A Case Study of Progressive Cavity Pump Gauges And Installation in Staatsolie, Suriname

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1. Company Profile Staatsolie Maatschappij Suriname N.V.

Staatsolie Maatschappij Suriname N.V., the State Oil Company of Suriname, was founded on December 13, 1980, as a limited liability company under Surinamese Law. The Republic of Suriname (figure 1) is the sole shareholder. Staatsolie has the mining rights to explore for and produce hydrocarbons in Suriname. It can exercise this right as an independent operator or in cooperation with other oil companies. The initial idea was to have Staatsolie as an advisory body to the government, with the principal task of monitoring the activities of oil companies performing petroleum activities in Suriname. However, in its drive to contribute more to the Surinamese economy, Staatsolie took the development of earlier made onshore discoveries into its own hands. With the inauguration of the refinery in 1997, it became an integrated petroleum company that now employs 640 people. The turnover of more than two hundred million US dollars makes Staatsolie a sizable contributor to the economy of Suriname (for more company info see website: www.staatsolie.com).

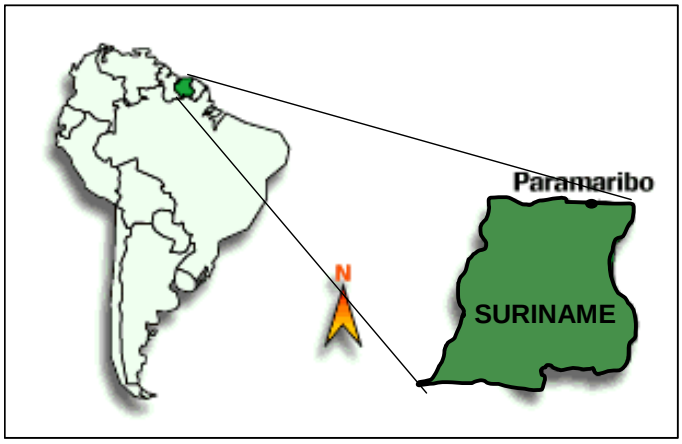

Figure1: Location map of Suriname (Staatsolie Maatschappij Suriname N.V, 1998.)

Staatsolie produces the Saramacca Crude from the Tambaredjo Oilfield, which is owned and operated by Staatsolie. The oilfield is situated in the District of Saramacca, about 55-km west of Paramaribo (figure 2). The current daily production is reached at averagely 12,500 barrels oil per day. Saramacca Crude is transported via a 55-km high-pressure pipeline from the production facilities to the storage and distribution facilities at the refinery (Tout Lui Faut), located near Paramaribo. The refinery products are: diesel, hvgo (heavy vacuum gas oil), fuel oil and asphalt bitumen. The markets of Staatsolie are local consumers and countries in the Caribbean, ie. Guyana, Trinidad and Barbados.

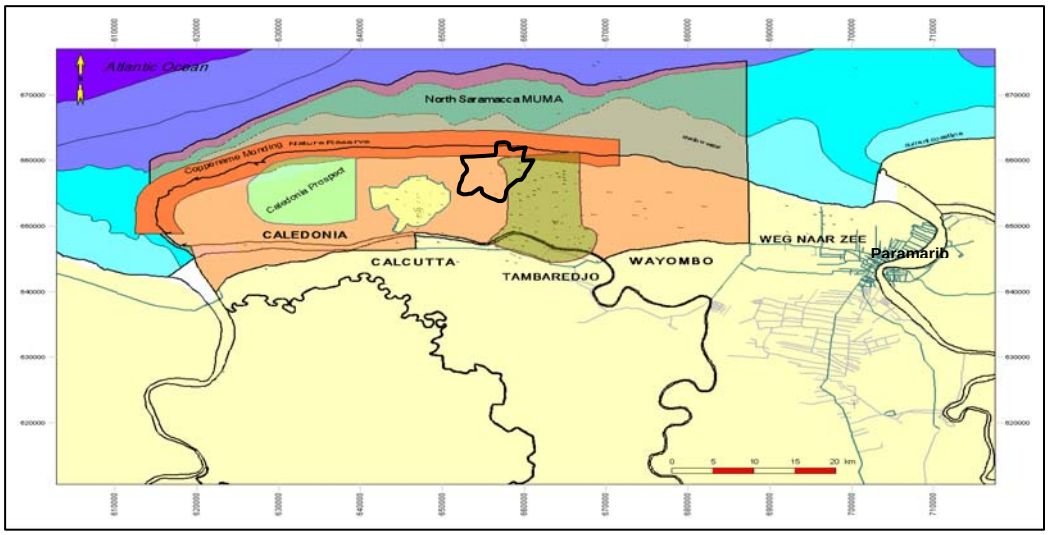

Figure 2: Tambaredjo oil field location in District Saramacca west side of Paramaribo

2. Historical overview of Crude Oil Activities in Suriname

Traces of Petroleum-like substances at several places along the coastal plain of Suriname have been reported since the beginning of this century.

1928 First analysis that confirmed the presence of hydrocarbons were carried out on samples from a 30ft shallow well, drilled in the District of Nickerie.

1965 The Geological and Mining Service (GMD) encountered heavy oil in the Miocene interval at a depth of 450 ft, while drilling for potable water on a schoolyard in Calcutta in the District of Saramacca. Encouraged by this find, GMD carried out a drilling program in the vicinity areas of the discovery well (1966).

1968 Oil was encountered at a depth of approximately 850 ft. in the Paleocene interval in the village of Tambaredjo.

1970 Execution of Hydrocarbon exploration campaign in the Coastal plain of Suriname

1980 The State Oil Company Suriname (Staatsolie) established on December 13th by the Government of Suriname.

1982 Production activities started with 5 test wells with average daily production of 200 BOPD

1996 Establishment of the Staatsolie Refinery at Tout Lui Faut (TLF)

2003 Discovery made in the neighboring Calcutta block where full-scale production development activities will be completed in 2006

2004 Staatsolie entered exploration activities offshore by acquiring 3,500 km 2-D seismic data, signed two Production Sharing Contracts; one with the Spanish oil company Repsol YPF for offshore block 30 and the other with the Danish oil company Maersk Oil. Production test program carried out on the first well CC-16 of the Calcutta field

2005 Production test program continued on additional 4 wells in the Calcutta field. Third offshore contract signed with Occidental Petroleum Company.

2006 Official declaration of the Calcutta (second onshore) oilfield. An average daily production of 12,500 BOPD of the Tambaredjo and Calcutta field realized as end of February 2006.

3. Geology of the Tambaredjo Reservoir

3.1 Regional Geology

The Precambrian Guyana shield covers about 80% of Suriname's territory onshore. In the coastal plain, the oldest strata overlying the basement are sediments of Late Cretaceous age, whereas offshore the sediments are of the Berriasian age. The Guyana sedimentary basin is composed of the offshore and coastal plain of Suriname together with those of French Guyana and Guyana. Evolution of the basin started in the Late Jurassic-Early Cretaceous period with the opening of the Atlantic, as the South American and the African plates began to drift apart.

The sediments in the Suriname part of the Guyana basin are deposited in a passively trailing margin style environment with minor tectonic activities and are grouped in the Corantijn Group. The Group consists of a monocline northern dipping section of predominantly classic sediments, deposited under fluvial to marine conditions.
Onshore, oil is encountered at several stratigraphic levels in the Tertiary sediments. In the Tambaredjo area, the Paleocene to Eocene sediments, called the Saramacca Formation, is the oil-bearing formation. The Formation is characterized by a regular alternation of relatively thick (up to 50 m) sands (more or less kaolinitic) with kaolinitic clays. In the Tambaredjo area the Formation is 120 – 150m thick. Oil production in the Tambaredjo field is from the T-unit, a Paleocene member of the Saramacca Formation.
The Tambaredjo field is located on a NE-SW trending structural high of the Precambrian basement, possibly an extension of the so-called Bakhuys horst. Along the coastal plain the highest part of the Saramacca Formation is situated on this structure (main reason for the trapping of the oil in the Tambaredjo area).
All Formations gently dip towards the Atlantic Ocean. The contours of the Top-Cretaceous unconformity show an undulating surface with a regional dip of about 1 degree to the North.

3.2 The Tambaredjo Field

The Tambaredjo field is located in a marshy area in the coastal plain of Suriname, in the district of Saramacca about 45 km West of Paramaribo. The crude production is from the T-unit, a Paleocene member of the Saramacca Formation. The recoverable reserves of this field are proved at about 107 MMSTB as end of December 2005. The oil produced is heavy crude (15.6 degree API) of intermediate naphtenic origin with low sulfur and low metal contents. The reservoir was discovered in 1968 by the GMD (Geologische Mijnbouwkundige Dienst), near the village of Tambaredjo, by wildcat well C9 (TA-4) at a depth of 850 feet.

The oil is produced from the T-sands, a Paleocene unconsolidated quartz sand body in the lower part of the Saramacca formation. The depositional environment ranges from fluvial to estuarine. The T-sands are informally divided into a basal T1 sand and upper T2 sand (figure 3).

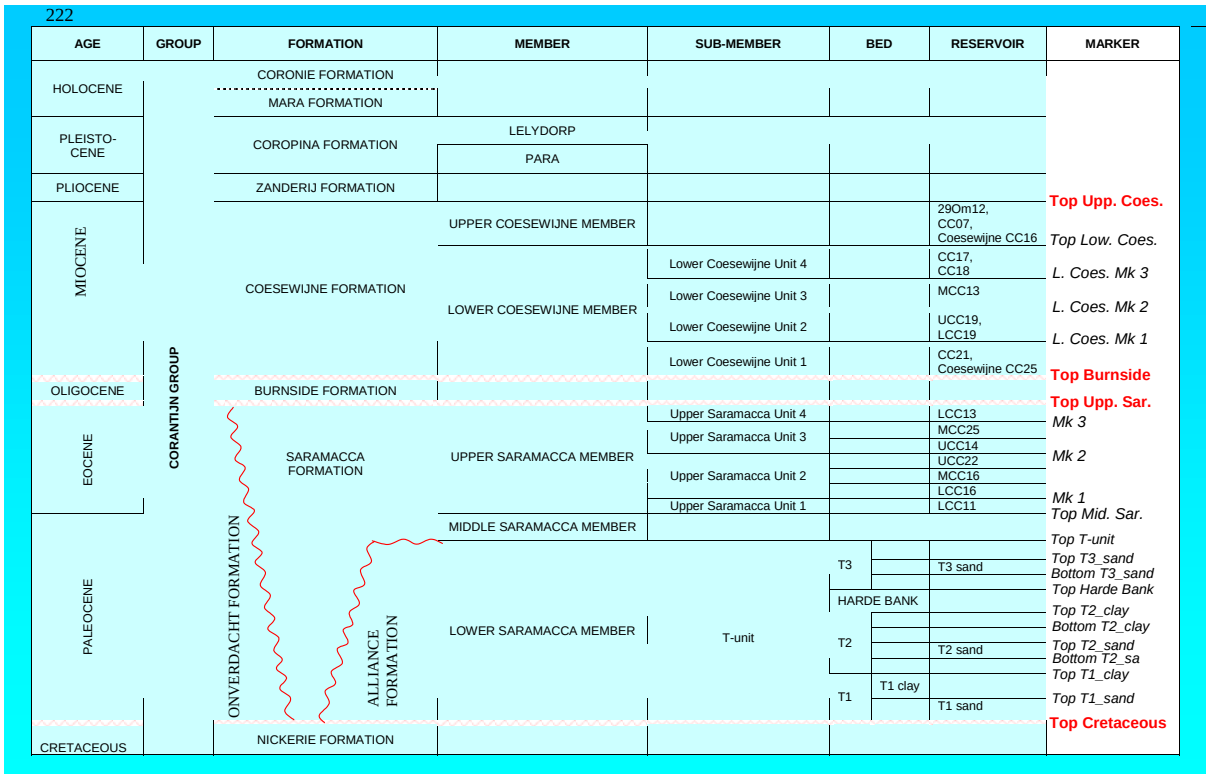

Figure 3: Stratigraphic column of the coastal plain of Suriname

The T1-sands are deposited as channel fill sands by low sinuosity channels. The sand body geometry is mainly controlled by the underlying Cretaceous erosion surface. The T1 sands are described as moderately to well sorted, medium to coarse-grained sands.
The T2-sands range from isolated point bars to estuarine-fill and crevasse splay. The reservoir is found at a depth of 850 ft in the southern part of the field and dips about 1 degree to the North forming a stratigraphic trap towards the South. A regional transgressive clay body caps the sands. The T2 sands are relatively finer and clayey. The average permeability is less that for the T1 sand. Often only the lower part of the T2 sand has favorable reservoir characteristics. Both sands show a fining-upward pattern.
Thickness of the Tambaredjo reservoir varies from 0 to 50ft, porosities are in the range of 35 to 42% and permeability can be several darcies (0.5 to 40 darcies).

The Tambaredjo field is subdivided into different areas based on geographical location and flow line design (figure 4). The Southern areas are producing more dry oil with an average water cut of 50%, whereas the northern areas are also producing foamy oil, possibly due to higher initial GOR and/ or production below bubble point.
A total number 886 production wells are in production in the Tambaredjo field as of end February 2006 with an average daily production of 12,500 BOPD. Due to low reservoir pressures, crude production is realized by means of artificial lifting. A total of 875 wells are being operated by means of Moyno progressive cavity pumps and the remaining by means of pumping jacks.

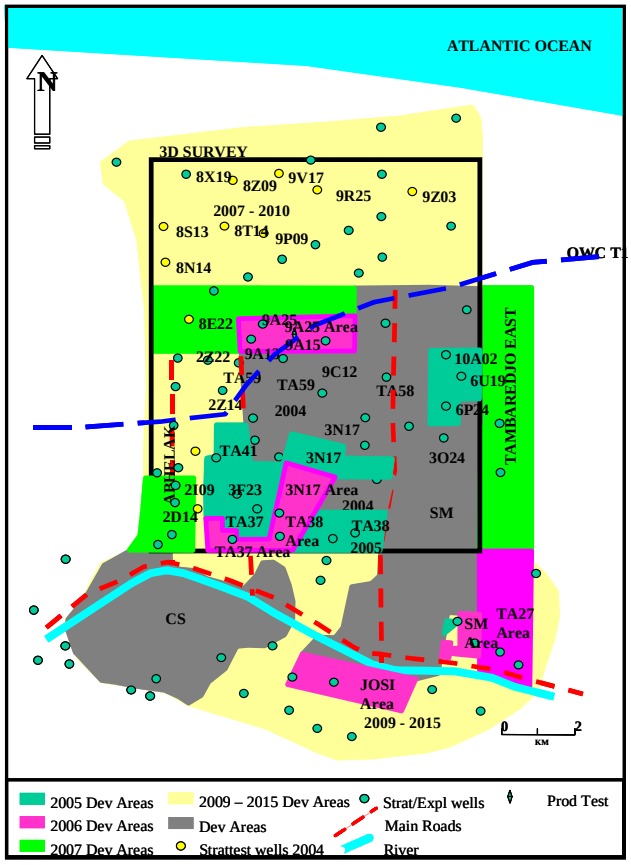

Figure 4: The different production areas of the Tambaredjo oil field

4 Determining Flowing Bottomhole Pressure by means of downhole pressure sensors

4.1 Background

Movement of fluid causes fluid flow in a reservoir from a high-pressure area to a low-pressure area. Fluid flow into a well bore occurs when fluids present in the well bore are removed so that the pressure is decreased in the well bore. Then, fluid from an area of higher pressure flows into the lower pressure well bore.

Fluid flow increases with increased differential pressure between reservoir and producing bottom hole pressure. Four factors are important in analyzing well performance:

1. Reservoir pressure
2. Producing bottom hole pressure
3. Well production
4. Pump capacity

For maximum withdrawal, the producing bottom hole pressure must be low compared to the reservoir pressure or static bottom hole pressure. The pressure at the well bore can be obtained from the depth to the liquid, the casing pressure, and knowledge of the fluids present in the casing annulus.

The pressure at the well bore can be determined by means of several methods:

- **Acoustic Echo Well sounder method with an acoustic liquid level instrument:** this can be used to determine the amount of liquid above the pump or formation. The instrument works on an echo principle and is commonly used at Staatsolie Maatschappij Suriname N.V.
- **Improved measuring technology:** by means of the application of down hole pressure sensors/ gauges. There are several types of down hole gauges:
    1. ***Down hole Memory gauges***, these gauges needs a programming for periodic recording before it is installed in a well. Based on the test program the gauge records the pressure and temperature in time, which can be downloaded after the gauge is retrieved from the well. No online real time data is available. At Staatsolie a number of 7 of these types of gauges are being used for periodical data gathering purposes.
    2. ***Surface Read-Out Gauges (SRO),*** are gauges, which can be permanently installed in a well to provide down hole pressure and temperature data. Staatsolie had purchased and installed two of this gauges in two wells successfully. Additional 21 sro gauges were purchased for reservoir technical en production technical evaluation purposes.
    3. ***Down hole gauges with surface transmitting systems,*** these gauges emits electromagnetic signals to the surface where the data can be recorded by means of a special interface box in a data logger.

The acoustic FBHP calculating method has various inaccuracies due to the presence of a foamy column above the fluid level in the annulus mainly for the wells in the northern areas of the Tambaredjo field where foamy oil is produced.
An accurate FBHP result is needed mainly for optimum well performance analysis. The acoustic methods results into high FBHP data as a result inaccurate well performance evaluations can be done. For more accurate down hole pressure data, the pressure sensor technology can provide with a high percentage of security accurate down hole data.
Also according to an extended reservoir pressure and FBHP gathering program for an optimally well performance monitoring of the reservoir, a number of 21 SRO gauges (Amerada gauges) has been purchased by the Production Engineering Department. These gauges will be installed in active producing wells and in development wells in 2006. For the installation assistance of the gauges on the first 5-10 wells, a technician of the Amerada Company visited Staatsolie.

4.2 Objectives:

The objectives of sro gauge installation can be defined as reservoir technical and production technical reason.

The **reservoir technical objectives** of this data acquisition program (reservoir pressure data) were defined as follows:

- To determine more accurately the reservoir performance and pressure distribution within the developed producing area of the Tambaredjo field for improved reservoir management decision-making
- To reduce both the cost and risk involved in drilling infill locations, performing work-overs and implementing IOR/EOR projects. This can be done by acquiring representative sample of data points per production area in order to more accurately

determine the reservoir pressure distribution within the developed producing area of the Tambaredjo field.

- To gather reservoir information for production optimisation purposes (i.e. distance to boundaries, faulting, reservoir permeability, skin factor, productivity index etc.),
- To more accurately forecast the production and reserves,
- To determine inputs for the evaluation of well productivity of potential drilling locations and work over candidates,
- For reservoir simulation history matching,

The production technical objectives were defined as:

- To determine accurate FBHP (Pwf) as an essential element in predicting the well's productivity index (PI) and its inflow performance relationship for an optimal pump design and well performance.
- To determine the FBHP performance around the bubble point pressure acoustically and correlate with SRO gauge data. Below the bubble point pressure, dead-oil gradient cannot be used, so the gradient correlation factor should be determined for especially the foamy oil producing wells in the northern areas of the Tambaredjo field for an optimal well performance
- To perform pump efficiency evaluations at multi rate productions and to determine pump capacities for optimal pump performance

4.3 SRO gauge installation program Staatsolie

During the period February 27th till March 12th of 2006, the SRO gauge technician (Paul Sargent) paid a visit to Staatsolie. The aim of his visit was to guide and train Staatsolie employee during installation of sro gauges.
From March 1st to March 10th, eight gauges were installed into the wells as given in table 1:

Well name	Remarks
3D23	Successfully installed
3V18	Successfully installed
3N05 ZZ04	Cable broke at surface while dressing around the top tubing
1M09 1N06 WW06 SOM10	Successfully installed
29Ob222	Successfully installed by Staatsolie personnel

Table 1: SRO gauge installed wells during the period March 1st till March 21st of 2006

1. Well 3D23 (gauge 92663) on Wednesday, March 01 of 2006:

Well 3D23 is located in the TA-38 area and was completed as open hole over the T1 and T2 interval over a 63 ft. net pay. Both T-sands were well developed and well saturated with oil. According to the log results the production of this well was estimated 80-100 bopd. Based on this estimation the PCP was designed and the well was started up at 60 bfpd. Further optimizing the well production to the estimated production was unsuccessful. The well production and pump efficiency decreased at the initial same pump rate, which can possibly be the effect of gas interference or completion failures. Based on the fact that this well is producing far below expectations and that there is no availability of accurate down hole pressure data of this well and area, an SRO gauge installation was proposed for this well to acquire the following information:

- Reservoir Parameters as Reservoir Pressure, Productivity (PI), and effective oil permeability
- Near well bore damage (skin) evaluation
- To acquire accurate pressure data for PE projects: gas interference and reducing of casing pressures for optimizing production
- To compare FBHP data from Echo Sounder and Down hole gauge

This information will give an indication about the reasoning of low production performance of this well (troubleshooting pump problems at this gassy well with potential problem at low pump efficiency). In combination with the SRO gauge a gas separator (Guiberson type) was installed to separate the produced solution gas down hole before entering the PCP for optimizing the well production and extending the PCP life. Besides this information the SRO gauge will be useful for production optimization projects with updated real time pressure data

2. Well 3N05 (gauge 92677) on Friday, March 03 of 2006:

Well 3N05 is located in the 3N17 area and was completed as open hole over the T1 and T2 interval over a 46 ft. net pay. A 4 ft. clay layer intercalates the T1 sand. The T1 and the T2 sands are separated with a 4 ft. clay layer. Both completed T sands are well saturated with oil. According to the log results the production of this well was estimated 70-80 bopd. The PCP was designed according to the estimate as guideline. While optimizing the production it became clear that this well was not able to reach near the estimated production. Based on the realized production the PCP was re-designed by installing a small capacity PCP. The current production potential of the well is more than 50% less than was expected due to unknown reasons. Since is believed that the presence of clay layers in the completed interval could probably affect the inflow performance of a well, this well was all the more the proper candidate for an SRO gauge installation. The following information will give a better understanding of the reason of the unexpected low well production:

- Reservoir Parameters as Reservoir Pressure, Productivity (PI), and effective oil permeability
- Near wellbore damage (skin)
- To acquire accurate pressure data for PE projects: gas interference and reducing of casing pressures for optimizing production
- To compare FBHP data from Echo Sounder and Down hole gauge

This information will give an indication about the reasoning of low production performance of this well (troubleshooting pump problems at this gassy well with potential problem at low pump efficiency).

Permanent Down Hole Gauges (DHG) with surface readout option (SRO) have been recommended to be installed in the Calcutta and Tambaredjo Field in order to more accurately determine the reservoir pressure distribution within the developed producing areas. The next group of wells have been selected based on the reservoir that was completed and taken into production and on the geographical distribution and to further optimize the well productivity based on accurate gauge data.

3. **Well 3V18 (gauge 92679) on Thursday, March 02 of 2006:**
   Reservoir pressure monitoring of a pre-infill well in proposed infill area (E&FE)
4. **Well 1N06 (gauge 92653) on Friday, March 03 of 2006:**
   Pilot well for EOR projects (E&FE)
5. **Well 1M09 (gauge 92684) on Sunday, March 05 of 2006:**
   Pilot well for projects EOR (E&FE)
6. **Well ZZ04 (gauge 92688) on Thursday, March 09 of 2006:**
   Monitoring reservoir pressure of existing well in matured production area for production improvement projects (E&FE)
7. **Well WW06 and gauge 92676 on Thursday, 09 March:**
   Monitoring reservoir pressure of existing well in matured production area for production improvement projects (E&FE)
8. **Well SOM10 and gauge 92652 on Friday, 10 March:**
   Monitoring reservoir pressure of existing well in matured production area for and production improvement projects (E&FE)

Note: Gauge with serial number 92687 had a malfunction. Paul has taken this gauge with him back to check and repair in GRC shop.

On well 29Ob222 (Calcutta development well) also an sro gauge was successfully installed by Staatsolie personnel for reservoir pressure and productivity measurements of the new MCC25 reservoir.

4.4 Future Planning:

According to a data acquisition program a proposal has been made by the Reservoir Engineers to install a number of 40 sro gauges in the Tambaredjo and Calcutta field.
To date a number of 21 gauges has already been purchased by Staatsolie in 2005. For 2006 a schedule is made to purchase additional 20 gauges. For the years hereafter a planning will be made based on the data evaluation of the installed gauges.