DAILY PRODUCTION ACCOUNTING AT FRONTIER'S CHEYENNE, WY REFINERY

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Abstract

This presentation will describe Frontier Cheyenne’s yield accounting experience using the S-TMS Production Accounting System on a daily basis since 2003. In addition, it will touch on the implementation stage of the tool at the site.

As one of the “fundamentals that we need to get right”, production accounting technology has helped refineries and petrochemical facilities detect material losses. This is done by improving data quality and operating procedures, detecting measurement errors (such as data entry errors), instrument failures, missing movements, etc. Operation and planning decisions have also benefited from the revised data.

At Frontier Cheyenne, the information for the mass balance and daily production accounting is obtained from available data sources. These results are sent to the company’s ERP system in Denver Colorado.

The S-TMS Production Accounting System; ensures daily inventory positions, quantities of all movements, evaluation of the uncertainty of the custody transfer measurements as well as other flow meters, and the yields of the process units. All of this is done daily at the facility. In addition, cross-checking is done on a daily basis subjecting the inventory, movements and flow meter information to the constraints of the mass balance.

The presentation will describe many aspects of the daily operation of the system in the refinery, what errors are typically found and how S-TMS helps find these errors. It will also describe how the model is maintained and adapted to plant change.
INTRODUCTION

Refinery wide mass balance is an achievable and worthwhile goal. It is the basis of any loss control initiative.

The simultaneous cross-checking of the site’s transactions, movements, inventories, lab data and measurement systems, on a daily basis, by subjecting them to the mass balance constraint is the cornerstone of good refinery information. As a result of these cross-checks, errors are captured at the source.

The Cheyenne Refinery has a permitted crude capacity of 52,000 barrels per day. Frontier markets its refined products primarily in the eastern slope of the Rocky Mountain region, which encompasses eastern Colorado (including the Denver metropolitan area) and eastern Wyoming.

Frontier Refinery has a coking unit, which allows the refinery to process up to 100% heavy crude oil for use as a feedstock. The ability to process heavy crude oil lowers our crude supply costs because heavy crude oil is generally less expensive than other types of crude oil. Historically, heavy crude oil has accounted for 80% or more of the Cheyenne refinery's crude oil charge. The Cheyenne refinery's product mix includes gasoline (41%), diesel fuel (30%) and asphalt along with other refined petroleum products (29%). Crude oil is purchased from local producers and also imported via the Express Pipeline from Canada.

Cheyenne refinery embarked in a refinery-wide mass balance initiative in 2003. The project took approximately a year from the kick-off to the use of the new production accounting system. Soteica's S-TMS production accounting system is now used for solving the daily mass balance.

Soteica LLC provided S-TMS software and implemented the production accounting system. Soteica is a technology company that develops, implements and sustains applications for the process industry in the following areas; Production Accounting, Advanced Planning and Scheduling (S-TMS), Energy Management and Optimization (Visual MESA) and Operator Trainers (S-OTS). Soteica also provides services in the area of advanced control.
THE PRODUCTION ACCOUNTING PROJECT

Great value was captured throughout the project, which included; hydrocarbon streams that was previously ignored and review of the flow meters and accounting procedures. Afterwards, when the mass balance was executed on a daily basis, exceptions were caught that otherwise would have been ignored. Sponsorship of the project by the refinery management team and active collaboration of Soteica's and Frontier's project managers, both in the implementation stages and afterwards, were very important to the success of the project.

The mass balance model has a level of detail that provides sufficient redundancy of measurements and cross-checking between measurements. Analysis is done simultaneously in the whole refinery on a tank by tank and unit by unit basis instead of a product by product basis.

The Cheyenne refinery model includes the processing units as black boxes and has the receipt and shipment points of the site as boundary limits. The tank farm is modeled tank by tank. The inventories also include other inventories not stored in tanks such as; the coke pile, sulfur inventory, and loaded but not shipped railcars. The model includes the generation and consumption of fuel gas, fuel oil, natural gas and the sulphur and hydrogen produced and consumed. Crude composition is also calculated on a daily basis.

Initially, an external reconciliation engine was used, but later replaced by the S-TMS embedded reconciliation engine. The S-TMS reconciliation has available both the traditional gross error identification method and the successive error identification and simultaneous compensation method. This change highly facilitated the model's operation and maintenance.

The role of production accounting, assisted by process engineering, is to find sources of errors and work in a continuous improvement mode towards having an overall measurement system in the best shape possible. The reporting fulfills an additional function which is to become the common information platform for the refinery’s data. This data consists of charges, yields, errors in measurements, etc., both for the refinery as a whole, as well as a unit by unit basis.

Best practices say that production accounting cannot be done “automagically”. In all cases the accounting and analysis phase is done on a daily basis with human intervention. The yield analyst has to be in control of the data he or she is using to achieve the goal of producing the mass balance.

S-TMS is highly integrated with other Frontier systems, thus minimizing the manual data entry efforts and avoiding duplicated entry errors. S-TMS retrieves information from the data historian and imports information from the truck dock system and the weigh scale system. After the balance is solved, S-TMS exports information to the in-house ERP system which resides in Denver at the corporate office.
The model is easily maintained and adapted by the yield analyst to plant changes including; new meters, new tanks and even new process units.

**S-TMS Production Accounting System**

S-TMS is a web application that allows production accountants to model inventories and material movements (purchases to tanks, tanks to sales, process to tanks, tanks to tanks, etc.) typical of the process industry.

The goal of this model is to capture all necessary measurement information for the calculation of inventories and material movements in a given period. This information is used to generate a mathematical reconciliation model that, when solved, allows the analysis of loss detection, measurements errors (such as custody transfer meters) and data input errors in a generalized and methodical way.

An S-TMS model consists of nodes and connections. Examples of nodes are: tanks, points of receipt and shipments, process units, etc. Examples of connections are: flows and movements through which material is transferred between nodes.

Nodes have a series of common properties such as name, material and timestamp. Connections have a series of common properties such as name, start and end time, source and destination material and source and destination node.

In S-TMS, the rest of the node and connection properties are administered by small applications called plug-ins. Plug-ins are calculation routines that can be associated to nodes or connections. Each calculation plug-in specifies a set of input and output properties. Input properties must be entered by users at a measurement creation time and can be obtained from multiple data sources. This input data is used by the plug-in to calculate the outlet properties of the measurement. A given node or connection may have more than one plug-in associated with it and dependencies between plug-ins can be established. Implicitly, via dependencies, other nodes and/or connections are also properties. The properties can also come from manual input, other connectors or S-TMS itself. (The data entry and edit screens for inventory measurements, movements and flows can be seen in Fig. 2, 3 and 4).

The connectors are drivers that bring data (typically time stamped data) from other time series databases (i.e., levels, flows, purchases, sales, etc. from historians, truck dock systems, ERP, etc...), or from other relational databases. (i.e. density, BS&W from the lab database). (see Fig. 1 below).

S-TMS version 2.1.0. Has an embedded engine for the statistical errors minimization algorithm for mass balance reconciliation. Both the traditional gross error identification method and the successive error identification and simultaneous compensation method are available. If multiple gross errors are present in the data (most frequent case), the traditional gross error identification method will spread the error in a way that makes it very difficult to detect its location. Therefore, S-TMS implements a successive error
identification and simultaneous compensation method which allows for a much more precise location of the gross error. (leaks, instruments bias, etc).

Gross error detection and mass balance analysis can be done via the Soteica Result Analyzer (client application) and the standard or custom reports. (Figs. 5, 6, 7 and 8). The Result analyzer displays the information in the different color coded views that allow detecting gross errors easily.

Fig. 1: Information Flow
Fig 2. : Inventory measurements data entry screen

Fig 3. : Movements data entry screen
Fig 4. : Flows data entry screen

Fig 5. : Excel Add-in for data analysis and reporting
Mass losses

<table>
<thead>
<tr>
<th>Processed charges</th>
<th>(lb)</th>
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<tr>
<td>Receipts - Refinery</td>
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<tr>
<td>00. Gas</td>
<td>3,150,830</td>
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<tr>
<td>10. Crude</td>
<td>73,793,683</td>
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<td>20. Liquefied Gas</td>
<td>282,734</td>
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<td>Subtotal</td>
<td>76,444,067</td>
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<th>Charges Inventory</th>
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<td>175,417,130</td>
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<td>Final inventory</td>
<td>173,217,078</td>
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<td>Inventory difference</td>
<td>2,095,452</td>
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Total processed charges | 76,204,019 |

<table>
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<th>Total losses</th>
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<td>Unaccounted losses</td>
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<td>% Total losses</td>
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<tr>
<td>% Unaccounted losses</td>
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Fig 6. : Reports in pdf format

Fig 7.: Report designer
Fig 8.: Results analyzer
PRODUCTION ACCOUNTING PROJECT BENEFITS

During the model building phase, the project team gained a detailed knowledge of the plant operations and the tank farm movements. All existing accounting procedures were reviewed and improved in order to gather the information required to perform the daily mass balance.

Production accounting is a process of continuous improvement. S-TMS has helped Frontier resolve many balancing issues with ease that may have been difficult to find without a good gross error analysis tool. Some of these examples are as follows:

- Frontier had a valve that failed on a coker charge tank which allowed product to leak to an asphalt tank. This tank was out of service, therefore, the tank was not gauged on a daily basis. With the loss of product in the coker charge tank an error was identified using the Result Analyzer. Finding this error in an aggressive manner alleviated the possibility of a tank spill and selling out-of-spec product.
- Frontier had a sales tank that developed an underground leak. This was found through an investigation which was launched after several consecutive days of reported losses. The tank was quickly taken out of service and repaired, saving thousands of barrels of finished product.
- A receipt or shipment will occasionally get overlooked, such as a missing pipeline shipment, or a receipt recorded with an incorrect product code. With the use of the Results Analyzer and the product balance report, errors such as these are easy to identify.
- Flow meter inaccuracies are identified with the help of the product balance and unit yield reports. Correcting these meters improves the mass balance on a continuous basis. Typically, yielding will discover a meter discrepancy before operations notices the error.
- The crude composition report has helped planning with crude purchases, setting unit charge rates and inventory levels. Frontier uses its crude tanks as slop tanks and it is important to identify the intermediate stock in these tanks to set charge rates and to carry those inventories to month-end financials.
- With the market getting tighter there is an increased emphasis on having an accurate mass balance. There are several reports that help Frontier identify areas that need attention. Process Engineering and Planning work closely with Operations and Yielding to have meters recalibrated, orifice plates checked, and factors verified. The Refinery Manager closely watches the monthly loss report and gives direction based on these results.

It is very difficult to put a typical dollar amount on the benefits, because, once the problems are discovered and corrected, they can produce positive or negative monetary impacts (for example a sale can be under-measured or over-measured). The most important benefit in all cases, is the improved process knowledge and the certainty that proper accounting is being performed.
Conclusions

A refinery wide mass balance production accounting system is the first step towards a loss control initiative. In addition, it provides useful information for the continuous improvement of the overall measurement system and generates widely accepted results for the yields of the units individually as well as the refinery as a whole.

By tackling the measurement and human errors at the source it allows the system to handle all the exceptions that occur with hydrocarbon management.
Bibliography
