Society of Petroleum Engineers

SPE 28765

Gaslift Operations in Bass Strait

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This paper was prepared for presentation at the SPE Asia Pacific Oil & Gas Conference held in Melbourne, Australia, 7-10 November 1994.

ABSTRACT

Gaslift is of high importance to Esso Australia's Bass Strait operation, with 65% of oil production being gaslifted, an average of 198 kbd for 1993. As water cut increased in recent years, the importance of gaslift to crude production was recognised, hence a co-ordinated effort to improve the gaslift operation was embarked upon, including the following elements:

- A quality assurance program was commenced which has resulted in more reliable downhole gaslift installations.
- Inventory, valve testing and setting, and tracking valve histories have been established - all important in achieving quality gaslift installations.
- Improvements were made in gaslift optimisation through computer modelling, gaslift metering, well control and problem diagnosis to increase production within platform facility limitations.
- Development of a gaslift design method which is easy to understand and has provided reliable and efficient gaslift designs, including optimal injection depths and successful dual gaslift wells.
- Comprehensive operator training.

The combination of these elements into a co-ordinated gaslift improvement program has been successful at EAL and can serve as a model for other operations to achieve a high level of gaslift performance.

References and illustrations at end of paper.

INTRODUCTION

Esso / BHP Petroleum currently produces around 280,000 bbl/d (45 Ml/d) from Bass Strait, situated offshore of South-East Australia, with 14 platforms, 2 mono-towers and 2 sub-sea completions. Figure 1 shows the existing Bass Strait production facilities operated by Esso Australia .

Oil production began in 1969 but it wasn't until the early '80s that water was produced in significant quantities (Figure 2). Since that time there has been a steep increase in water production such that currently more than 60% of total fluid produced is water. In order to mitigate oil production decline due to increased water cut, gaslift facilities have been progressively installed. Gaslifted wells account for:

- 65% of current oil production
- 75% of a total 150 active completions

The dependence of future Bass Strait production on gaslift was recognised, and in 1990, a program was instigated to optimise gaslifted production through improving quality assurance and enhancing design standards and practice.

Evaluation of Esso's gaslift operation identified key areas with potential improvement:

- gaslift valve supply and preparation to improve reliability
- metering and testing facilities to measure gaslifted well performance
- gaslift design method to provide consistent and efficient well completions
- field optimisation

Esso initiated an improvement program with the following results :

- a seven-fold reduction in the production downtime due to gaslift problems equating to more than 300,000 bbl (48 Ml) increased production per year (Figure 3).
- an average of 5800 bbl/d (920 kl/d) oil production increase due to more efficient gaslift designs
- an average 3% production increase due to gaslift optimisation

QUALITY ASSURANCE PROGRAM

Optimisation begins at the workshop level - a high standard of valve preparation and refurbishment ensures quality for the gaslift installations in each well. Confidence in the gaslift equipment allows for a higher degree of optimisation and makes trouble-shooting easier.

Quality of valve supply had been a concern with valves not set correctly, incorrect orifice sizes installed, 'modified' valves created from leftovers of other valves and little consistency of refurbishment. These concerns were addressed in a Quality Improvement Team consisting of Esso personnel and service company representatives. The service company upgraded the workshop facilities to API standards and appointed a specialist gaslift technician to refurbish, set valves and administer valve ordering and movements. A gaslift specialist worked with Esso for six months to lend his experience and advise on what was required for a gaslift workshop and develop an Esso standard for the setting and testing of valves.

A contractual agreement incorporating these standards and a re-worked pricing schedule for repair and testing of valves provided the incentive for the service company to improve the cost control and quality in the gaslift workshop.

The workshop is regularly audited by Esso against a set of standards and procedures which are being continually enhanced and refined to reflect changes in the business.

The success of the improvement in valve quality has been due to the close working relationship between Esso and the service company, with both actively exchanging ideas to achieve the one goal.

VALVE INVENTORY AND TRACKING

Establishment of an inventory needs to balance the requirements of having valves ready at short notice, minimising shelf stock and accounting for the number of used valves which are refurbished back into service.

All ordering of new valves and instructions to prepare valves for forthcoming work is controlled by the Esso gaslift technician based on a review of wireline and workover requests and through tracking valve movements on a computer database. Valves are identified in the database via a unique identifying code which incorporates the valve type, valve size and a sequential number. There are more than 1200 valves either downhole, on the shelf or in transit which are tracked by the database.

An essential part of this tracking process is the receipt of movement reports in/out of the gaslift workshop and in/out of wells. The valves are physically tagged with the well from which they are pulled or to which they are to be installed. Wireline/workover personnel record the serial number, mandrel number, success of installation, wireline tool string used and valve condition and then store the information in the valve tracking database. Based on this data, reports are easily generated to show which valves are installed downhole, which valves are in stock and the history of a particular valve.

The database has also allowed a study of valve performance to be made by trending the modes of failure to identify design problems which has been passed on to the valve manufacturer to be addressed in new designs.

The typical number of valves handled during a month is in excess of 100. This number includes valves actually run, valves prepared as backups in case of miss-run, valves pulled and repaired and valve condition reports. An average of 14 wells per month require valves for changeouts and new completions. The valve changeouts include jobs for rate enhancement, mechanical repair and routine reservoir surveillance.

METERING

The accuracy and consistency of metering is very important to be able to optimise gaslift usage. Facilities on Bass Strait platforms were installed prior to the development of high water cuts. Field production rates have also been a lot higher than forecast so the facilities were often inadequate to meter and control gaslift. As part of the program to improve gaslift efficiency a study of facilities identified upgrades required. Ideal metering cannot always be economically justified, but through understanding the limitations and making minor improvements the existing metering can be used to obtain reasonable conclusions on well performance.

Measurement of the amount of gas injected is critical to optimising a well's gaslifted performance. Control by setting a choke is often not accurate enough especially when compressor facilities are fully utilised. Orifice plate meters had previously been used on some installations to measure gaslift injection rates but proved unreliable due to problems with liquid drop out and the need for regular maintenance.

One inch vortex meters have been identified as the most accurate method to measure injection gas in Bass Strait. The vortex meters are less vulnerable to liquid drop-out, require low maintenance and are easy to install in existing meter runs. Two inch vortex meters had previously been trialled but proved too large to consistently report the gaslift injection rates. There are now six platforms which have vortex meters successfully installed and further platform installations have been justified. The vortex meters together with control valves and trending facilities can measure and monitor the injected gaslift rates to ensure the optimum is maintained.

Test separators provide the means of measuring well performance versus gaslift rate and need to be calibrated so that a test is a true representation of performance. Well test results are used to tune a well for optimum performance and are the basis for well computer models. Replacement of inadequately sized test separators is uneconomic so other solutions to provide meaningful tests have had to be found. By making valving changes and installing booster pumps the problems of high differentials between test and production systems has been partially alleviated, allowing improved well testing to be achieved.

COMPUTER MODELLING

Modelling of wells is important to enable analysis of changes in behaviour as water cut increases, separator pressures change and the field is depleted. Unless well behaviour can be accurately modelled many well tests and surveys would have to be performed incurring significant production losses. Modelling is also essential for the accurate forecasting of future field performance.

Since 1991 Esso has been successfully using an Exxon developed proprietary computer simulation program to model tubing hydraulics as input to gaslift designs, completion design and forecasting. This program models a flowing oil or gas well, an artificially lifted oil well or an injection well and and runs on standalone personal computers. The system components that can be modelled are: reservoir, completion interval, well bore pipe segments, gaslift valves, flowlines and chokes. By linking a series of these components together, well flow from reservoir to delivery point can be accurately modelled. A "node" is defined for each component connection point where pressure and temperature are computed.

Flowing gradient surveys are used, if available, to build the well simulation model and match pressure losses using one of the published multi-phase flow correlations. Models have been able to be match the measured pressures and temperatures within +/- 5%. The best correlations for Bass Strait oil wells have been found to be Moreland-Mobil-Shell Method and Hagedorn-Brown. For high angle wells it was found that when a well segment is greater than 60 degrees inclination from the vertical then the Beggs and Brill horizontal flow correlation best matches well behaviour. Enough flowing gradients have been analysed to allow confidence in well modelling where the surveys are unavailable. Esso has now developed simulation models for all wells in Bass Strait.

Diagnosis of well slugging problems can also be enhanced through the use of the computer simulation program. Several wells with slugging behaviour, through low productivity and a large tubing size, have been modelled and solutions identified. This has been critical in the decision to do workovers on some marginal well completions by using small diameter tubing inside existing large tubing.

For use in gaslift optimisation the simulation models need to be calibrated against a "four point" well test. This test is performed for each well to measure the change in flow rate as gaslift rate increases. Typically wells have a rapid increase as gaslift is introduced and eventually reach a point where increase in gaslift has no appreciable effect on oil rate (Figure 4). Working with field personnel on these tests allows definition of the stable flow range for each well and the operational considerations to define optimal gaslift injection rates. The degree of match of these well tests versus the simulation model behaviour gives results within +/- 10%.

The decision to retest the well needs to balance operational considerations versus the confidence in the computer simulation model, hence the following guidelines have been established for re-testing:

- water cut increases by more than 10%
- six months has elapsed since last test
- a new valve design is installed
- a new tubing configuration is installed
- the well is stimulated
- major change in facilities impacts well performance

For each well on a platform a simulation model is run for a range of water cuts, gaslift injection rates and separator pressures to produce gaslifted well performance curves. These curves are input into a gaslift allocation computer program which models a platform facility with all its constraints. The available gaslift gas, water handling capacity, pump capacity and separator pressure are also input, then the model computes the optimum gaslift gas distribution to maximise oil production. The program simply takes each well performance curve and allocates gas to wells to make the oil production per unit of injected gaslift gas equal, i.e. the operating point on each curve has the same slope.

The results output from the model have been used successfully on four platforms so far to identify the best allocation of gaslift gas to optimise production. These computer models have been installed on PCs on many Bass Strait platforms. As the facility limitations vary from day to day the computer model can be re-run by operations personnel to determine the best allocation of gaslift gas.

The key to success with these models is to give control to operations personnel so that the optimisation process is on-going and updated in response to daily operations. Without this involvement the optimisation process will only be effective for each "snap-shot" of time when a full optimisation is performed by engineering staff, and will only be optimum until the next change in conditions (Figure 5).

DESIGN METHOD

The design of gaslift mandrel depths and valves had been inconsistent over the years prior to the gaslift improvement program. In the late '60s there was uncertainty as to the effectiveness of gaslift in 5-1/2" tubing thus early mandrel designs specified only one location. This design was simply based on an unloading gradient from the delivery pressure at the surface to the injection pressure at depth. More gaslift experience showed the advantages of multiple mandrel locations and the use of side pocket mandrels but design became more complicated. Since the time of the early multiple mandrel designs, conditions have changed leaving many of the original mandrel placements inappropriate. Figure 6 shows an early design with only one mandrel location, Figure 7 shows a later design with side pocket mandrels but some of which are unusable and Figure 8 shows an optimum mandrel placement with a minimum of mandrels but the ability to achieve efficient gaslift.

Esso had previously organised gaslift design courses but these were found to be complicated and much of the material not applicable. What was needed was a simple consistent design method which gave the designer a good feel for what was happening as the well began to gaslift. The gaslift specialist seconded from Exxon USA in 1991 provided valuable guidance for the design process.

The resultant method uses manual graph techniques on plots of tubing pressure versus depth given delivery and injection pressures. The tubing pressure gradients are calculated by the computer simulation model for a range of sensitivities, for example water cut and reservoir pressure. They are then plotted on the one graph and with some construction lines for unloading gradients a set of mandrel depths and valves can be designed to operate the well efficiently for the range of sensitivities. The graphical method is simple to follow and allows the designer to review designs quickly and spot anomalies in the design which make it impractical, for example mandrels spaced too close and not enough differential pressure across installed valves.

Application of this method, including refinements to adapt it specifically to Bass Strait conditions has resulted in reliable designs and a revisit of most wells in Bass Strait to install the most efficient gaslift valves.

An example of a typical Bass Strait gaslift mandrel design for a well producing 9100 bbl/d (1440 kl/d) of total fluid at 50% water cut and a gaslift rate of 1.25 Mmscf/d (35 km3/d) is as follows (Figure 8):

Three 4.5 inch side pocket mandrels with 1 inch pockets set at :

Mandrel 1 - 2500 ftTVDKB (760 mTVDKB)
Mandrel 2 - 3550 ftTVDKB (1080 mTVDKB)
Mandrel 3 - 4050 ftTVDKB (1230 mTVDKB)

Using the computer simulation model to analyse the well flow rate and comparing injecting at mandrel 1 with mandrel 2 shows that there is a 190 bbl/d (30 kl/d) oil rate benefit from injecting in mandrel 2 with the same injected gas rate, so the following optimal gaslift valve design is installed:

Mandrel 1 - 1 inch nitrogen charged unloading valve with 12/64 inch port and test rack opening pressure of 1200 psig (8300 kPa).
Mandrel 2 - 1 inch orifice valve with 20/64 inch port
Mandrel 3 - 1 inch dummy valve.

Injecting at mandrel 3 is not possible with the current water cut because there is not enough differential between casing and tubing to pass the required gaslift rate. This mandrel location will be able to be used later in the well's life as the water cut increases thus lowering the tubing pressure which allows enough differential to inject gas.

DUAL GASLIFT

The philosophy of going back to simple design methods has been used for successful gaslifting of common annulus dual strings. The problem with dual gaslift is how to control the gaslift to each string given the different flow characteristics and hence gaslift requirements. A search of published papers found many theoretical discussions on dual gaslift with complicated procedures to determine valve set pressures but there was little guide as to how reliable dual gaslift installation had been achieved in practice. Esso took a step back to basics and was able to install dual gaslift on several wells which has been highly successful.

Well 1

The well contains two 3-1/2 inch tubing strings each with two side pocket mandrels with 1.5 inch pockets at depths of 3120 and 4265 ftTVDKB (950 and 1350 mTVDKB) (Figure 9). The short string produces 1890 bbl/d (300 kl/d) of total fluid at 90% water cut and the long string produces 3775 bbl/d (600 kl/d) of total fluid at 50% water cut. Based on simulation model analysis the optimum gaslift rate for the short string is approximately 0.9 Mmscf/d (25 km3/d) whereas the optimum gaslift rate for the long string is approximately 0.35 Mmscf/d (10 km3/d). By simply installing a circulating valve with a different orifice size in each string at 3120 ftTVDKB (950 mTVDKB) - 16/64 inch orifice in the short string and 10/64 inch orifice in the long string - the short string receives 3 times the gas injected into the long string. This well flowed under dual gaslift for six months prior to a mechanical failure in the long string.

Well 2

The well contains two 3-1/2 inch tubing strings with two sidepocket mandrels with 1 inch pockets at depths of 3445 and 4265 ftTVDKB (1050 and 1300 mTVDKB) (Figure 10). The short string produces 1570 bbl/d (250 kl/d) of total fluid at 0% water cut and the long string produces 1890 bbl/d (300 kl/d) of total fluid at 75% water cut. The long string requires a constant gaslift rate of 0.7 Mmscf/d (20 km3/d) whereas the short string requires gaslift for well unloading only. The solution is to install an unloading valve at 3445 ftTVDKB (1050 mTVDKB) in the short string which has an opening pressure greater than the normal operating injection pressure required to inject into the long string. The long string is installed with a circulating valve with a 12/64 inch orifice at 3445 ftTVDKB (1050 mTVDKB). Thus both strings were able to be unloaded at start up and then the injection pressure dropped so that the unloading valve closes and gas continues to be injected into the long string only. It is expected that at high water cuts the well will require a similar valve installation to that described above in Well 1.

GASLIFT TRAINING

In order for gaslift optimisation to be fully successful, operations staff need to understand gaslift principles and the methods to keep the wells optimised on a day to day basis. Operations know the most about the facilities and wells so that when a change occurs the response can be immediate to re-optimise under the new conditions rather than wait for an expert to visit the field to re-optimise. The secret is to empower the operations staff to optimise production on an as needed basis to maintain the optimum level.

Education of operations staff in gaslift principles specifically for Bass Strait conditions is the most effective training. Prior courses on gaslift had been general and highly technical making little impression on the operations staff when trying to apply it to the field. The courses held in 1994 have aimed specifically at simplifying the gaslift subject and applying it to real situations in Bass Strait with the result that operations staff are enthusiastic to put into practice on their platforms what they have learned.

CONCLUSION

The dependence of the Bass Strait operation on gaslift means that efficient gaslift is critical to a continued successful operation. By improving the following key areas:

- Quality of valve supply
- Gaslift workshop for setting and testing valves
- Well modelling and optimisation
- Consistent design methodology
- Training and involvement of operations personnel

Esso has been able to build an efficient gaslift operation which can serve as a model to other organisations who are faced with a large gaslift operation.

ACKNOWLEDGEMENTS

The author wishes to thank Esso Australia Ltd.and BHP Petroleum Pty. Ltd. for permission to publish this paper and Halliburton Australia for their support in improving gaslift valve quality.

Bass Strait Production Facilities

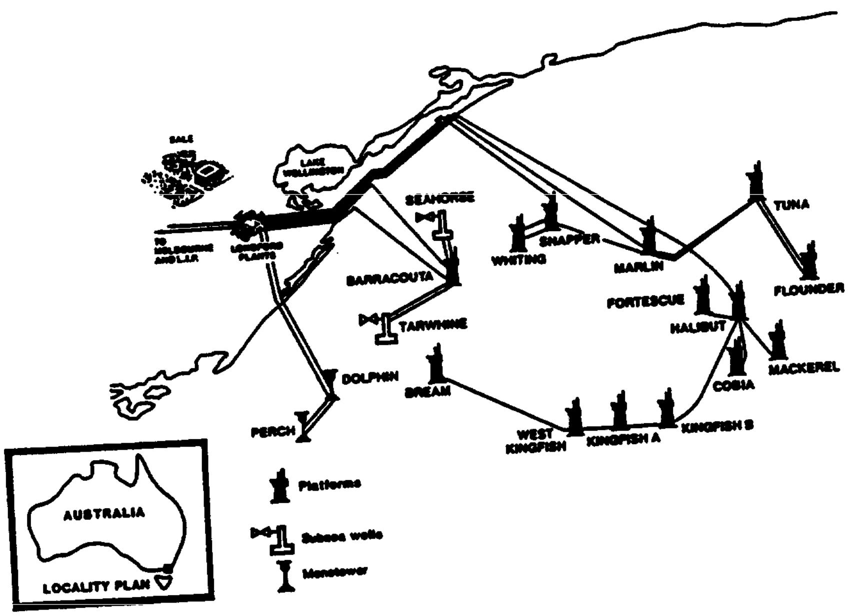


Figure 1.

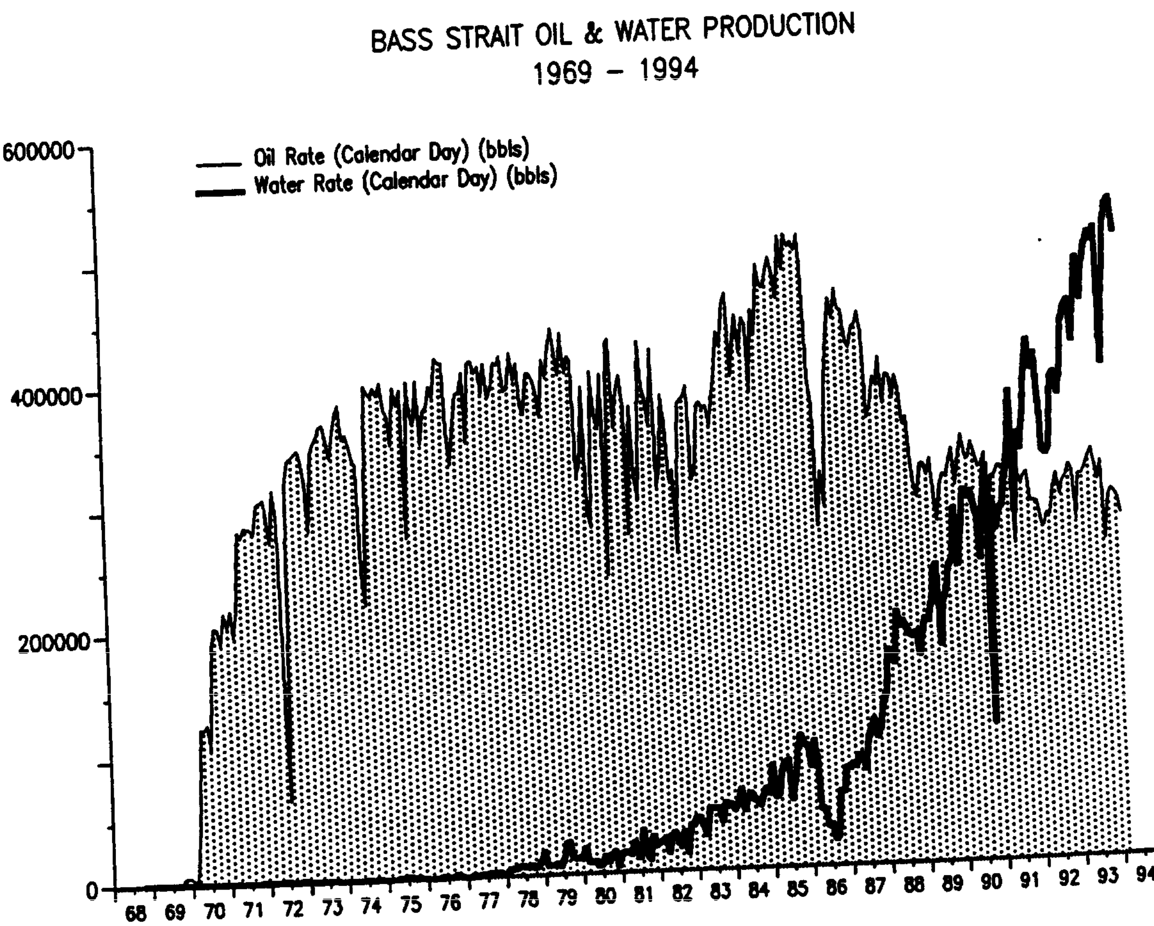


Figure 2.

Production Downtime Due to Gaslift Valve Problems

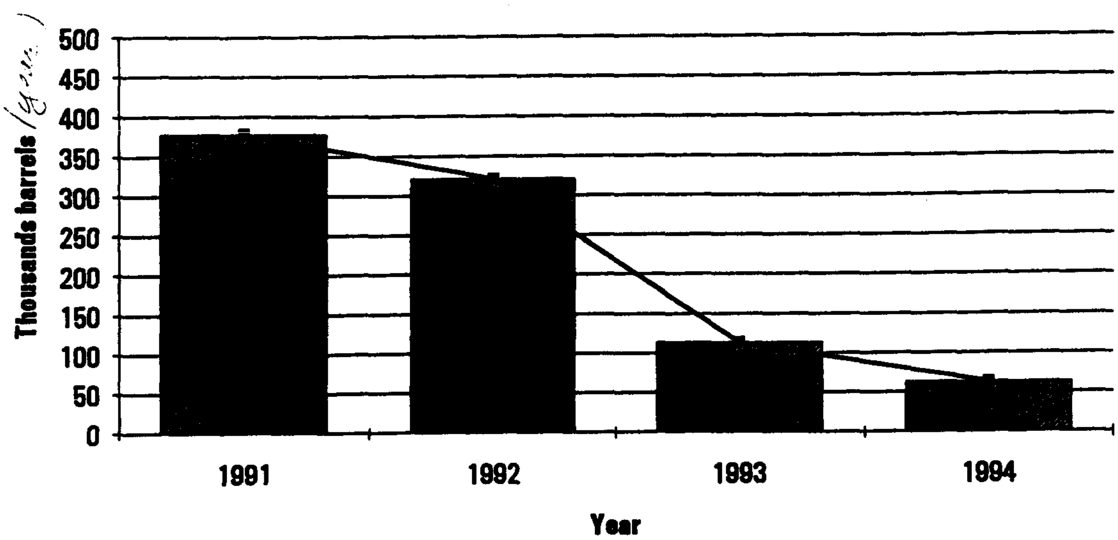
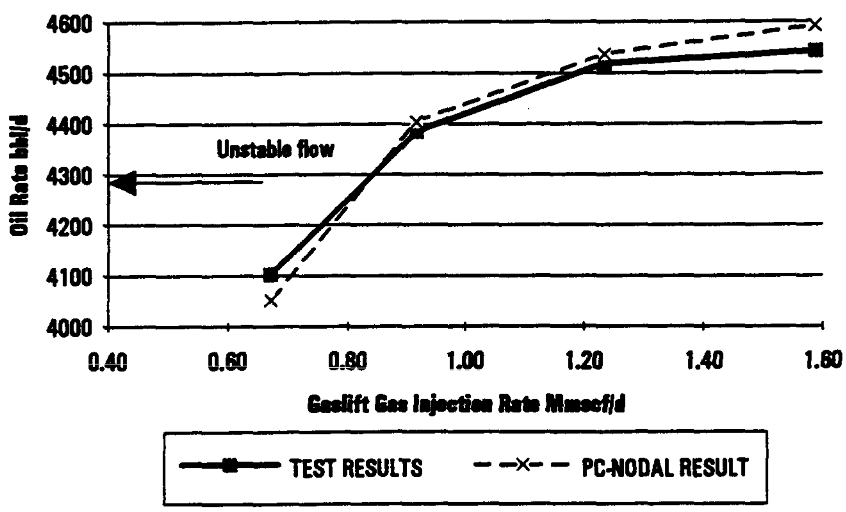


Figure 3.

BASS STRAIT WELL FOUR POINT TEST



Comparison of Test versus Computer Model

Figure 4.

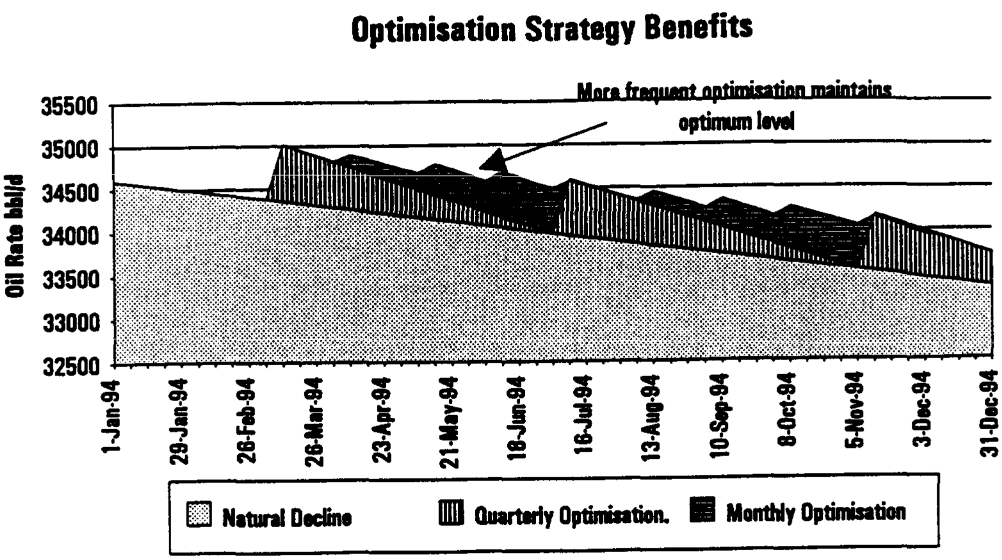
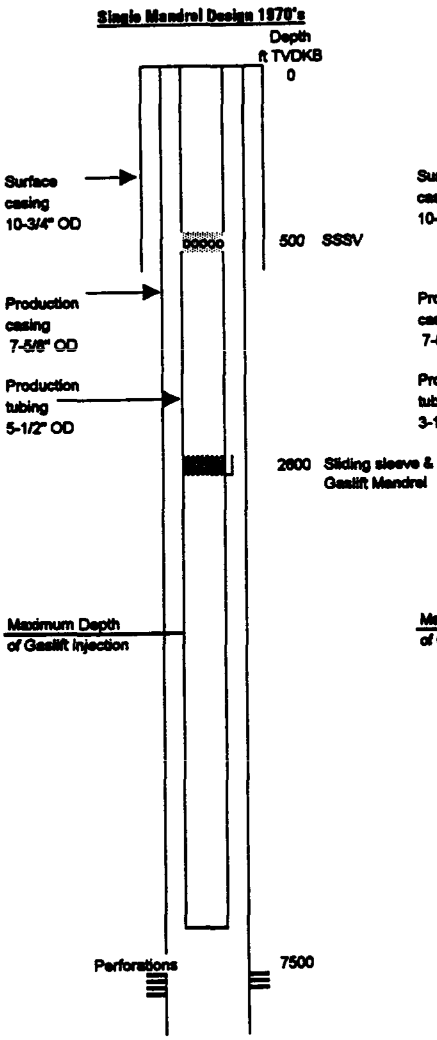


Figure 5.



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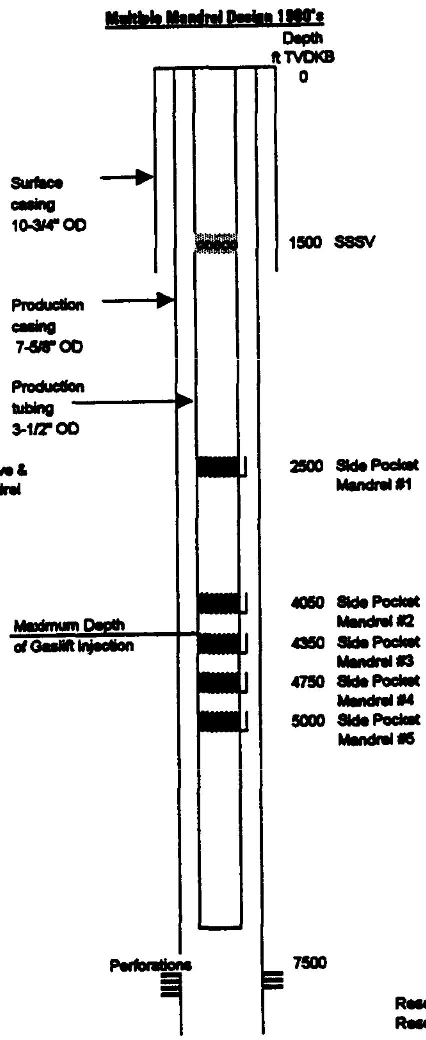

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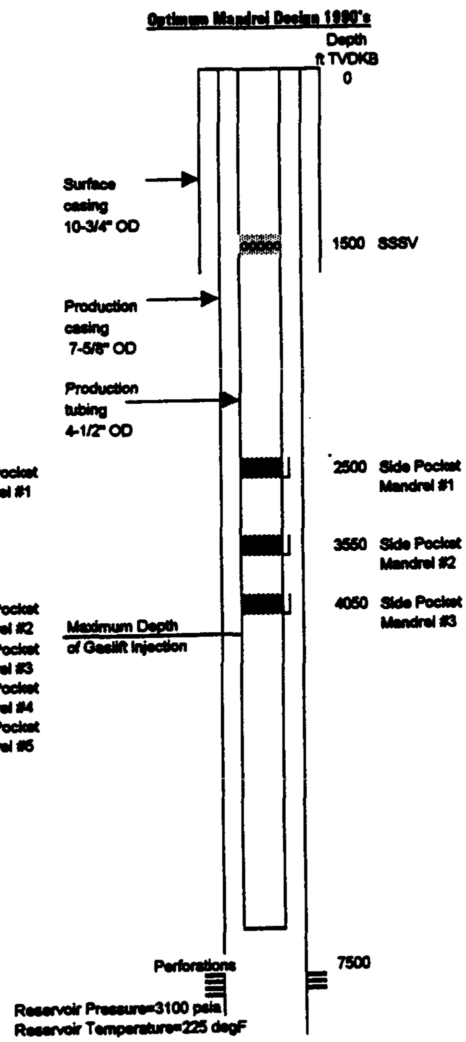

Figure 8.

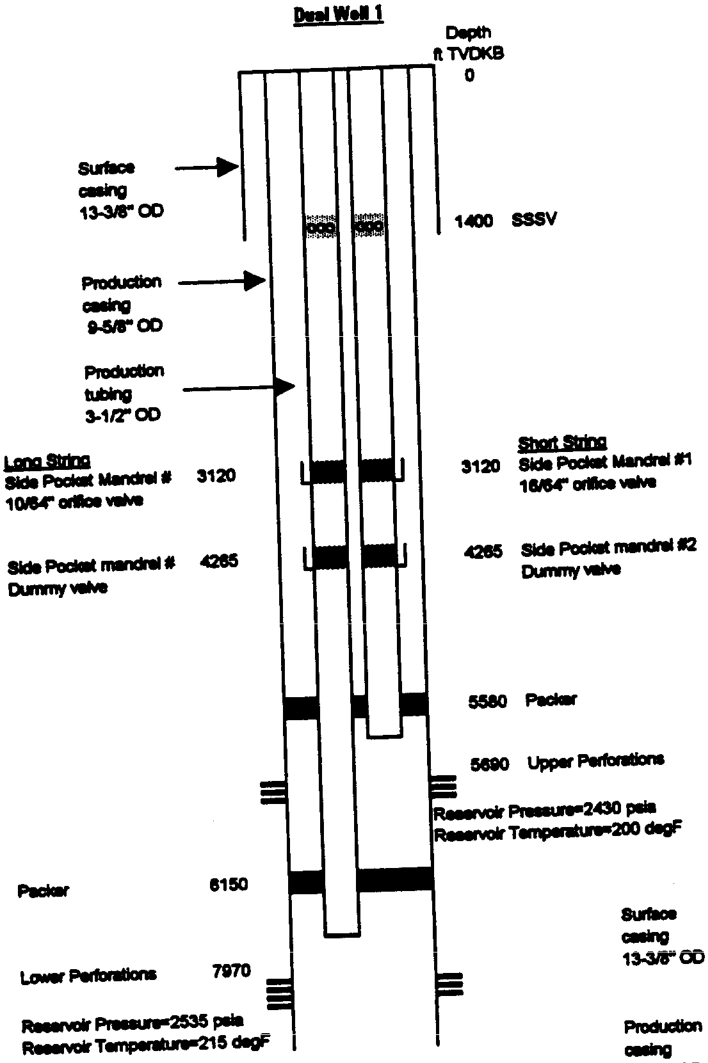

Figure 9.

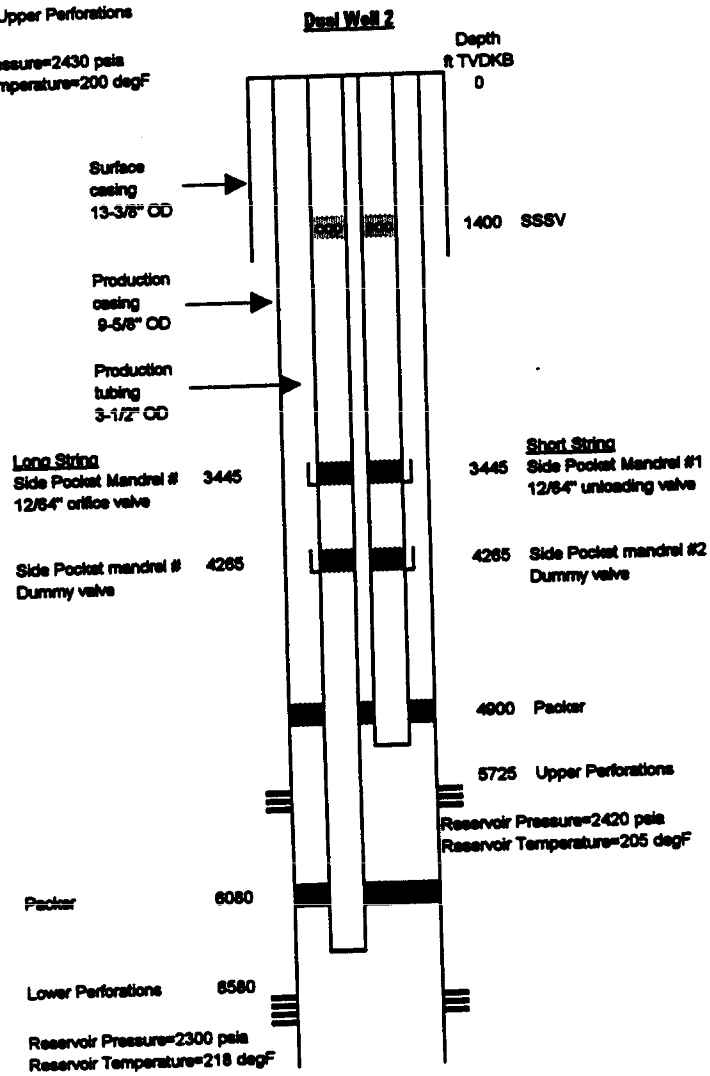

Figure 10.