The Maui Field Oil Development "Whakaaropai" – FPSO Experiences and Lessons Learned –

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Abstract

In 1993 oil was discovered below the gas bearing sands of Maui B. Recoverable reserves were estimated at only 22 million barrels with a short plateau [3 to 6 months] and an economic production period of 5 to 7 years. The Maui infrastructure is primarily designed for gas/condensate and the presence of asphaltenes in oil prohibited co-mingling of oil with the gas/condensate stream from considerations of gas system reliability, risk to personnel on Maui B and management of waste. Further, Maui B is a minimum facility satellite to Maui A with limited capacity for major expansion. However, economic success for the FPSO Oil Project is dependent on this infrastructure for evacuation of associated gas.

The challenge was one of developing an economically attractive project whilst maintaining technical integrity and HSE standards.

The outcome was a FPSO development that produced first oil from the Maui B field three and a half years after discovery, just 19 months after investment approval, and within 12 days after being anchored on location. Handover of a performance-tested facility occurred within eight weeks after first oil, and the FPSO achieved a mature operating crew level of 16 staff on the same day. The project was completed just under its 50:50 budget estimate of NZ$ 200 m and has operated at over 37,000 bbl/day against a nameplate capacity of 31,000 bbl/day.

This paper discusses the brief history of Maui Oil - from development into operations, reviews some of the factors that made the project a success, and identifies some of the lessons learned.

Acknowledgements

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It is also appropriate to acknowledge the efforts of those [both STOS and contractors] involved in the initial development and execution of the project, and importantly, those people who took up the operating challenge and made the concept work. Without their collective energy, commitment and innovative thinking, it is doubtful whether Maui Oil could have become reality.

Introduction

On 10th April 1996, the then Prime Minister of New Zealand, the Honourable James Bolger, accompanied by members of the Board of Maui Development, dignitaries from Taranaki Iwi, and representatives of Shell Todd Oil Services Ltd, conferred the name "Whakaaropai", on the first Floating Production, Storage, and Offloading [FPSO] facility to be installed in New Zealand waters.

The name "Whakaaropai" loosely translates as "Good Thoughts", a choice that has thus far seen the happy coincidence between the name of the FPSO and the performance of both the reservoir and the facility.

This paper backgrounds the development and subsequent operating performance of the production of oil from the Maui field, and reviews the lessons learned from both a local New Zealand perspective, and the broader industry perspective.

Maui Field History and Overview

The Maui gas field is located in PML381012, 30-60 km offshore south Taranaki on the west coast of the North Island of New Zealand. The field was discovered in 1969 by a consortium led by Royal Dutch/Shell [37.5%], and comprising BP [37.5%], and the Todd Corporation [25%]. Subsequent to discovery and as part of securing the gas sales agreement, the New Zealand Government [The Crown] assumed a 50% participating interest in the venture. Subsequent changes in equity, notably The Crown's exit in the late 1980s has led to a revised equity holdings namely: Shell - 83.75%; OMV - 10%; Todd - 6.25%.

In 1996 at the time of the Maui Oil Development, Joint Venture Participants were Fletcher Challenge [68.75%] Shell [18.75%], and Todd [12.5%].

The field comprises two main hydrocarbon bearing accumulations, Maui A and Maui B, containing an estimated ultimate recovery volume of approximately 3.5 TCF of gas.

Subsequent to discovery, the parties concluded a field development plan and a 30-year gas sales agreement that is encapsulated in the 1973 Maui White Paper. The agreement underpinned the development of the Maui Field that, even in 2004 provides the backbone of New Zealand's gas infrastructure.

The Maui field is managed and operated by Shell Todd Oil Services Ltd, while NGC operate the onshore pipeline system. Field development has occurred in three main stages.

- **Maui Stage 1:** Development of the larger, eastern Maui A area with production commencing in 1979. Key infrastructure components are the Maui A platform [including 14 development wells and associated plant, separation facilities and utilities]; the pipelines from Maui A to the onshore processing plant; and onshore storage and distribution facilities. First production from Maui A commenced in June 1979.
- **Maui Stage II:** Development of the smaller southwestern gas accumulation via a satellite development to Maui A. Key infrastructure components are the Maui B platform [including the ten development wells and associated plant and utilities] and the single interconnecting pipeline between Maui B and Maui A. First production from Maui B commenced in April 1993.
- **Maui Oil Development:** The discovery of a small oil accumulation underlying Maui B during the 1993 development drilling of Maui B wells, led to the development of a separate oil production facility. Key infrastructure components are five oil wells drilled from Maui B, a FPSO, and an interconnecting gas pipeline between Maui B and the FPSO. First production from the FPSO commenced in June 1996.

In the intervening time other smaller projects have been implemented including LPG processing and storage, Naphtha processing, and gas chilling facilities.

Maui Oil Discovery

During the early 1990s STOS undertook a comprehensive 3D seismic acquisition programme to better delineate the Maui A and B structures, and to shed light on further exploration possibilities within the Mining Licence. Analysis and interpretation of this seismic data identified a Maui F sands prospect underlying the main producing C & D sands. This prospect was initially evaluated as a gas bearing structure with potential for approximately 60 BCF gas.

This prospect was tested in May 1993 during the development-drilling phase of Maui B by deepening the fifth of the initial eight Maui production wells. The result was the discovery of the Maui F sand oil accumulation that was subsequently appraised via two other wells in August 1993 resulting in the confirmation of an estimated 22 MMBO of recoverable oil. Eventual development was from two further horizontal wells one of which tested at a production rate of almost 35,000 bbl/day. Additional work in the mid to late '90's identified a smaller oil accumulation in the shallower D sand. This zone was developed starting in 2000 with 2 deviated wells and the deepening of an existing well. The Maui BD Oil Development helped extend the FPSO ultimate recovery to the current estimate of 28.7 MMBO.

FPSO System Overview

The FPSO is an integrated floating oil and gas production, storage and offloading system. FPSO systems can come in many different shapes and sizes including converted barges, tankers, or purpose built vessels, and very large semi-submersible vessels.

The purpose of a FPSO is to receive and process fluids from the reservoir [often via sub sea wells] and store the stabilised product until it can be transferred to tanker for dispatch to market. Historically, FPSO developments have been employed to exploit relatively remote oil fields. Associated gas is used for power generation while surplus gas was flared. However, recent developments in technology are realising the first of a new breed of FPSO's which can be used to exploit remote gas fields by processing the gas and storing it as LNG in readiness for export to LNG markets.

FPSO systems are now recognised as being one of the most convenient and cost effective of offshore oil development concepts, especially for deep water, or relatively remote locations where development requires a standalone facility or where field economics demand low cost solutions.

Main Advantages	Applicability to Maui Oil
• System autonomy	☑
• Versatility with respect to vessel selection, construction, installation and relocation	☑
• Large deck area to accommodate production equipment	☑
• Relative insensitivity to variations in payload, even during operations	☑
• Simple and proven construction technology	☑
• Able to store large volumes of oil	☑
• Potential for lease / charter arrangements	☑
• If carefully managed can have lower development cost, and shorter development lead-time than the more traditional/conventional offshore structures	☑

Main disadvantages are:

- Costly to work over if connected to sub sea wells [not applicable to Maui]
- Need to provide the vessel with the capability to weather vane, and thus the need to design a coupling [swivel] that allows fluid transfer.
- Well stream processing, storage and vessel stability need to account for vessel movement.

Project Development and Execution

The Economic Challenge

Given the volatile oil price environment in the late 1990s, and the low reserves volumes, economics were always going to be marginal. Independent assessments at the time concluded that minimum economic oil reserves for new developments in the Taranaki Basin [100m WD; 50km from shore] were around 44 MMBO. Given that in the Maui F sands reservoir was estimated to contain half this amount on a P_{50} basis [P_{90} -16 MMBO], the Operator was presented with a serious challenge to identify an economically viable development plan that could be executed in a very short time period.

However, there were a number of factors working in favour of the project:

- The field was directly underlying Maui B, and therefore the existing offshore infrastructure could be used.
- Discovery coincided with major field development activities and so resources were available to tackle the challenge.
- All major drilling infrastructure was on hand and mobilised.
- Production wells could be drilled from the Maui B platform allowing easy well access and low cost interventions.
- Joint Venture participants were generally bullish about the opportunity.

The Development Challenge

Initial project evaluation focussed on conventional approaches involving production of Maui Oil via the existing Maui gas infrastructure. Several development options were considered with two major options being carried forward into the feasibility study.

- **Integrated Oil and Condensate Production:** Integrated oil and gas production facility including the installation of processing facilities on Maui B, export via a co-mingled oil/gas/condensate stream to Maui A, primary separation on Maui A, and export to the onshore production station [MPS] for final treatment.
- **Segregated Oil Production:** FPSO moored close to Maui B to provide separation, storage and offloading of oil with associated gas returned to Maui B for export through the existing system.

Option selection economics were too close to call, showing a crossover of NPV vs. Reserves marginally favouring the integrated [co-mingling] option at the high end of the probability distribution.

A FPSO upside was that it left capacity at Maui Production Station to manage a high gas / condensate throughput, a need that was realised very shortly thereafter during the 1996 drought where New Zealand became reliant on [thermal] gas electricity generation stations to supplement the country's hydroelectric energy sources which at the time were under severe pressure.

However, analysis of Maui oil samples and subsequent testing by Adelaide University highlighted that mixing of light end cuts of Maui condensate [C_3 – C_7] with Maui oil was shown to cause asphaltene precipitation. Santos, who kindly shared their experiences with STOS, experienced identical issues at its Port Bonython plant, when co-mingling Moomba gas condensate with new oil production. The result was that its columns and heat exchangers became filled with asphaltene precipitation within a week. Even though Maui oil contains only 14% v/v asphaltenes, this is enough to deposit 10 tonne/day of asphaltenes at the production station. The consequent risk to Maui production and the obvious implications for downstream gas customers was deemed clearly unacceptable.

While the conventional option remained the front-runner, and despite the scepticism of management of the time and the reluctance from some of the joint ventures, a small team including industry advisors [Intec] was established, to further investigate FPSO options as a means to counter the asphaltene risk.

The result of this work was the eventual selection of a low-cost FPSO development, set up to run independently of the Maui gas system.

Project Development

The project comprised three main activities:

1) Development Drilling
2) The purchase, conversion and installation of the FPSO, and
3) Minor modifications to the existing Maui B platform

Development Drilling

Development drilling was relatively straight forward insofar as the activity became an extension of the Maui B Drilling programme.

FPSO

The MV Ellida, a 19 year old ex trading tanker of 137,000 DWT Suez-Max class, was purchased, converted in a Singapore shipyard, sailed to New Zealand under its own power, moored in position and commissioned. The entire project was contracted to MODEC Inc of Tokyo.

Field life was defined at four to seven years and facility life at ten years. Technical specifications were based on national, international and Certifying Authority standards, in addition to Safety Case and Hazop studies. To avoid any dry-docking costs for a fifth year certification survey, the FPSO specification called for the hull, tank internals and the fatigue life to be suitable for a seven-year economic life.

Two skids were installed above the main deck to support the oil separation process vessels and the gas recompression compressors.

The bow of the FPSO was modified to accommodate the process fluid swivels and mooring arrangement. These swivels cater for two flexible flow lines; a pigable 10.5" oil product line and a 4.5" gas return line. A midwater arch provides the flexible flow lines with a catenary for movement of the FPSO, and is free hanging at the platform end. A chain-table holds 10 anchor legs, each of which is connected to drag-embedment anchors located on the seabed. The mooring system is designed to withstand a 100-year storm with one anchor disconnected.

Oil is exported via a floating hose to shuttle or export tankers moored at the stern of the FPSO.

Facilities Modifications on Maui B

The modifications to Maui B involved the installation of production, testing and gas lift manifolds, a test separator, vent KO vessel and vent tower, flow lines, chemical injection facilities, associated controls and telecommunication equipment. As Maui B is a not normally manned platform, construction was modularised to a large extent thus minimising installation time. Flexible free hanging risers were chosen at Maui B to tie-in the flexible lines to the FPSO.

Contracting Strategy

FPSO's are a making of three very different engineering cultures:

- Traditional tanker and shipping conventions;
- Mooring and marine conventions and;
- Exploration and Production [E&P] oil and gas conventions.

The secret to successful cost-effective and safe development and operation of the amalgam is to avoid any one of these cultures dominating the other inappropriately. This balance is considered to have been a key success factor in developing the Maui FPSO, where specialist contractors were allowed to manage their own aspects, with the all-important interfaces being handled by an experienced management contractor.

The contracting strategy set out to eliminate non-value adding interfaces and, in particular, to use EPC contracts to the fullest practical extent. The result was the award of very few contracts, with only two major contracts being let:

- Engineering, procurement, conversion, installation and HUC [Hook-up & Commissioning] of the FPSO and associated flow lines. [Contractor - MODEC]
- Engineering, procurement management, construction, installation and HUC of the Maui B platform modifications. [Fitzroy-Worley - now Transfield-Worley]

The JV owners purchased the vessel. Although originally tendered on a lease basis with a purchase option, subsequent evaluation determined significant advantages to purchasing of the vessel/facilities arising from STOS's ability to:

- Capture economies of scale via existing management and support services
- Influence/control the manning profiles and the capacity to undertake a campaign maintenance programme approach using existing Company resources.

JV ownership of the vessel paid dividends late in life by allowing economic recovery of the recently developed BD oil accumulation. High lease payments would have made the relatively low rate late life recovery uneconomic.

Project Execution

FPSO conversion and installation - MODEC

STOS experience in design and operation of FPSO's was virtually nonexistent, and thus Consultants [Intec] were engaged in the feasibility and contract tender periods. As a result, the FPSO contractor was required to technically manage the works with oversight only provided from STOS. For this reason the tender list was restricted on SIEP advice to those contractors having a proven track record of FPSO supply under similar contract structures. The work was subsequently awarded to MODEC.

To expedite development, the FPSO Contractor agreed prior to Contract Execution, to commence front-end engineering on a 50:50 cost share, no commitment basis. This allowed work to commence some 8 weeks prior to final development approval with significant resultant schedule savings.

The Company also purchased and free-issued the longest lead item [the HP Compressor] to the Contractor, using Shell's global contracting leverage. This allowed the project to make the most of cost and schedule opportunities arising from the decision. Additionally, STOS and MODEC entered into a risk sharing arrangement for a two-phase offshore installation programme. The agreement contained incentives for efficient installation and the outcome was payment of a bonus for the phase II installation in the most extreme weather period of the year.

Nineteen months after formal contract award, the FPSO produced its first oil; the MODEC contract value had altered by a mere 2%, the majority of which was associated with an increase to the previously undefined repair scope of the vessel. The turnkey contract was conventional and included provision for liquidated damages. MODEC executed the contract with great honour and full integrity.

The very harsh environment of the Tasman Sea [waves, wind and prevailing swells] can at times create significant vessel roll, within design fatigue and mooring parameters. The performance of the above-deck, NATCO-designed processing plant [elevated to avoid wash or "green water"] has been remarkable. Their equipment is based on empirical internals design, derived from a moving table that mimics the six FPSO movements [roll, pitch, heave, sway, yaw and surge]. Mooring design by SOFEC was also based on empirical test results, and underpinned by a very good Maui hindcast model developed in-house by STOS.

Maui B Modifications - Fitzroy/Worley JV

The modifications to the Maui B platform were initially let as separate engineering [Worley NZ Ltd] and construction [Fitzroy Engineering Ltd] contracts. An alliance-style contract was subsequently established for the Maui B modifications, a first for the E&P industry in New Zealand.

This choice arose from the success of BP with many of its international projects, and, in a New Zealand context, advice from the Te Papa project manager. As a result, the two companies combined to form a joint venture [Fitzroy-Worley Ltd] to deliver the EPC contract for the total Maui B work scope, leading to significant interface efficiencies for all parties.

Project Manning

The project team comprised a small group of people in New Plymouth, and a site team of around eight people based in Singapore, with specialists engaged on an audit basis only. This "minimum manning" philosophy was adopted to ensure that the "hands off" approach could be maintained and was considered very successful

Environmental Impact Assessment

As in any E&P project, an early deliverable is an Environmental Impact Assessment [EIA]. This was carried out by a combination of international and local consultants, and concluded that offshore offloading of large parcels of crude [ca. 600,000stb] carried significantly lower risk than the load out of small parcels in Port Taranaki to coastal tankers.

Even though the development was to occur 50km offshore, because there has been no such previous development in New Zealand, it was important to establish constructive and open relationships with the Parliamentary Commissioner for the Environment and the Maritime Safety Authority. The relationship with both was considered by STOS to have been highly constructive and open.

Safety and Risk Management

Significant emphasis and effort was applied to safety performance. A project engineer with HSE experience was a part of the contract management team providing ongoing monitoring and assistance.

The Project adopted principles and philosophies consistent with business practices of the time:

- All accidents are avoidable
- Investment in HSE management provides payback
- All personnel are involved in safety management
- HSE is to be treated as any other part of the business
- Development of the HSE management planning. The objectives and progress of the various aspects of Management commitment to HSE from both organisations must be evident to all

The most serious incident involved a boiler explosion, which occurred close to shipyard completion. While very serious, the project was extremely fortunate to avoid greater damage to both people and plant. The incident resulted in moderate injuries to one of the boiler technicians, and a four-week delay to sail-out from Singapore. Notwithstanding, the safety record at Keppel Shipyard [LTIF of 2.9] was considered at the time to have been successful as compared to the Singapore LTIF averages [11 for heavy engineering and 13 for shipyards]. The single most significant factor in the management of HSE was the visible commitment shown by management personnel from both STOS and contractors.

Technical risks were managed through the audit process. No "hold" or "approval" points were included in the contracts other than jointly managed HAZOP and Safety Case reviews. Rather, the critical areas of the work were identified and informally reviewed on an ongoing basis whilst less critical areas were periodically examined at a less detailed level. Reviews required by the certifying authority were also adopted as a control.

Safety Case/QRA

While not required by regulation, a safety case was prepared for Maui B oil. This is a primary tool for overall management of technical and facility risk.

Examples of the advantages of the safety case approach were:

- Evaluation of platform based and FPSO approaches to development showed marginal economics between the options. QRA showed the FPSO to be superior in individual risk terms and influenced the selection of the development option.
- HP gas compression was shown to present a significantly lower risk when utilising a single centrifugal compressor instead of the originally proposed three reciprocating compressors.
- Contrary to perceptions held by the engineering staff, riser connections to the Maui B platform were shown to provide no greater risk when free hanging than the proposed water level connections, producing a saving in the order of US$750,000.
- The selection of davit launched rather than free fall TEMPSCs was justified through QRA.

The use of QRA and safety case from the early stages of feasibility studies to project completion to provide an additional perspective in decision making ensures safety of the facilities and frequently improves economic design. The safety case/QRA studies may be used to justify deviation from standards which regulatory authorities have previously been reluctant to accept.

External Audit

The operation of FPSO facilities in the Australasia and Oceania regions is relatively well established resulting in a number of operators having considerable experience in construction and operation. During project development and execution, significant benefit was derived by inviting experienced operators from BHP and Woodside to participate in a number of reviews and audits.

Operations Group Involvement

The Maui B Oil project adopted a very focussed, fit for purpose design approach, which required ownership by both designers and operators. In the case of STOS this ownership was achieved by:

- Operator involvement in the project justification for the standards adopted;
- Workshops at which the concept was fully explained, discussed, and justified by senior members of both the project and operations groups;
- Having achieved initial ownership, operating crews were involved in design decision-making and in the latter stages of construction.

For STOS the strategy resulted in a highly motivated operations team keen to ensure the success of their concept. Few modification designs were adopted in the latter stages of the project. Operations staff concentrated on understanding the facility and developing methodologies to optimise its performance. Selection of operating personnel to ensure the correct attitudes and skills mix are available is clearly an essential element in this process.

The engagement and support of the Operations group in STOS was a critical success factor for this project.

Crewing

The FPSO is permanently moored and is classed as a fixed installation.

In line with the Maui A and Maui B facilities the multi-skilled operations technician concept was extended to include the FPSO and thus the FPSO operation is an integral part of the overall Maui Field operation.

These factors have enabled on FPSO crew size as low as 13 [less than a third of that at other comparable FPSO's] with a corresponding saving in operating costs. The use of limited multi-skilling allowed this screening benchmark to be set using maintenance campaigns as planned technical integrity projects.

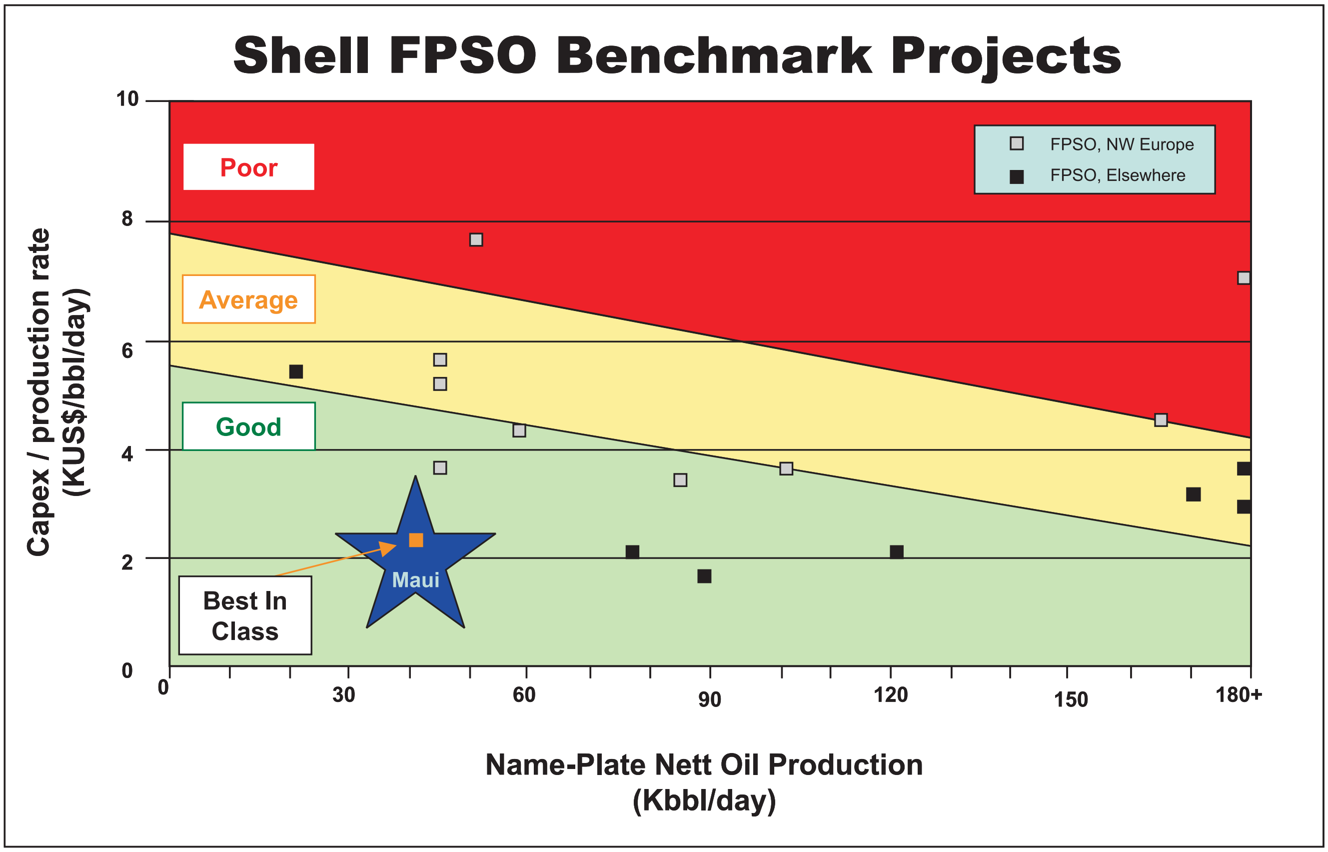
The operator of the majority of FPSO's in Australasia visited the "Whakaaropai" in 1998 to use the STOS experience as a basis for one of their new projects.

Benchmarking

The figure overleaf illustrates the results of a comparative review of the performance of 17 FPSO projects from within the Shell Group. At US$2/bbl/day, the Maui oil project is more than twice and in one case four times as productive other comparative small volume projects in the database.

It identifies the Maui Oil project as clearly "best in class".

The project has been held up as a groundbreaking approach to developing and operating small volume oil. FPSO operators from both within and outside the Shell Group have taken time out to meet visit and discuss the approaches, techniques and lessons learned by STOS.



Operational Performance

Reservoir

Early production was exclusively from the F Sand reservoir, the deepest of the Maui Reservoirs. Subsequently, two wells were completed into the oil column in the Maui B 'D' sands reservoir, increasing P_{50} reserves estimates from 22 MMBO to 25 MMBO.

The additional volumes from the 'D' sands and good 'F' sands performance are expected to realise total recovered oil volumes of around 29 MMBO over the project life.

Facilities

Facilities performance has been largely consistent with design expectations. Early problems with the compression systems [mainly commissioning type problems] resulted in some production interruption, but these were addressed in the first year of production following which the facilities performed as required.

Key issues in the production performance were related to the marine performance of the FPSO and the consequence for the oil and gas treatment process. This process was designed for 7° pitch and roll and while the design criteria for pitch was close to actual experience, the roll experienced was more than three times design criteria [in the worst case 22°]. Reassessment of environmental conditions concluded a likely worst-case event could trigger a 28° roll, still much less than instability condition. The greater than expected susceptibility to roll forced modifications to the process control systems. Specifically, a number of level controls

SYSTEM	DESIGN
Crude Oil Process	Achieved 37,700stb/day 41,000 stb/day at peak
Low Pressure Gas Compression	11 MMCF/day
High Pressure Gas Compression	24.5 MMCF/day
Flare and KO Vessels	LP Flare – 24 MMCF/day
	HP Flare – 34 MMCF/day
Cargo Offloading System	27,000 bbl per hour.
Deck Crane	15 Tonnes, 15 m boom.
Auxiliary Boilers	28000 Kgs steam per hour per boiler firing with fuel gas.
Steam Turbo Alternators	900 kW each

were replaced with high integrity / short time delay instruments to overcome the transient surge problem.

Maintenance

The requirement for the vessel to be on location for up to ten years resulted in the imposition of very stringent Certifying Authority requirements and thus a very full maintenance programme. This was made all the more challenging by the fact that the project could not bear the cost of even a single dry-dock and so all inspection and maintenance had to be carried out in situ.

Additionally the sheer scale of the facility was breathtaking.

The storage volume of 200,000 m^3 (1.2 MMB) is equivalent to 50 of Maui's onshore condensate storage tanks at Oaonui. The size of the tanks is such that the STOS New Plymouth Head office eight-storey tower block is swallowed up by just one of those tanks. The plate area alone [i.e. excluding stiffeners and beams etc] is sufficient to cover 14 rugby fields and their inspection required 22,000 thickness determination points. Each of the 72 hull penetrations [only one was above the water line] and the 11 sea chests required thorough inspection/repair at various stages during the life of the facility.

All of this combined to present major challenges for the operations team. Necessity was very much the 'mother of invention', and was always underpinned by a huge commitment from and ownership by the operations and maintenance teams.

Each of the multiplicity of problems was successfully addressed. Sea chests were inspected and in some cases replaced, tanks the size of cathedrals were repaired and in cases partially recoated, seawater piping and valves that were open to the sea were successfully repaired / replaced, decks, vessels and pipework were recoated ("zincing the limit"), all while the facility remained operational.

The outcome of the maintenance programme is that the FPSO is now in a considerably improved condition from start-up!

Environmental and Safety Performance

The FPSO operation achieved five years without a lost time incident, a record only recently blemished by two incidents involving a sprained ankle and a bruised leg.

Similarly almost 100 product transfers between the FPSO and tanker ships have been achieved without incident, with the only environmental mishap to occur thus far, being the accidental release to the environment of one cubic metre of crude oil.

Without diminishing in any way the seriousness of any of those events and at the risk of inviting fate to call the lie to these achievements, the performance has been quite a remarkable testament to careful planning, judicious execution, and a total commitment to operational excellence in a very challenging operating environment.

Lessons Learned

The overall outcome is satisfying in that it delivered a project that has realised economic returns in excess of the investment assumptions.

The following are some of the main lessons learned:

- A clear understanding was achieved in the project team of the critical factors and a deliberate and generally good quality decision-making process led to establishing the source of expertise and the appropriate controls.
- The scope of and latitude for performance by various participants [advisers, contractors and sub-contractors, and within STOS] was targeted and clear. Thereby response to upsets was focussed and well targeted. A key driver was a STOS project team of only 15, which forced a "results-effective" use of resources and largely eliminated non-value adding interfaces. This also helped in the fast implementation schedule and reduced its "invisible cost burden" to the project.
- The buy in to the project life cycle objectives by key contributors [Petroleum Engineering, Projects and Operations] was excellent. Whilst the "check and balances" of different prime interests was maintained, it was tested against a shared life cycle objective. The main benefits were a focus on finding the optimum solution rather than preserving the functional positions and, during commissioning an excellent understanding of the facility by Operating staff and a strong motivation for a successful start-up. A "problem-solving" environment was created by a contractor interface that recognised contractual responsibility during commissioning but without either party feeling commercially threatened.
- The emphasis on decision-making based on its quality of thinking, its results orientation, and its appropriateness to managing the risks dominated the "comfort of compliance" approach. This culture was key to encouraging a performance where norms were challenged but with a high sense of responsibility for the ownership and accountability of the alternative.
- A focus on key success factors produced excellent results in many areas, a particularly satisfying one being a Singapore shipyard LTIF of 2.9 on the project compared to the shipyards average of 13. The offshore work at location was completed without an accident.

On a "bottom line assessment" the project is a success in that it set new cost and schedule milestones in the Shell Group, and in the industry. Importantly, in demonstrating the viability of small oil accumulations, it provides the confidence that such opportunities can be commercially attractive. It provides the assurance that an enterprising approach can be recognised based on overall results and helps erode the comfort of rewarding status quo or compliance irrespective of results.

Appendix 1 – Glossary

ABS	American Bureau of Shipping
BI	Budget Item
CA	Certifying Authority
CTR	Cost Time Resource (sheet)
DES	Drilling Equipment Set
dwt	Dead Weight Tonne
EDP	Emergency Depressurisation
EPC	Engineer, Procure Construct (contract)
EPIC	Engineer, Procure, Construct, Install & Commission (contract)
ESD	Emergency Shutdown
FEGL	Fitzroy Engineering Group Limited
FPSO	Floating, Production, Storage & Offloading vessel
FPT	Fore Peak Tank
FWJV	Fitzroy Worley Joint Venture
FX	Foreign Exchange
GWL	Global Worley Limited
HUC	Hook-Up & Commissioning
JV	Joint Venture
LAT	Lowest Astronomical Tide
MOFP	Maui Oil Facilities Project
MPA	Maui Platform A
MPB	Maui Platform B
NDT	Non Destructive Testing
NPV	Net Present Value
OpCo	Operating Company
PVDF	Polyvinyldenefluoride (Coflon)
QRA	Quantitative Risk Assessment
ROE	Rate of Exchange
RT	Real Terms
SHEMS	Shell Export Materials Services
SIEP	Shell International Exploration & Production
STOIIP	Stock Tank Oil Initially In Place
STOS	Shell Todd Oil Services Limited
TSS	Turret Support Structure

Appendix 2 – List of Main Contractors

Maui Joint Venture Participants	Shell Petroleum Mining, Todd Energy, and OMV
Operator	Shell Todd Oil Services Ltd
Major Contractor	MODEC
Shipyard Contractor	Keppel
Process Equipment	Natco
Flexible Risers	COFLEXIP
Turret Contract	SOFEC
Maui B Modifications	Fitzroy-Worley Ltd

Appendix 3 – Project Dimensions

Cost Data

The total FPSO project cost was originally estimated at NZ$200MM and the project was completed under budget. Actual costs were as follows: -

FPSO Capex	US $ 99,894,000
Maui B Capex	NZ $ 39,500,000
Opex	NZ$15-18 Million pa

Technical Data

Reserves (recoverable)	22 MM bbls (mid range)
Operating Life	5 to 7 years
Process oil capacity	30,000 bbl/d
Export gas capacity	24.5 MMCF/d
Produced water capacity	18,000 B/d
Maximum storage capacity	95,960 mt of cargo
Maximum offload parcel	84,320 mt of cargo

Oil Characteristics

Pour point	18-21 ^{o}C
Cloud point	42-45 ^{o}C
Storage temp	45 ^{o}C
TVP	100kPa @ 45 ^{o}C
Asphaltene	1.7% by wt

Process Equipment

2 stage separation

Thermal and electrostatic dehydration

L P gas compression 2 x 50%

H P gas compression 1 x 100%

Produced water treatment via flash tanks to <40 ppm

HP and LP flares with knock out drums

Chemical injection

Met-Ocean Data

Water depth	110m (LAT)
Design storm condition	100 yr.
Significant wave height (Hs)	10.7m
Maximum wind-3 min gust	45.3m/s
Maximum surface current	1.15m/s
Offloading conditions (max.)	
Significant wave height (Hs)	3.5m
Current at surface	0.4m/s
One minute sustained wind	29m/s
Mooring centre from MPB platform	1.3km
Mooring	10 No. chain/wire mooring lines connected to drag embedment anchors
Flow lines [flexible]	10.5" oil line, multiple layer Polyvinyldenefluoride (PVDF) Coflon construction
	4.5" gas return line, Rilsan construction
Vessel Dimensions	

FPSO On its Delivery Voyage

FPSO Installed and on location and Maui B

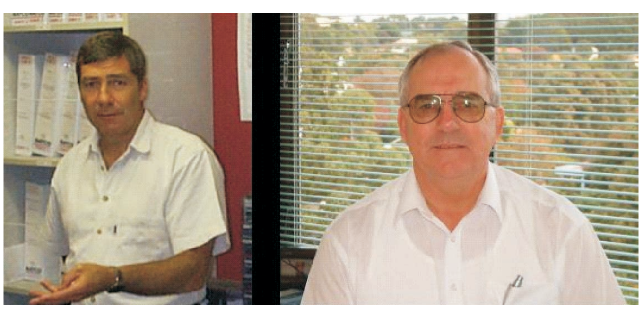
“Whakaaropai” - The Blessing [November 1996]

Tanker Loading Operations

FPSO in Production

Dr David Kirk MBE
Chairman of Maui Development Ltd [1996] at FPSO Opening

Chris Beath and Mahdi Hasan
Two previous GMs of STOS



Des Horton [FPSO Asset Holder] and
Ian Browning [Maui Asset Manager]