) has received support to proceed from the facility engineering team leader and operations manager. Pre-work required populating the SIFpro database has commenced but is currently on hold due to workload and availability of SIL study participants.

Progress on this task has been limited due partly to my assuming the role of facility control engineer and partly due to the availability of required SIL study participants within the internship timeframe. This task should be considered as a candidate for future work as it has potential to address some important regulatory compliance requirements for the facility and has useful learning outcomes for an engineering student.

4.7 CSS Modification Work

4.7.1 Background

The Combined Safety System (CSS) describes the system physically implemented on two separate Triconex (Tricon) triple redundant safety PLCs. The two systems are:

CPESD (Cossack Pioneer Emergency Shutdown) – responsible for safe shutdown of the facility under normal and emergency situations. CPESD has direct control of all critical SDVs and XDVs (diverter valves) and BDVs (blowdown valves) and initiates shutdown of the facility under detected abnormal operating conditions and in response to external shutdown requests (eg from a PCS request or manually operated ESD pushbutton)

CPFNG (Fire and Gas Control System) is responsible for the detection, monitoring and control of fire and gas events within the facility. Detection of these events is achieved through a series of smoke, detectors, flame detectors, gas detectors, fusible loops and other fire and gas detection apparatus. The FNG system is responsible for deploying fire control systems (eg deluge system and Innergen and CO_2 fire suppression systems) and initiating alarming and process isolation in the event of gas detected.

Due to the criticality of the Triconex systems strict change management procedures are in place to ensure that proposed changes have to be carefully designed and reviewed to confirm the changes don't introduce extra risk (incorrectly implemented code) and that the process is not affected while implementing the changes.

4.7.2 Task Definition

There have been number of projects requiring modifications to the CSS Tricon PLCs:

1. The previous task implemented a modification in the Tricon ESD logic due to the unknown state of shutdown valve (5-SDV-061) to ensure the executive action close signal to this valve also included a downstream SDV (5-SDV-064) as a backup. SDV061 has been replaced during the September shutdown and the modifications previously made to the CPESD Triconex PLC had to be reversed.

2. Tricon Forces removal work: The Tricon system includes the facility to 'force' a particular point to a specific value regardless of the logic implemented on that point within the running code. This feature, called "Disable Points Manager" in Tricon terminology allows for the temporary changes to be made to override points during temporary work and during various testing activities. These forces are implemented from a separate utility within the Tricon programming interface (TriStation) without having to make permanent code changes. The forces function is intended to be used for short term (temporary) changes to the system. Within the CPESD system 8 forces have been identified which have been in place long term (some since 2003). This task involves removing these forces and where necessary implementing other changes to include the modification permanently in the Tricon code.

4.7.3 Current Status

The first task has been completed and closed out. The logic changes were trivial, but it was significant in that it was my first attempt at modifying the Tricon code. A lot of research was required to get up to speed with the system and the procedures required

for implementation and backup of the various code versions. The task is further complicated in that there is no remote access available. The changes had to be performed by the core crew Inlec technicians onboard under (my) telephone guidance from Perth.

The second task was only partially completed during the internship. Removal of the forces requires investigation into the reason for the implementation of the forces and validation that the force is still required. If so it has to be removed from the forces list and permanently implemented in the Tricon code. Feedback from the facility process engineer was required to verify the suitability of the current (forced) values. A report detailing work completed is included on the CD.

4.7.4 Learning Outcomes

The main learning outcomes from these tasks included:

- Gaining familiarity with the Triconex TriStation programming interface and the rigorous change procedures required for the CSS.
- Experience creating detailed and comprehensive work packs (work instructions) for implementation by offshore crew.
- Collaboration with Core Crew Inlec technicians who have a wealth of hands on experience with the systems on Cossack.

5. Internship Outcomes

Learning outcomes noted for each of the main tasks were presented in the previous section. With reference to the specific stated internship competencies [2], the following general competencies have been met during the internship:

Engineering Operations – The internship has provided direct exposure to the practical aspects of an operating facility and the internal workflow and change management processes

Engineering Planning and Design – a range of experience acquired through various small design projects including knowledge of drawing update procedures and documentation requirements (work packs)

Materials/Components/Systems – The internship has provided an introduction to a range of engineering systems including PLC programming packages, DCS interface and internal workflow management systems (TCMS, SAP)

Self Management in the Engineering Workplace – This was a large part of the internship role particularly in the latter part where prioritisation skills were critical.

Investigating and Reporting – This formed an important part of many of the tasks performed. Each required investigation to determine problems and find potential solutions and reporting of the findings / results in written form.

6. Potential Future Work

As has been previously mentioned, future work in this role is difficult to predict. The internship period in Cossack Pioneer facility engineering team has been a 'window' into the continuous role in engineering operations. During this time some partially completed work has been taken on and brought through to closure. Other tasks have been stated and completed in their entirety, whilst other jobs have commenced, but not progressed to completion.

The following list details some of the tasks that have substantial work to be completed and have learning outcomes reflected in the internship requirements.

1. Cossack Pioneer SIL Study – This task only had preliminary work commenced during the internship. It is a good candidate for potential future work for an internship student as it has potential to address some important regulatory compliance requirements for the facility and has useful learning outcomes for the student.

2. Triconex Forces Removal Project – This task was partially completed during the internship and is a high priority task to be completed. This task will provide an internship student with excellent opportunities to learn about the workings of the Triconex Safety PLCs that are very commonly used in this type of industrial application.

3. Compressor Controls Corporation (CCC) Trainview compressor control system upgrade – This task only emerged at the end of the internship (to my disappointment). The CCC controller provides anti-surge protection to the centrifugal compressors whilst allowing them to run close to their performance curve limits. Compressor surge (rapid reverse then forward flow oscillations) has the capacity to completely destroy a centrifugal compressor in a short space of time. The CCC controller is the most complicated control system that I have found so far on the facility (Cascaded PI loops with feedforward). The system has been neglected up until this point and it is not being used to its potential. With the recent commissioning of the Angel gas platform near Cossack, pressure profile have increased in the gas export line. It is now more critical than ever that the export compressor performance is optimised for highest throughput. The new version of the CCC Trainview software has been purchased, but not installed. It would make an excellent task for an internship student to take charge of upgrading, configuring and properly documenting the use of this system.

7. Conclusion

This report has provided an account of the work performed and experience gained during the engineering internship with Woodside's Cossack Pioneers Facility Engineering Team. This team provides the onshore engineering support required to maintain the reliability and integrity of the FPSO. The teams' role involves a substantial reactive component to address maintenance, repair, reliability and regulatory requirements as they arise, limiting the ability to plan a substantial amount of the work.

Projects have included: First priority modifications to the Oil Discharge Monitoring valve control logic and Nitrogen Generation systems, and tracing of critical metering instruments for the facility's production accounting system, modifications to the Honeywell TDC3000 DCS and the Tricon PLCs which comprise the combined safety system (CSS).

The most significant deviation from the original project plan presented in the preliminary report [11] is that the proposed SIL study was not progressed. This was due in part to the change of role midway through the internship, taking on the role of facility control engineer and partly due to the availability of required attendees for the SIL study.

Work during the internship has provided learning outcomes that align well with the stated internship objectives. These included:

- Systems experience – Programming of Allen Bradley PLC5 and SLC500 PLCs, Honeywell TDC300 DCS and Triconex PLCs. Good understanding of nitrogen generation systems, Oil in water analysis equipment.
- Design experience – Designing changes to the nitrogen generation system for improved reliability.
- Operations experience – exposure to the practical aspects of an operating facility and the internal workflow and change management processes.

Whilst the role of Facility Control Engineer was found to be extremely challenging, it has provided excellent exposure to an engineering operations role in the oil and gas industry. Performing this role has proved an efficient way to learn about the control systems on board the Cossack Pioneer FPSO.

Annotated Bibliography

[1]   Murdoch University, *University Handbook Unit Information ENG450*. [Online]
        URL: http://handbook.murdoch.edu.au/units/detail.lasso?unit=ENG450
        [Accessed Aug 2008].
        Description: The Murdoch University Handbook provides information for
        students on the various courses and units available as well as guidelines on
        university policy for matters such as assessment, plagiarism, examinations and
        appeal procedures. This online extract contains the unit outline for ENG450
        which details the aims of the unit and prerequisites.

[2]   Bahri, P.A., *ENG450 Engineering Internship – Study Guide, Semester 2*.
        Murdoch University, Perth, Western Australia, 2008.
        Description: This is the study guide for the engineering internship unit written by
        Unit Coordinator, Professor Parisa A. Bahri. The guide describes the broad aims,
        structure, assessment details, guidance for report preparation and guidelines to
        be followed during the internship.

[3]   Woodside Internal Document, *Cossack Pioneer Safety Case*, Controlled Ref No.
        E1000RF006.01, Woodside Energy Ltd., 2008
        Description: The Safety Case is generally developed during the design phase of
        a facility through the process of a formal safety assessment performed by the
        safety engineering team. It is modified as required throughout the facility life to
        reflect changes. In Australia it is a regulatory requirement to maintain a current
        safety case to operate an offshore facility. The safety case includes a description
        of the safety objectives of the facility and how they are fulfilled, a facility
        description, HSE management system description and a formal health and safety
        assessment for the facility.

[4]   Woodside Energy Ltd., *Woodside Corporate Profile*. [Online] URL:
        http://www.woodside.com.au/About+Us/Profile/ [Accessed Aug 2008].
        Description: This article located on the Woodside corporate website provides a
        brief summary of the companies profile, history and current goals.

[5]   Chemicals-Technology, *Sigrist Process Photometer* [Online] URL:
        http://www.chemicals-technology.com/contractors/controls/sigrist/ [Accessed
        Aug 2008].
        Description: This web article provides a short description of the Sigrist oil trace
        analyser oil in water monitoring device which is used on Cossack Pioneer to
        monitor the oil level in produced water discharged overboard.

[6]   Sigrist Process-Photometer, *Fluorescence Oil Discharge Monitor* [Online] URL:
        http://www.photometer.com/en/products/details/features.html?productid=245
        [Accessed Aug 2008].
        Description: This is the product page for the Sigrist 'OilGuard' oil in water
        monitoring device. It includes product specifications and a description of the
        principle of operation.

[7]   Horiba, *Horiba portable oil in water analyser* [Online] URL:
        http://www.jp.horiba.com/products_e/proenv/ [Accessed Aug 2008].
        Description: This is the product page for the Horiba portable oil content
        analyser. The page includes feature descriptions, product specifications and a
        description of the principle of operation.

[8]   VAF, *VAF Oilcon Mk6 Oil Discharge Monitor* [Online] URL:
        http://www.vaf.nl/products/oil_in_ballast_water.asp [Accessed Aug 2008].
        Description: This is the product page for the VAF Oilcon Mk6 Oil Discharge
        Monitor as used on Cossack Pioneer. The page includes feature descriptions,
        product specifications and a description of the principle of operation.

[9]   Woodside Internal Document, *Permea Nitrogen Generation System Operation
        Manual*, Controlled Ref No. E3167EM003.01, Permea Maritime Protection, 1995.
        Description: This is the installation and operation for the Nitrogen Generation
        System package provided to Woodside for use on Cossack Pioneer. The manual
        includes an overview of the system including description of the operating
        principle. As this unit is actually a package made up from components supplied
        by other vendors, the appendices include vendor manuals for various system
        components including the oxygen analyser.

[10]   ACM Facility Safety, *SIL Determination Techniques Report "White Paper"*, ACM
        Automation Inc., 2006.
        Description: This white paper prepared by ACM Facility Safety provides an
        overview of the background benefits and methods employed in a safety Integrity
        level (SIL) study. It compares some of the quantitative methods employed and
        provides some process industry insights into the current industry trends in this
        area.

[11]   Holmes, J.G., *ENG450 Engineering Internship – Project Plan, Semester 2*.
        Murdoch University, Perth, Western Australia, 2008.
        Description: This was the original project plan submitted by the author providing
        an overview of the internship and detailing work performed and future work
        envisaged at an earlier stage in the internship.

[12]   Woodside Internal Document, *Cossack Pioneer First Priority Action Report*,
        Woodside Energy Ltd, 2008.
        Description: This is an internal report regularly updated which details all
        outstanding first priority items for the facility. First priority actions arise from
        incident hazard reports (IHRs) raised on the facilities and are aimed at reducing
        the risk of any identified hazard. Each action includes a summary of the incident
        and the required corrective action to address the issue.

[13]   Woodside Internal Document, *Cossack Pioneer Performance Standards*,
        Woodside Energy Ltd, 2008.
        Description: The performance standards for Cossack Pioneer define at set of
        standards that the facility is required to meet to maintain the licence to operate.
        Each standard is developed to mitigate any risks identified that may contribute to
        or escalate the severity of a major accident event.

[14]   Triconex Corporation, *TriStation Multi-System Workstation (MSW) User's
        Manual*, Triconex Corporation, 1993.
        Description: This document is the complete user manual for the Triconex PLC
        interface and programming software (TriStation). In addition to providing a
        comprehensive usage instructions and programming reference for the Tricon
        PLC V7.1, it also includes an introduction which includes an overview of the
        Tricon PLC and summary of its features and benefits.

[15] Honeywell Inc, *High-Performance Process Manager Specification and Technical Data – HP03-600*, Honeywell Inc., 1999.
Description: This document is the technical manual for the Honeywell High-Performance Process Manager (HPM). In addition to providing comprehensive information on the usage and application of the HPM, it also includes an introduction which provides an overview of the Honeywell TDC3000 distributed control system.

[16] Woodside Internal Document, *Operational Reliability Improvement (ORIP) Standard*, Controlled Ref No. W6504SG3836292, Woodside Energy Ltd, 2008
Description: This standard defines how the ORIP process is applied to achieve reliability improvements across the facility and the organisation as a whole.

Appendix 1 – Cossack Pioneer Process Schematic

Figure excluded for copyright reasons

Appendix 2 – Internship Gantt Chart

ID	ⓘ	Task Name	Duration	Start
1	✓	Woodside Onboarding and Inductions	2 days	Mon 7/07/08
2	✓	**Critical Meter Tag Identification**	**20 days**	**Wed 9/07/08**
3	✓	Determine Task requirements	1 day	Wed 9/07/08
4	✓	P&ID Search/DCS tag match	9 days	Thu 10/07/08
5	✓	Present & Review list with Maint Group	1 day	Thu 31/07/08
6	✓	Create Procedure Documentation	1 day	Tue 5/08/08
7	✓	**Solar Turbines Training Course**	5 days	Mon 21/07/08
8		**N2 Generation System Analyser duplication**	**39 days**	**Mon 14/07/08**
9	✓	Documentation Search & Review	2 days	Mon 14/07/08
10	✓	Markup Drawings	2 days	Wed 16/07/08
11	▦	Specify logic changes to PLC & DCS	10 days	Wed 13/08/08
12		Create Workpack	3 days	Fri 29/08/08
13	▦	Submit notification & create work order	1 day	Wed 3/09/08
14		Review / Verify changes and Closeout	1 day	Thu 4/09/08
15		**ODME Valve interlock logic changes**	**18 days**	**Thu 31/07/08**
16	✓	Documentation Search & Review	2 days	Thu 31/07/08
17	✓	Specify logic changes to CCS PLC	9 days	Mon 4/08/08
18	✓	Modify Functional logic diagrams	2 days	Fri 15/08/08
19	✓	Submit notification & create work order	1 day	Tue 19/08/08
20		Create Workpack	3 days	Wed 20/08/08
21		Review / Verify changes and Closeout	1 day	Mon 25/08/08
22		**SIL Study**	**48 days**	**Mon 4/08/08**
23	▦	Review requirements, supporting documentation	3 days	Mon 4/08/08
24		Pre-work (populate SIFpro database)	20 days	Mon 25/08/08
25		Schedule SIL review meeting	8 days	Mon 22/09/08
26		Review outcomes and document	5 days	Thu 2/10/08
27	▦	**Internship End**	0 days	Fri 24/10/08

Project: ENG450 Internship Project Ga
Date: Fri 22/08/08

Task		Milestone	◆
Split		Summary	
Progress		Project Summary	
		External Tasks	
		External Milestone	◆
		Deadline	⇩

Page 1

47

Project: ENG450 Internship Project Ga
Date: Fri 22/08/08

Task	Milestone	External Tasks
Split	Summary	External Milestone
Progress	Project Summary	Deadline

24/10

48