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IMPLEMENTATION OF STREAM MANAGEMENT AT SOUTH NATUNA SEA BLOCK B, INDONESIA

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ABSTRACT

This paper discusses the implementation of a new methodology for conversion and management of streams for the South Natuna Sea Block B project. This project consists of multiple satellite fields, with vastly varying PVT fluid properties and transport requirements, producing to a single processing platform (Belanak FPSO). The fields are dedicated to two Gas Sales Agreements. Reservoir simulation models have been constructed, several of which include gas re-injection.

Topside / Process simulation for the design and optimization of the Floating Production Storage and Offtake vessel (FPSO) requires an *aggregated* compositional profile versus time. Process simulation uses a detailed equation-of-state (EOS) fluid model. Until now, no software or approach exists for automated generation of aggregated compositional streams from multiple reservoirs with different fluid PVT descriptions.

In this paper, software developed by PERA a/s called Petrostream Management™ (PSM) is presented, which allows consistent conversions of petroleum fluid streams from one representation to another (e.g. black oil to compositional), and aggregation of streams to a *common* time-basis for generation of total molar streams. PSM additionally allows the modeling of surface processing, forecasting of crude properties based on assays from individual wells, and optimized phase-in and production of all participating fields to fulfill contractual obligations while honoring the facility and model constraints. PSM calculations are based on post-processing of reservoir simulation results and are extremely fast and reliable. Critical conversions are performed at the grid-connection level for consistency and accuracy.

The software has proved more than adequate for the engineers requiring an integrated solution. The technology used in PSM conversions has been validated on many applications; depletion, gas injection and multiple PVT regions are easily handled. As implemented, molar rates of streams as a function of time are easily obtained for any node in the system (platform, pipeline etc.). Filtering allows extraction of molar profiles at any level of detail (well, PVT region etc.).

INTRODUCTION

The South Natuna Sea Block B (SNSBB) PSC, shown in Figure 1, contains numerous oil and gas fields from various sub-basins in greater West Natuna. In January 1999, the Natuna Sea Block A, South Natuna Sea Block B and Kakap Block partners announced the signing of a gas sales agreement (GSA-1) from the West Natuna Area to SembGas in Singapore, commencing in July 2001.

In March 2002, a separate Gas Sales Agreement (GSA-2) was signed by Pertamina and Petronas for SNSBB to deliver gas to Peninsular Malaysia over a 20 year period. First gas supply was delivered in August 2002. In order to provide gas to these two contracts, ConocoPhillips are developing fields and building infrastructure across a large area of Block B.

In the western area of SNSBB, also referred to as the "dry gas" area, several fields are already on stream

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providing gas as dedicated fields to both contracts, and other fields are in various stages of development. The gas is collected and compressed for export at the Hang Tuah facility. The gas produced from these "dry gas" fields is very lean and requires minimal processing prior to export.

In the eastern area, also referred to as the "wet gas" area, we are developing larger more complex fields comprising multiple reservoirs with a wide assortment of fluid types. The Belanak field will be the first field brought on stream, followed by several satellite fields. These fields will utilize processing, storage and export facilities at an FPSO and LPG FSO located at the Belanak Field.

Implementation of stream management has focused on the eastern area fields, which are compositionally complex and yield multiple revenue product streams. Nineteen reservoir models are used to model the various reservoir units that flow into the Belanak FPSO. The Petrostream Management (PSM) software presented in this paper is a solution to the long-standing problem of consistency and aggregation of multiple reservoir flow streams and easy transfer of petroleum fluid data from discipline to discipline.

FLOW SIMULATION MODELS

Nineteen reservoir geological models were constructed for each reservoir using Roxar/RSM™. The models were conditioned semi-deterministically with 3D seismic where possible and utilized stochastic modeling of facies and property distributions where necessary. Reservoir flow simulation using Eclipse was used extensively for each of the Belanak, Kerisi/Hiu and North Belut reservoirs. These simulations included radial-grid matching of DST tests for permeability tuning, fine-grid cross-section simulations to evaluate horizontal well placement and drawdown implications, fine-grid sectorial simulations to evaluate well type and spacing, and fullfield simulations for field production forecasts under various development options and key uncertainty sensitivities. Gas reinjection will be utilized in the Belanak (Massive and Zone 3 reservoirs) and Kerisi (Upper Gabus reservoir) fields.

Compositional modeling with Eclipse 300 has been used to validate our ability to use black-oil simulation for the majority of these studies and for input into the stream management system. Figure 2 shows PSM implementation target fields and their relationship.

PETROSTREAM MANAGEMENT TECHNOLOGY

Definitions

Data pertaining to petroleum fluids and containing quantity or amount information is defined as a *stream.* Reservoir simulators, the main subject of this paper, are used frequently to predict the production from reservoir models and can generate huge number of streams. A *characterization* is a set of *properties* that describe the character of the stream. The *name* of each component is the most important property. When dealing with hydrocarbons, molecular weight and other equation-of-state (EOS) properties can be used for stream conversions and are included as properties of the characterization.

Each stream can have some *attributes* other than the quantity data associated with it. These *variables* further qualify the stream. Black-oil simulators typically deal with two components in the form of volumes of surface oil and surface gas. A compositional simulator typically deals with 5-8 components and generates mass or molar amounts of the wellstream. Typical variables associated with these streams are the well name, pressure, region, group etc.

Stream Conversion

A stream conversion is the calculation of the quantities of the components of the stream in a different characterization. Figure 3 depicts the conversion matrix used in PSM. A source stream contains quantities of each component comprising the corresponding characterization. These are depicted as u_j with j ranging from 1 to *m.* This implies that we have *m* components in the original (input) stream. Similarly we have *n* components in the converted (output) stream with the quantity of each component being v_i. *m* may be less than, equal to, or grater than *n*. To effect the conversion, the value of each v_i needs to be computed. To do this we need to specify the portions of each j^{th} input component that partitions into the i^{th} output component. This portion is called the Split Factor S_{ij}.

BOz Conversion

The BOz conversion is the single most important conversion technique incorporated into PSM. The

black-oil to compositional (BOz) conversion method is essentially a recombination of the reservoir oil and reservoir gas compositions into a wellstream composition. This is similar to the recombination frequently performed on phase compositions from a well test to obtain the wellstream composition using Eq. (1).

$$z_i = \beta y_i + (1-\beta)x_i \qquad (1)$$

In a well test the test separator GOR uniquely defines the vapor mole fraction ß needed for the recombination. But for the phases flowing in the reservoir it is not easy to estimate this fraction. The only measure of its value we have are the surface volume fractions R_P, R_s, and r_s. Whitson and Brule (2000) have detailed the development of this fraction, which they denote F_g. It is essentially the mole fraction of the wellstream that comes from reservoir gas ($n_g/(n_g+n_o)$) and is only a function of PVT properties of the fluids, which are in turn only a function of the pressure. Knowing the pressure, these properties are available, and this fraction can be computed. Knowing the fraction and the phase compositions, the wellstream composition can be calculated.

In general any two mixtures can be recombined using Eq. 1. If mixture A (with composition z_A) has a surface OGR of r_A and mixture B (with composition z_B) has a surface OGR of r_B, then the BOz method provides the total composition z of any mixture with r_A = OGR = r_B. For depletion cases, a mixture of reservoir oil and reservoir gas is assumed to flow with producing OGR of $1/R_P$ where $r_s = 1/R_P = 1/R_s$. For gas injection cases, it is assumed that the flowing stream is a mixture of the reservoir gas and the injection gas with $0 = 1/R_P = r_s$.

The extended PVT data (standard BO-PVT properties, molar density and compositions) needed to obtain the ß fraction for re-combination is generated when a PVT modeling program generates the black-oil PVT table. When the black-oil PVT table is generated a "depletion-type" experiment is simulated – e.g. constant composition expansion (CCE), differential liberation test (DLE), or constant volume depletion test (CVD). The black-oil PVT table contains a number of saturated PVT data and, usually, some undersaturated data. The "extended" black-oil information uses only data from the saturated conditions during the depletion experiment. The format for this extended information is detailed by Hoda (2001 and 2002).

PSM uses this information to generate a standard PSM/Streamz™ split factor (conversion) table. This specifies, for nodal values of control variables (e.g. pressure), the split factors that each component of the input stream (i.e. q_o and q_g) uses to obtain moles of that output component. The step-by-step BOz conversion procedure is replaced by the Split Factor Matrix multiplication implementation. As an example, for a particular output component *i*, the moles m_i of that component is given by Eq. (2)

$$m_i = q_o S_{oi} + q_g S_{gi} \qquad (2)$$

In Eq. (2), q_o and q_g are the input black-oil streams, and S_{oi} and S_{gi} are the split factors for component *i*. A set of such conversion factors is generated for each depletion stage pressure used in the BO-PVT table. Once generated, it can be used to convert all black-oil streams originating from simulation that uses the corresponding BO-PVT table.

In the case of gas injection an additional set of conversion tables is generated for a mixture of reservoir gas and *injection gas*. PSM/Streamz then uses this set of conversion factors to convert any black-oil stream with values of q_o and q_g and an associated pressure.

One example, out of many on which the BOz method has been tested and used, is presented in Figure 4. This is from a North Belut radial reservoir (radius = 3000 ft) case. It is a 5 layers (4 gas bearing, one oil bearing) synthetic model with fluids from the North Belut reservoir. A depletion case has been simulated with 5 Black-oil PVT regions representing the 5 fluids. The symbols represent results from the Eclipse 300 compositional reservoir simulator. The lines are results from a corresponding Eclipse 100 Black-Oil simulator to which the BOz method was applied to obtain component molar rates. Results for C_1, CO_2 and lumped components C_3C_4 and C_{5+} are shown. The agreement is excellent.

z-to-z Conversion

Due to computational limitations, compositional reservoir simulation is performed with the minimum

possible component description (usually 5-8). Conversion to a more detailed characterization (15 or more components) is required for process calculations. Usually, the C_{6-} components are de-lumped using multi-dependent split factors. The exact procedure for obtaining the dependencies varies, and is usually specific to the particular case. The C_{7+} components are readily converted using the generalized Gamma Distribution.

The Gamma Distribution is a probability density function that has been shown by Whitson (1982, 1983, 1984) and Whitson et al. (1989) to model the molar distribution of petroleum fractions very well. Heptanes plus fractions of petroleum fluids are usually characterized by breaking them down into a manageable number of pseudo-components. Each such pseudo-component is given an average molecular weight and an amount. This is called its molar distribution as shown in Figure 5 at left.

This discrete molar distribution can also be described by a continuous function as shown on the right in Figure 5. The probability of occurrence of each molecular weight is plotted versus the molecular weight. The Gamma Distribution allows more flexibility to describe a wider range of fluids. The areas under the curve are, by definition, the normalized mole fractions. Hence, this is essentially a representation of the molar distribution as adjacent areas under a continuous function. The function is defined from a lower MW value, at which the function is zero, to any other MW value. To obtain the mole fraction for a particular component, we obtain the areas under the probability density curve up to adjacent MW bounds and then take the difference.

When a conversion using the Gamma Distribution is performed, the incoming stream C_{n+} quantities, u_j, and their corresponding molecular weights are used to fit to a Gamma Model. The model parameters (alpha, bound and average molecular weight) are regressed to obtain the best fit. The model found is the continuous function. To obtain the output stream C_{n+} quantities v_i, i.e. to effect the conversion, the continuous model is discretized into the output characterization with identified molecular weights or bounds. The model parameters and the MW bounds uniquely define the areas under the curve, i.e. the normalized mole fractions. These are scaled to give the actual molar quantities v_i for the output stream. Once a model is obtained, it can be discretized to any desired representation as shown in Figure 6. Each representation would have its own number of component and corresponding MWs or MW bounds. In the current implementation, Gamma Distribution was used to convert each reservoir's reservoir-EOS molar rates (obtained from BO rates using the BOz method) to Single Carbon Number (SCN) molar rates.

Equation-of-State (EOS) Conversions

A stream may undergo separation (e.g. a wellstream entering a surface process). PSM/Streamz™ includes sophistical EOS capabilities to perform such conversion involving separation. Each separator can use *a)* an EOS flash at known temperature and pressure *b)* k-values for each component specifying the ratio of each component in the vapor phase to that in the liquid phase after separation, or *c)* split factors to specify the fraction of each component that goes into the liquid phase or into the vapor phase.

PSM allows the linking of multiple separators into a pseudo-*process*. A complete user-defined process consisting of surface separators can be designed. The separators can be lined up in various configurations and each can take the feed from one or more of other. The only limitation is a "reflux"; i.e. taking feed from a downstream stage. The result of the full "process" (or any intermediate stage) can be obtained. Gas Plant tables used in reservoir simulators can easily be simulated within PSM/Streamz using this feature.

Calculation of volumes from molar streams for a specified temperature and pressure is another EOS based conversion that is extensively used.

Stream Management

A reservoir simulator produces tens of thousands of streams. A typical field with sufficiently different geology and fluid systems would normally require separate fluid models for each identified reservoir unit. This translates into huge databases of petroleum fluid streams. With the application of state-of-the-art technology, real-time data acquisition systems generate huge amounts of production data. There is a real need for managing and filtering streams data. PSM provides extremely flexible and powerful filtering features that are used extensively in the Block B implementation. Selection of production well, special satellite processing for certain fields,

collection of oil and gas streams are example uses of filters.

To ensure accuracy, conversions are done at each time-step and at each well-grid connection level. Once converted, streams are consolidated to monthly or yearly averages. Also streams originating from different simulation models need to be added before providing aggregated streams for process simulation. Using the stream management features provided by PSM/Streamz™, the following requirements were fulfilled:

1. Aggregation of streams from all models to well and reservoir levels.

2. Aggregation of all streams to common time basis (monthly).

3. Aggregation of all streams to common denomination characterization (SCN: single carbon number to C_{30+}).

4. Combined molar streams for providing to process simulation group.

5. Selectively process streams at satellite platforms.

6. Combine only oil streams for processing through surface liquid process.

7. Combine gas streams from different models and also all vapors from liquid separation flashes for processing through surface Gas Plant process.

8. Select streams from unique "sources" for Crude Assay estimation.

9. Generation of monthly cum-curves for the PSM/Optimize module.

Easily obtainable are the molar/volumetric rates at any point in the system. For example combined molar rates for Hiu and Kerisi can be obtained for pipeline design. Combined volumetric rates of the 9 reservoir models for North Belut can be obtained for satellite platform sizing. Detailed results like the propane yield for a certain PVT region 2 in the Belanak Lower reservoir can also be obtained.

Optimization

PSM/Optimize™ uses the *cum-vs-time* relationship for each reservoir as input. These curves are made available for all components. Gas injection is handled by specifying multiple relationships for each scenario. These relationships can be specified manually by the user, or are generated automatically by PSM.

PSM allows the reservoir engineer / field integrator to automatically phase-in an unlimited number of fields (reservoirs) through respectively identified surface process facilities to contribute to respectively identified contracts. Required amounts of fluids are withdrawn from each field's potential. Earliest date of availability of each field and facility is honored, as are the capacities and constraints. The ultimate aim is to meet the targets (specified as BBTU/day as a function of time) while maximizing production of liquids (oil, naphtha, butane, propane). A detailed optimized component molar rates profile is automatically obtained to submit for process simulation.

APPLICATIONS OF PETROSTREAM MANAGEMENT TO BLOCK B

Molar Streams for Surface Processing

Nineteen reservoir models have been used to model the various reservoir units that flow into the Belanak FPSO. These models have vastly different fluids requiring four equation-of-state (EOS) PVT models and 12 PVT regions. Each BO-PVT table generated for black oil reservoir simulation has a different surface process.

The models are phased in at different times but co-mingle to flow into the FPSO. The different fluids initially existing, the different potentials and the different timing combine to give a difficult-to-predict aggregated molar flow into the FPSO. Even though the model results are the surface volumes of oil and gas, they cannot be added as they are not the same oil and gas.

The process on the FPSO is a 3-stage liquid separation train and an efficient gas processing plant that produces multiple streams (separator oil and condensate, export gas, propane and butane (LPGs), and gas plant condensate (naphtha). Detailed process simulation requires a consistent aggregate molar rate profile for proper equipment sizing and efficient process design.

PSM implementation uses the BOz technology to convert each Block B model's surface oil and gas volumetric rates to molar rates consistent with the Reservoir equation-of-state characterization used originally to generate the BO-PVT tables. This characterization uses pure components up to C_6 and pseudo-components for C_{7+}. C_{7+} is split into single carbon number (SCN) components using the Gamma Distribution technology. Both conversions are performed at each time-step at well-grid connection level for accuracy and consistency.

Each of the reservoir model SCN streams is progressively consolidated to well and reservoir level. The streams are simultaneously averaged to monthly streams. The streams retain their time stamp according to simulation start times in the reservoir simulator. They are thus in a common denominator characterization and on the same (monthly) time basis with relative time stamps. These streams are in a format for easy consolidation at any level required, or for extraction of information at any level of detail needed. PSM converts each SCN stream to the characterization used for process simulation in Hysys. This is an 18-component EOS model. PSM then performs an aggregation to obtain, as requested, monthly or yearly component-wise molar rates in this characterization.

Figure 7 shows the gas stream profiles input to the Belanak FPSO. These are an aggregation of streams from satellite fields and gas streams after satellite processing. Figure 8 is the corresponding profile of liquid input streams to Belanak FPSO. Streams from the Belanak fields (Massive, Zone3 and Lower) are aggregated with liquid streams from other satellite fields.

Optimized Development Phasing of Fields

The Block B reservoirs are linked to Gas Sales Agreements (GSAs). Scheduling capabilities are required that will allow meeting set export gas schedules without having to rerun simulations to match total export. Currently this is accomplished with black oil streams in a compositing spreadsheet by phasing fields and drawing from deliverability sequentially as needed to meet the targets. Oil, condensate and LPGs are tracked based on yield relationships or by lookup from cum gas versus cum liquid tables. Gas reinjection into some of the reservoirs is managed using cum relationships based on wet gas production derived from the simulation runs. With multiple fields feeding into the FPSO and multiple ways to meet contract obligations, this is a difficult task even with the semi-automation provided by modern spreadsheets. The initial implementation of PSM ensured that the basic input to the spreadsheet solution was as consistent as possible. However, a fully automated and consistent scheduling solution was needed.

The PSM/Optimize™ module provides the reservoir engineer / field integrator with a tool that allows automatic optimization of field phase-in through respectively identified surface process facilities to contribute to respectively identified contracts, while being compositionally consistent. A convenient graphical user interface (GUI) is provided for preparing the input file, launching the module, and plotting the results. The ultimate aim is to meet the target (specified as BBTU/day as a function of time) while maximizing production of liquids (oil, condensate and LPGs).

Based on user-defined priorities, earliest availability of facilities and models, and model constraints, PSM optimizes the phasing in of all available reservoirs. The targets are simultaneously met. All the input used is pre-generated by PSM from simulation results. A formatted result file is produced for diagnostic purposes. A pre-identified set of plots specific to each case is generated. Apart from being consistently sound, it is completely automated and provides the user with total control to maximize any component (product), and to specify re-injection and constraints.

Figure 9 is a schematic example of molar streams from multiple reservoirs being phased, aggregated and processed through the Belanak facility.

"Belanak Blend" Crude Assay Profile for Marketing

The properties of the crude exported from Block B are expected to change dramatically over time. This will occur not only as result of the mixing of various reservoirs but also from significant changes within a reservoir; for example, when production transitions from primarily oil rim "black oil" to gas cap "condensate". Stream management using PSM allows us to improve the estimates of value parameters for the blended export crude over time. In addition to the obvious quality indicators like API

gravity and sulfur content, we are also able to predict refinery product yields.

Full crude assays have been conducted on most of the DST samples used to develop the reservoir fluid characterizations. The logical solution was to build this capability into PSM by correlating the available crude assays to the molar streams calculated by PSM from black-oil simulations

The PSM/Crude Assay Module™ calculates average properties based on accurate accounting of amounts from different "sources" in various reservoir models with consistent summation and processing. It is assumed that fluid PVT regions in reservoir models can be uniquely linked to particular crude assays, separate processing of "source" streams closely approximates the combined processing, and assay summary sheets are available in a fixed (i.e. ITS Caleb Brett) format.

Averaging is done by taking mass amounts at each chosen time (interpolating if required) for each cut of each reservoir source file. Volume for each cut is calculated from specific gravity from the linked assay sheet. Properties from assay sheets linked to the particular reservoir source file are used. Mass-based averages are calculated for properties reported on a mass basis. Volume-based averages are calculated for properties reported on a volume basis. Whole Crude specific gravity and °API are obtained from accurate variation of mass distribution in each cut at a requested time. Other properties (Sulfur, Nitrogen, Pour Point etc.) of the whole crude are obtained as mass based averages of individual Assay sheet whole crude properties.

This PSM/Assay module provides downstream evaluation of changing product properties at a level of detail never before available. Figure 10 shows an example of a composite assay sheet.

Surface Process Sensitivities

Reservoir engineers usually work with sensitivities for different scenarios involving reservoir model parameters. All reservoir models incorporate a single, simple surface process. For black-oil models the surface process is implicitly included in the PVT tables. For compositional models a simple 2- or 3-stage separation or GP-tables can be specified. For a black-oil model, a change in surface process requires a regeneration of BO-PVT tables. For either model a re-run of the simulation is usually needed.

PSM allows the reservoir engineer or integrator to perform sensitivities that involve the surface process. The BOz technology generates molar rates from BO rates. For compositional simulation models molar rates are available. PSM allows processing these molar rates through any surface process. The same surface process can be used as specified in the simulation model, but the user can vary separator temperatures and pressures. The simple process can be replaced by a detailed process more closely resembling the actual. PSM allows simulating a surface process, based on recovery factors, provided by the process simulation group. The reservoir engineers can evaluate multiple such processes.

PSM implementation at Natuna Sea incorporates a complete surface process comprised of a) an equation-of-state based 3-stage separation for the liquid streams resulting in an oil product, and b) gas plant recovery factor calculations resulting in gas, propane, butane and naphtha products.

SUMMARY AND CONCLUSIONS

The implementation of a new technology for conversion and management of petroleum fluid streams for the South Natuna Sea Block B project has enhanced our ability to optimize reservoir developments and facility design. This technology allows ConocoPhillips to effectively manage a number of complex surface and subsurface interactions, such as:

- Sequencing and timing of multiple reservoir developments
- Two gas sales contract requirements from dedicated reservoir sources
- Widely varying reservoir source compositions
- Throughput constraints at three compression facilities
- Multiple processing nodes, which ultimately feed the LPG extraction plant at the Belanak FPSO

Full field reservoir flow models have been constructed for each of the major reservoirs and

provide individual reservoir fluid streams that vary in terms of compositions, component properties and timing. The petroleum stream management methodology presented in this paper allows ConocoPhillips to aggregate all of these flow streams into a common component characterization and time scale, while including specific processing at any level for any reservoir stream. Additional modules based on this methodology have been developed which enhance our ability to; 1) optimize the phasing of these reservoirs to achieve sales contract requirements while maximizing the value of the oil, condensate and LPG revenue streams, and 2) forecast the export properties of the "Belanak Blend" crude more accurately than previously possible.

The Petrostream Management technology presented in this paper is a solution to the long-standing problem of consistent and easy transfer of petroleum fluid data from discipline to discipline. All the components of the technology are built to be entirely generic in nature, allowing adaptation to any and all petroleum fluid management problems. Links to existing reservoir simulators are available and new links can be built very easily. The suite of automatic conversions and aggregation to user requirement can be easily implemented. The basic PSM implementation allows easy expansion for new requirements as shown by the crude assay and the optimize modules. They become part of the total PSM solution and are themselves generic enough to be customized for a different implementation.

The solution uses tested technology and the conversions are implemented at the most detailed level for accuracy and consistency. Hundreds of thousands of streams are easily handled and the post-processing of the entire integrated system takes a fraction of the time of any single reservoir simulator run.

ACKNOWLEDGMENTS

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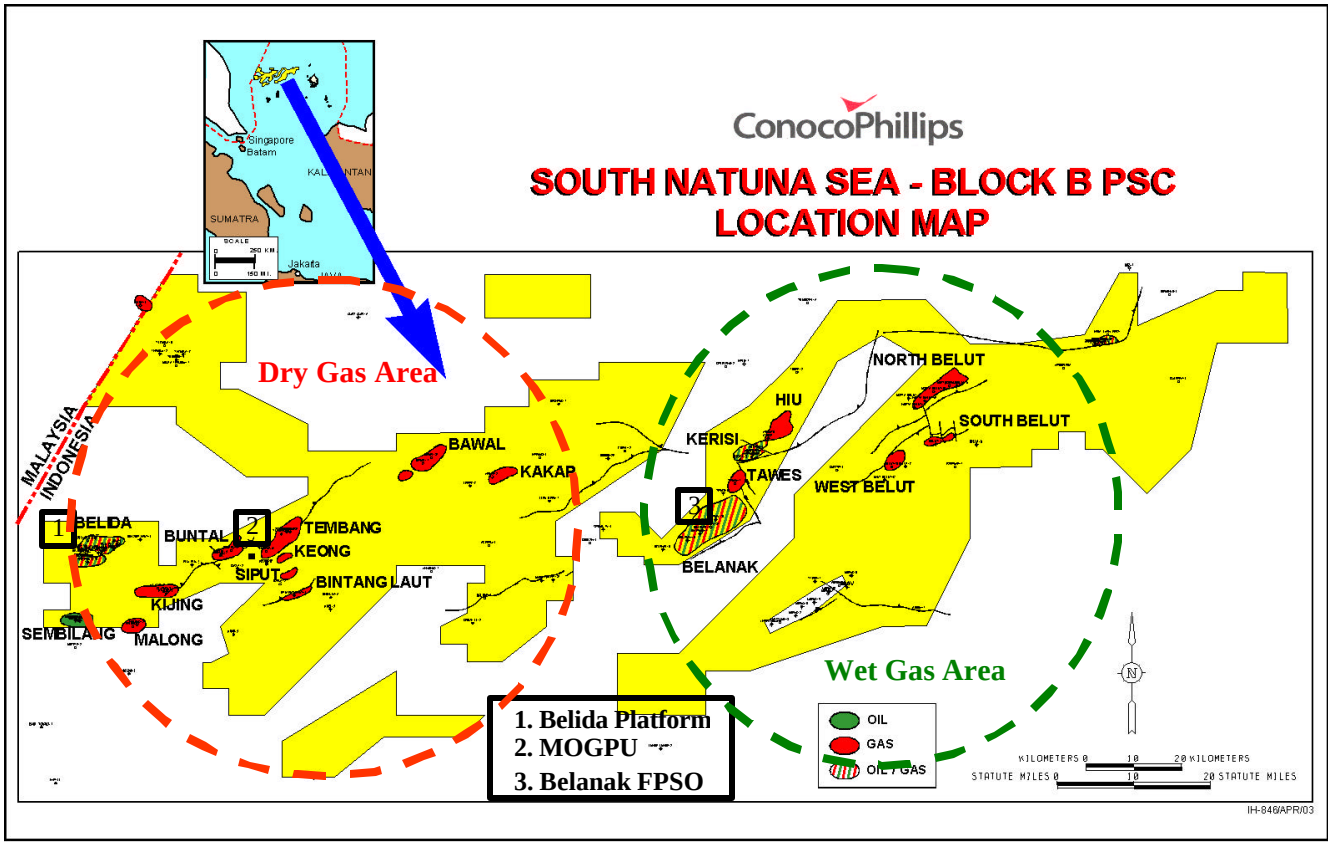

Figure 1 - Location of the South Natuna Sea Block B (SNSSB) PSC.

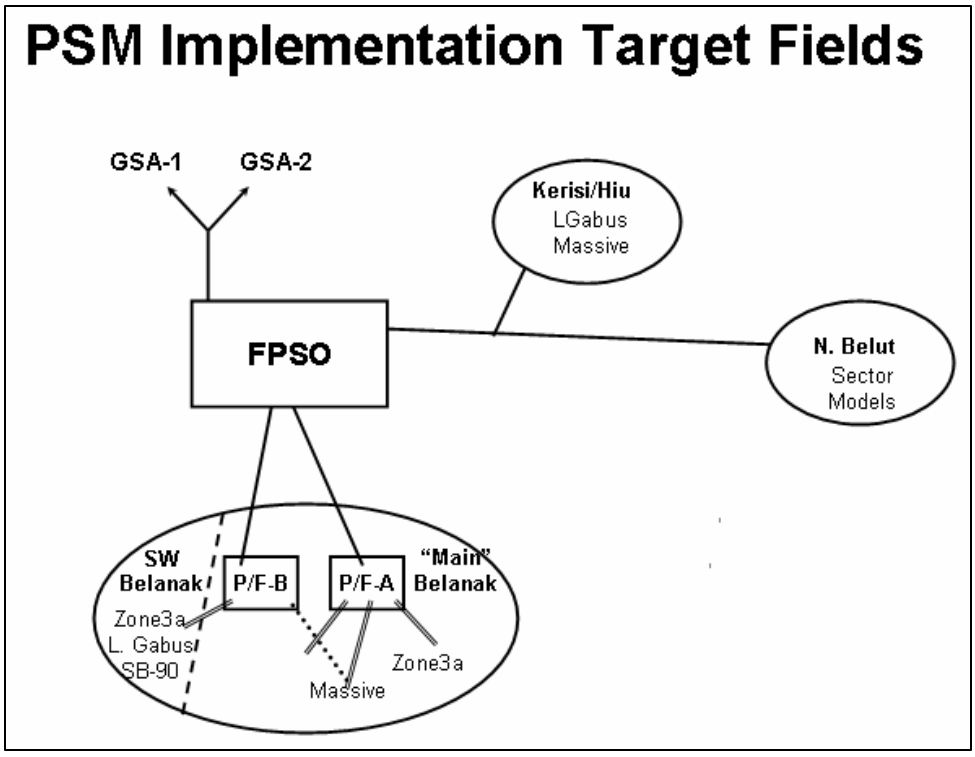

Figure 2 - PSM Implementation Targets and their Relationship.

$$v_i = \sum_{j=1}^{m} S_{ij} u_j$$

u_j : Original stream quantities (j = 1 to m)

v_i : Converted stream quantities (i = 1 to n)

$m < n$; $m = n$; $m > n$

S_{ij} : Split Factor (portion of j^{th} input component partitioning into the i^{th} output component)

$$\begin{bmatrix} v_1 \\ \vdots \\ v_i \\ \vdots \\ v_n \end{bmatrix} = \begin{bmatrix} S_{11} & \cdots & S_{1j} & \cdots & S_{1m} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ S_{i1} & \cdots & S_{ij} & \cdots & S_{im} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ S_{n1} & \cdots & S_{nj} & \cdots & S_{nm} \end{bmatrix} \bullet \begin{bmatrix} u_1 \\ \vdots \\ u_j \\ \vdots \\ u_m \end{bmatrix}$$

Figure 3 - The generic conversion matrix and the calculation of the quantities of the converted stream from original stream quantities.

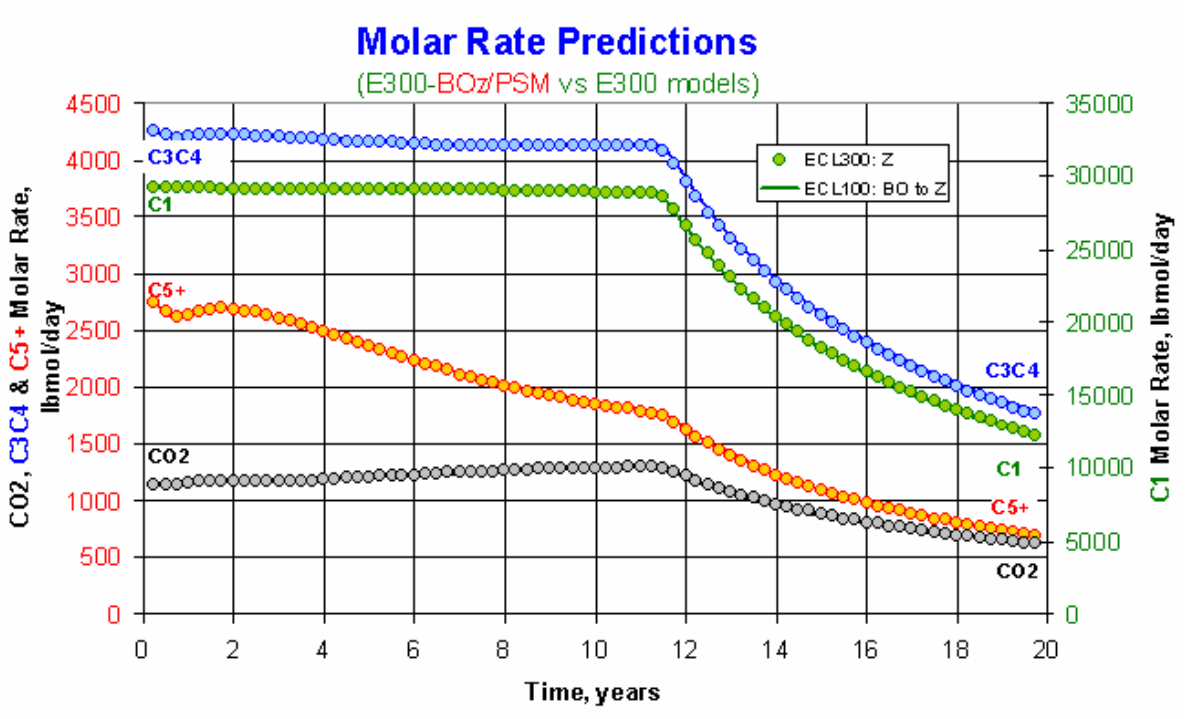

Figure 4 - BOz conversion example from North Belut 5 layer (5 fluid) case. Key components are chosen to show the accuracy of conversion.

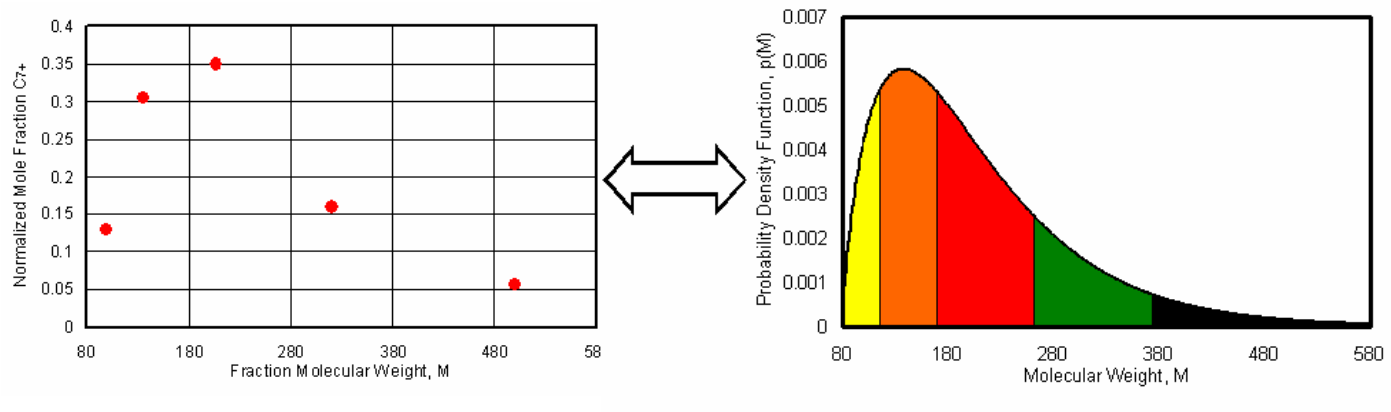

Figure 5 - Molar distribution represented as discrete and continuous distributions.

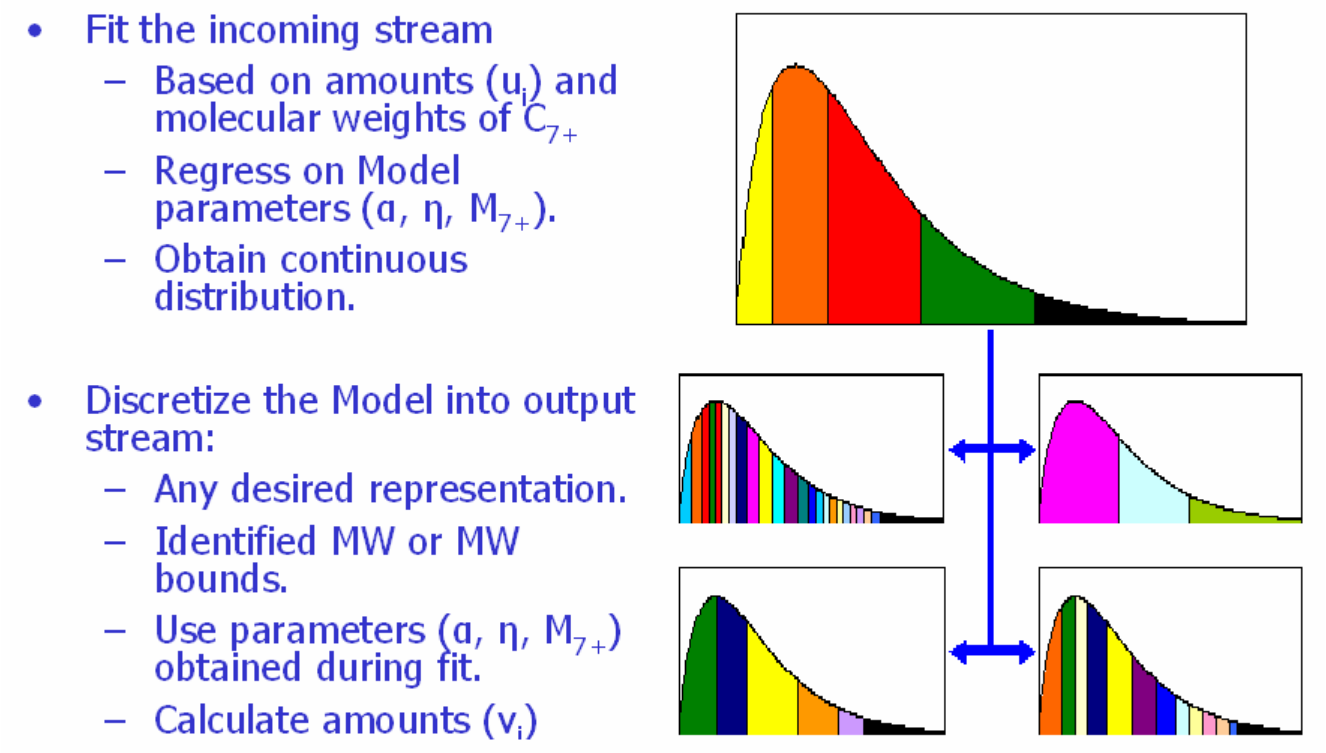

Figure 6 - Stream conversions using the Gamma distribution.

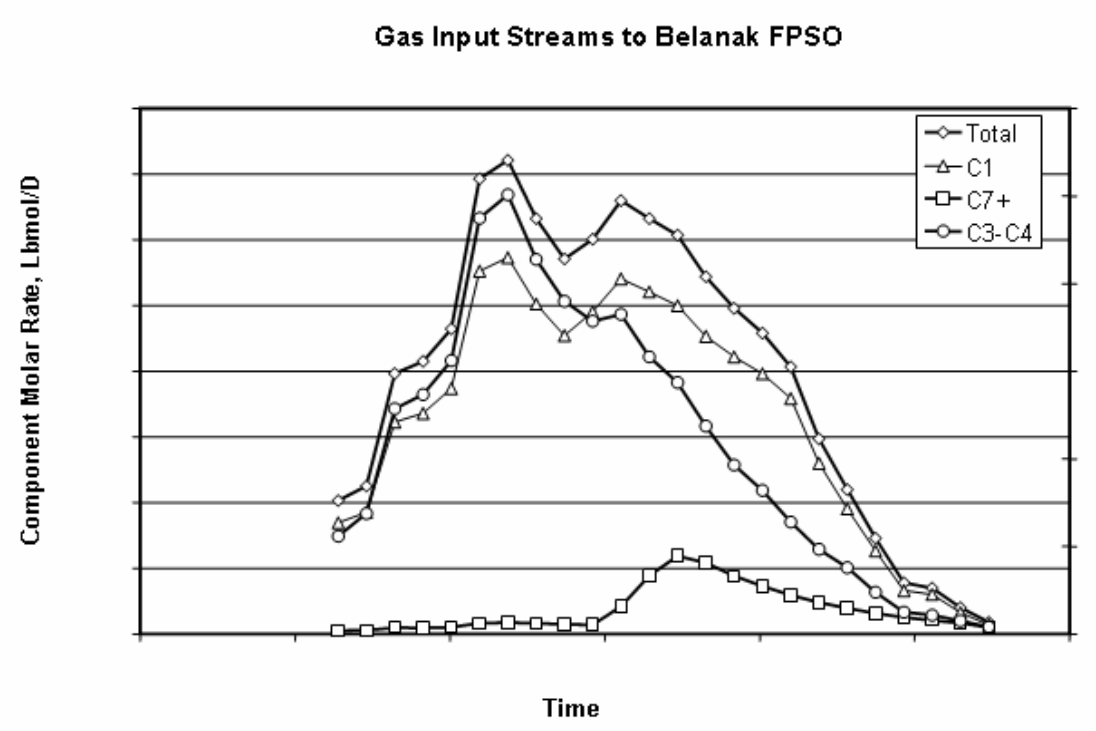

Figure 7 - Stream profile for chosen components/groups for gas streams input to Belanak FPSO. These are a combination of dry gas fields (Tawes, West Belut, South Belut) and gas streams from satellite fields.

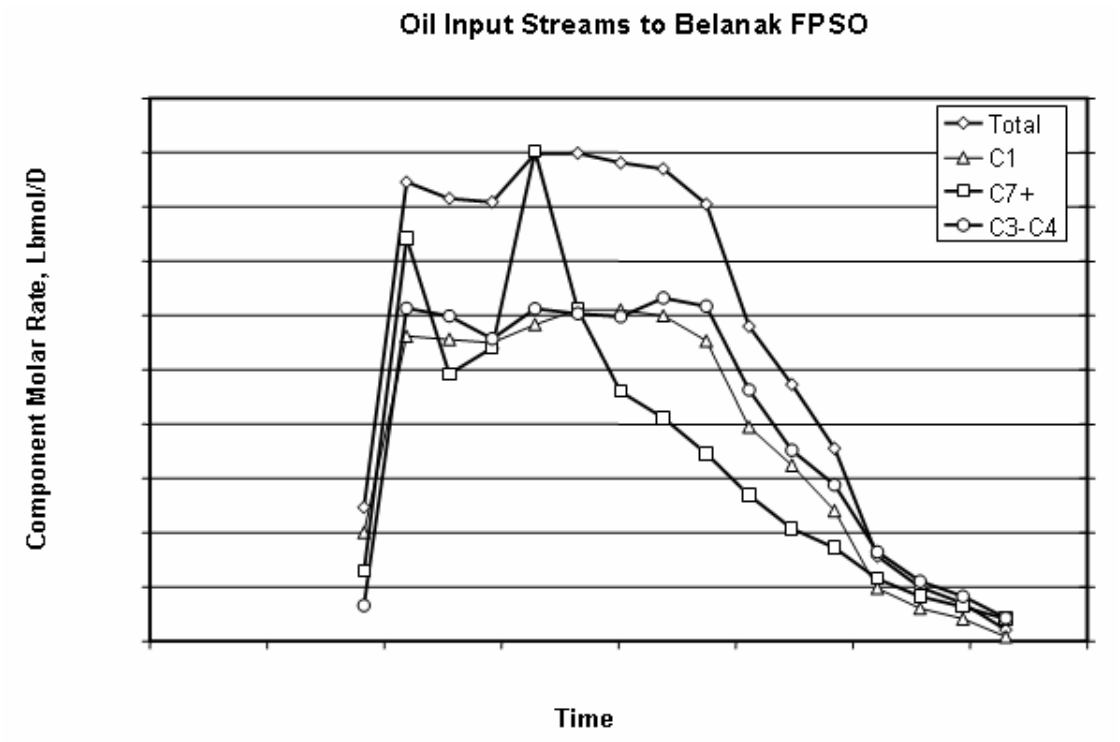

Figure 8 - Stream profile for chosen components/groups for oil streams input to Belanak FPSO. These are a combination of Belanak fields and oil streams from satellite fields.

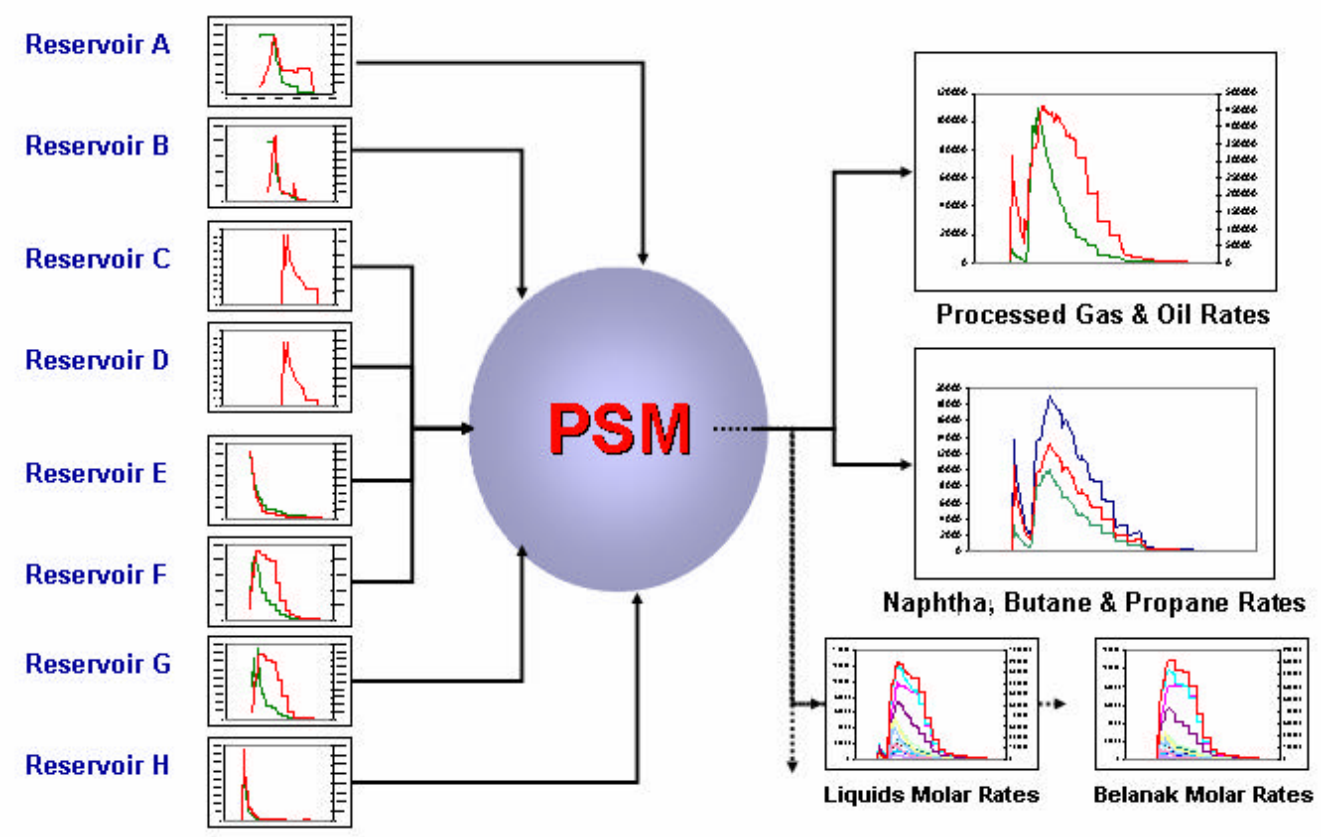

Figure 9 - A Schematic example of molar streams optimization.

Test	Method	Whole Crude Properties	LPG	IBP-23.9	To-68.3	To-85	To-98.9	To-168.3	To-193.3
Yields, Wt. %	Distillation			0.02	0.02	0.03	1.55	16.17	7.94
Yields, LV %	Distillation			0.03	0.03	0.04	1.72	17.41	8.32
APIGreavity @ 60F	D4052	45.0		105.0	83.1	68.2	65.4	58.5	53.4
Specific Gravity 60/60F	D4052	0.8019		0.5984	0.6594	0.7087	0.7186	0.7448	0.7653
Total Sulfur,Wt.% (max)	D4294	0.018609861			0.008898759	0.009678	0.007865	0.008576	0.009912
Marcaptan Sulfur, ppm (max)	UOP163/D3227	NC			3	3	3	3	3
Hydrogen Sulfide (H2S), wt % (max)	UOP1631/IP103	NC			0.000909166	0.000891	0.000822		
Gas Chromatography	D2427								
Paraffins, Vol%	D5134 MOD			96.82305	89.04755799	68.00682	66.89824		
Aromatics, vol °/,	D5134 MOD			1.045411	3.371995576	5.755386	5.063263		
Naphthenes,Vol%	D5134 MOD			2.008168	7.575769689	25.50831	28.0382		
Paraffins,vol !	D5443/D6239							69.22999	67.15025
Naphthanes, vol %	D5443/D6239							21.99475	16.27339
Aromatics, vol %	D5443/D6239							8.515413	9.210641
>200 Deg C, vol %	D5443/D6239							0.035593	3.57624
Polynaphthenes, vol%	D5443/D6239							0.162041	3.442235
Aromatics, vol %	D1319								
Olefins, vol %	D1319								
Saturates, vol %	D1319								
Research Octane	D2700/D2699				69.89095315	56.94878	48.40027		
Aniline Point, Deg C	D611								68.01695
Freeze Point, Deg. C	D2386								-48.25299
Cloud Point, Deg C	D2500								
Pour Point, Deg. C	D5853/D97	28.32288045							-21.14621
Total Nitrogen, wt %	D4629 MOD	0.013951754			5.63268E-05	0.480984	0.293751	0.950762	1.773556
Basic Nitrogen, wt% (max)	UOP 269				0.000898644	0.481385	0.294412	0.475786	0.59157
UOP/Watson K Factor									

Figure 10 - A composite (blended) assay calculated by PSM.