# STEADY-STATE SIMULATORS ARE DEVELOPING A DYNAMIC PERSONALITY

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## ABSTRACT

Process simulators have been used for years to design and model actual operation of all types of different plant processes. The majority of process simulators provide a "steady-state" picture of plant operations and do not account for changes in inlet or ambient conditions. Steady state simulators are very useful when first designing a plant under a certain set of conditions, or when developing a baseline for plant operation. These simulators are also much more affordable than the dynamic simulators that are available in today's market. Unfortunately, plant operating conditions very seldom match design conditions and it is difficult for the Operator to discern what effect the changing conditions have on his process without performing numerous simulations using trial and error and manual manipulation. Even then, these results are often times suspect.

Crosstex Energy Services, L.P. and Bryan Research and Engineering, Inc. undertook a project to model one of the Crosstex gas processing facilities using the ProMax simulation software. Using the program's capabilities to rate the performance of various plant equipment, as it executes the simulation, and by utilizing available parametric study features that allow numerous runs to be made consecutively, without interruption, the ProMax simulator was able to provide a series of "snapshots" that provided a realistic and accurate prediction of how the plant will respond to changes in conditions. While this is still a prediction of steady state operation, the simulator has approached the dynamic threshold and only lacks the time derivative to cross over into that next dimension. This paper will show the steps that were taken to reach this point, the benefits it provided and how it might be used at other plant locations.

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## INTRODUCTION

Crosstex Energy Services, L.P. (Crosstex) is owner and operator of the Gregory Gas Plant Facility in Southeast Texas. The plant processes third-party natural gas and delivers fractionated NGL products to pipeline and to trucks. The plant operation has changed over the years, with the inlet gas volumes declining slightly, but increasing in ethane-plus content. The plant had not been simulated under the new conditions and Crosstex was not convinced that they were operating the plant in the most efficient and productive manner. Using the ProMax simulation software, personnel from Crosstex and Bryan Research and Engineering, Inc. (BR&E) undertook the task to model the entire plant facility and determine what could be done to improve operations and to find out what bottlenecks existed and where they were. This paper endeavors to show what steps were taken to simulate the plant under numerous sets of different conditions, what information was garnered from the simulation results and the impact that was realized when those simulation results were applied to actual plant operations.

## DISCUSSION

Crosstex and BR&E used a “stair-step” approach to construct a realistic simulation of the different plant processes. These steps included: 1) building the base plant model; 2) inclusion of equipment rating and sizing; 3) using the equipment ratings and sizing within the simulation itself to predict actual performance of the entire plant for a given set of conditions; and, finally, 4) inclusion of a multi-case “Scenario Tester” that allows the plant model to be run automatically any number of times under varying operating conditions, with the predicted results for each case displayed side-by-side for easy comparison. By using this defined methodology and plant design data in the construction of the plant simulation, it was hoped that a reliable and accurate predictive simulation model would be developed that would help optimize plant operation.

### Building the Base Model

Using Plant PFD’s and P&ID’s, Crosstex and BR&E personnel built the base model of the Gregory Plant on six different Flowsheets (Figures 1, 2, 3, 4, 5 and 6) using the ProMax software package.

Each Flowsheet was developed using the appropriate thermodynamic package for that particular process. The different Flowsheets can interact by the use of Cross-Flowsheet Connectors, which allow either Process or Energy streams to cross from one Flowsheet to another. This permits the person using the simulator to view the impact a change to inlet parameters will have on a downstream system.

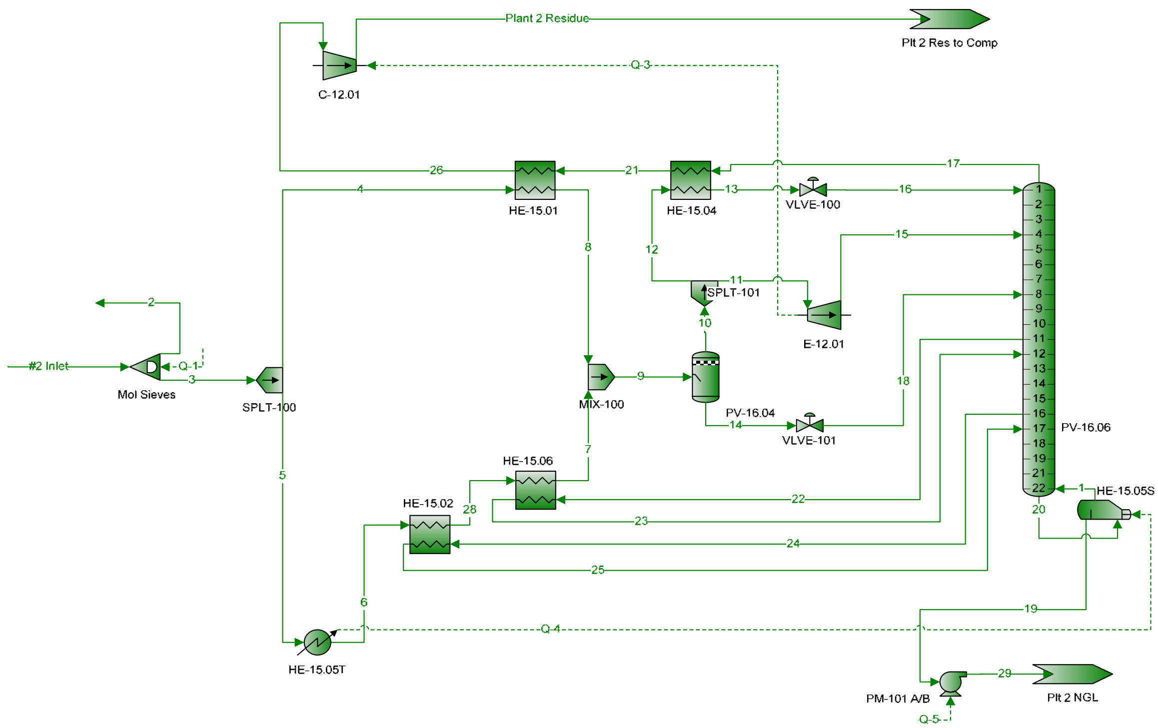



Figure 1 – Gregory Plant #2

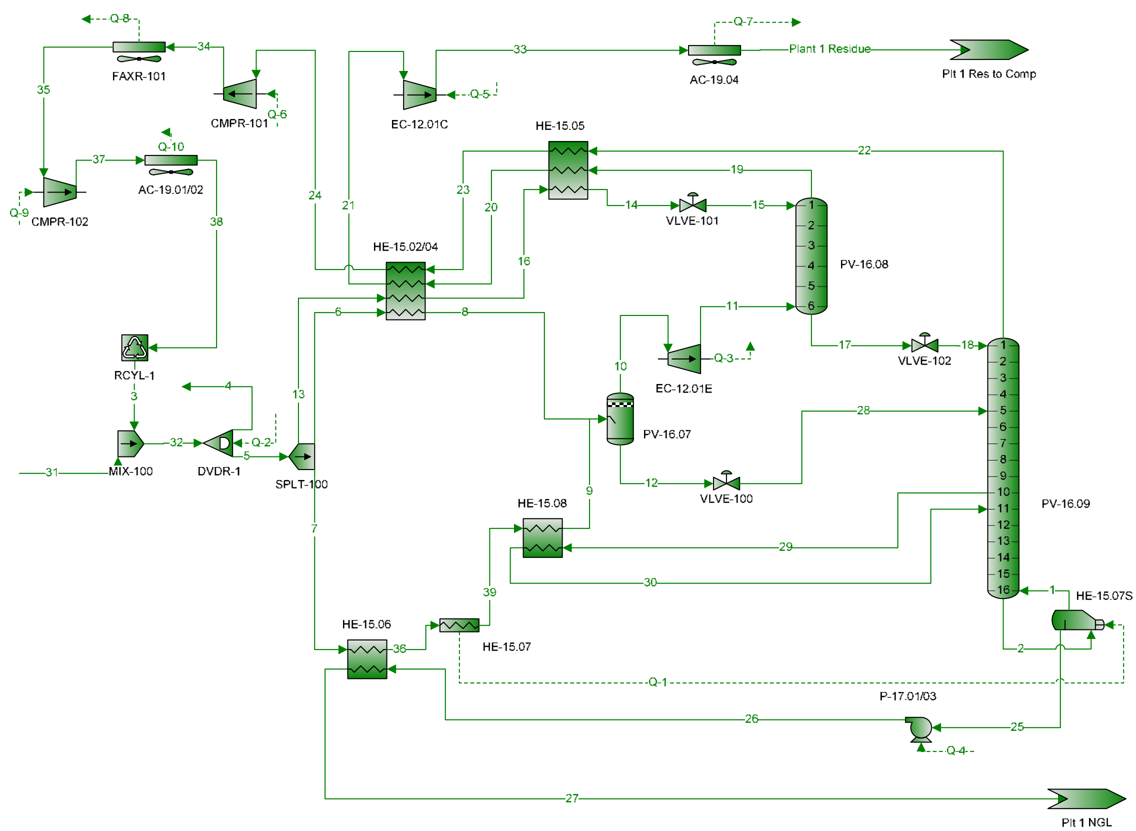



Figure 2 – Gregory Plant #1

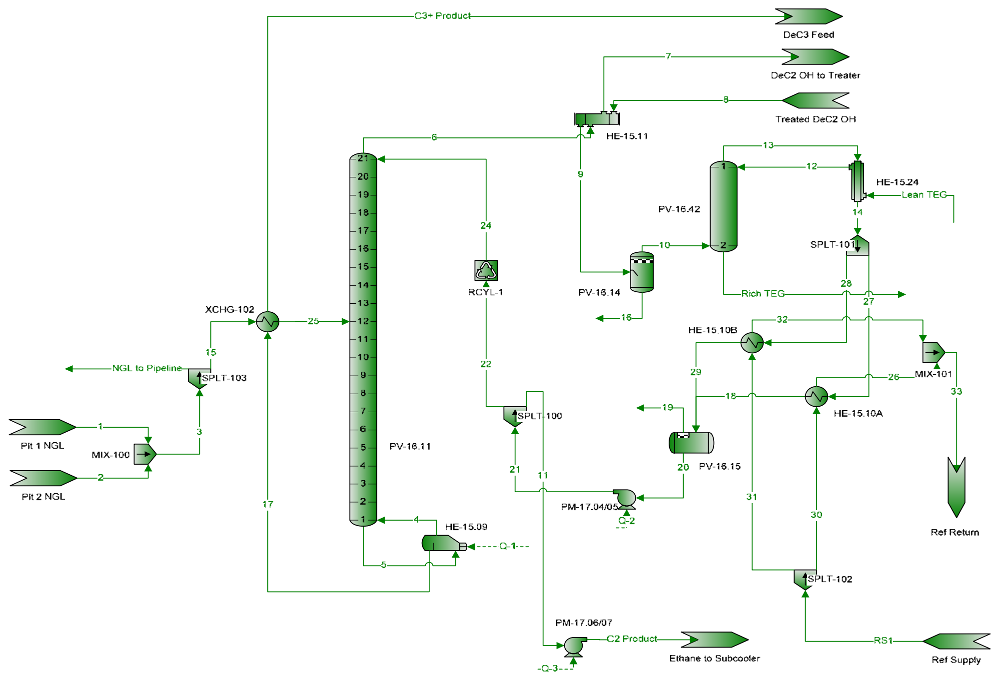



Figure 3 – Deethanizer

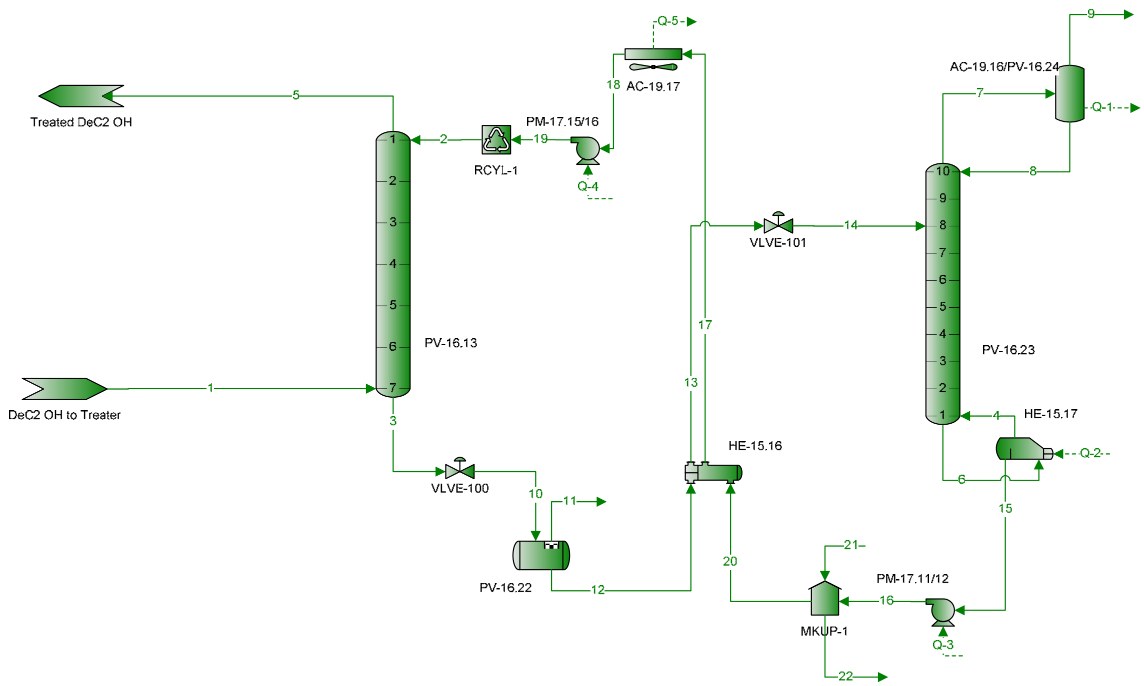



Figure 4 – Product Treater

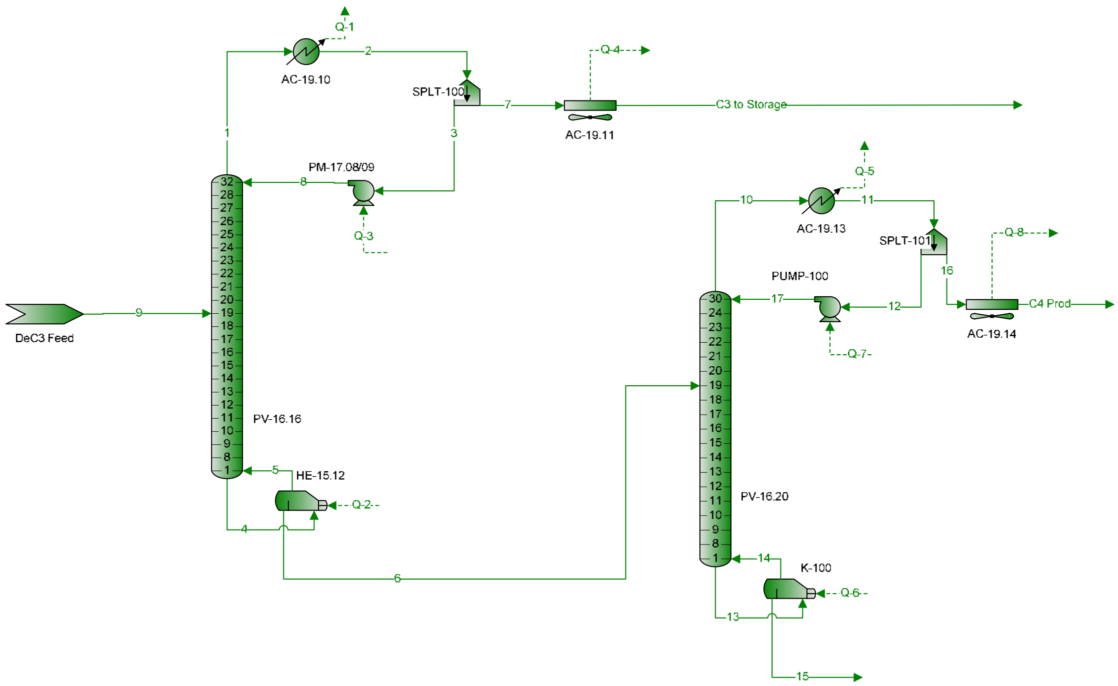



Figure 5 – Fractionator

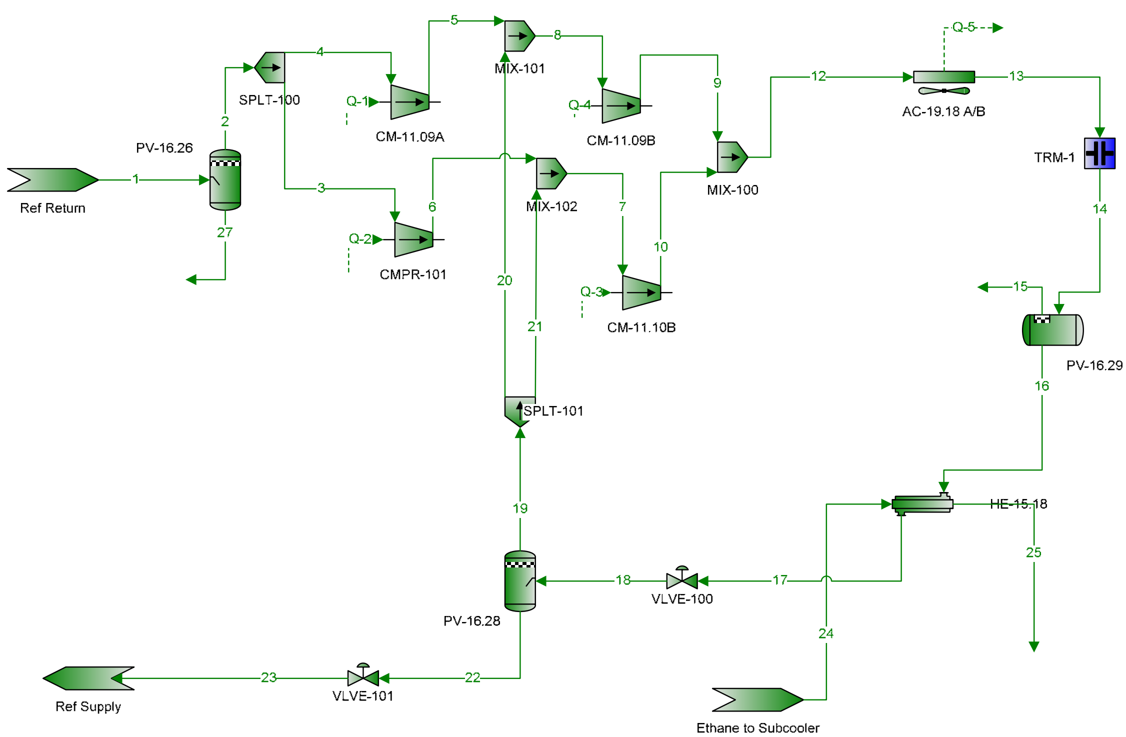



Figure 6 – Refrigeration System

## Rating and Sizing Process Equipment

Once the base model was completed, actual plant operating data were collected and put into the appropriate locations within the simulation. The simulator provided final results that matched very well with actual operation including product compositions and flow, heat duties and horsepower requirements. At this point, Crosstex and BR&E believed they had a model that represented the Gregory Plant well. The next step was to include information on the various equipment within the plant and rate the performance of that equipment.

Using Equipment Datasheets, the physical characteristics of the various heat exchangers, columns and separators were input into the rating sections of the simulator (Figures 7, 8, 9 and 10) to determine their performance and adequacy for that service and conditions. In order to confirm the simulator's equipment ratings, the original plant design data was used in a process run. The results were remarkably accurate. The program's predicted rating of each exchanger (including multi-pass brazed aluminum exchangers) was within +10/-5 percent of that predicted by the original equipment vendors.

The rating features provided information on potential areas of concern, such as calculated pressure drop through an exchanger, actual nozzle sizes versus recommended nozzle sizes and approach to flood within a tower. By having this information, Crosstex could easily determine where they were limited within the plant and determine where they might make changes. Also, by rating the exchangers and recognizing that their rated performance (i.e. 0% Over Design in the simulator) almost exactly matched actual operating performance, gave good indication that the rating program was accurate. This was very important in the next phase of building a flexible model that predicts performance under varying process conditions.

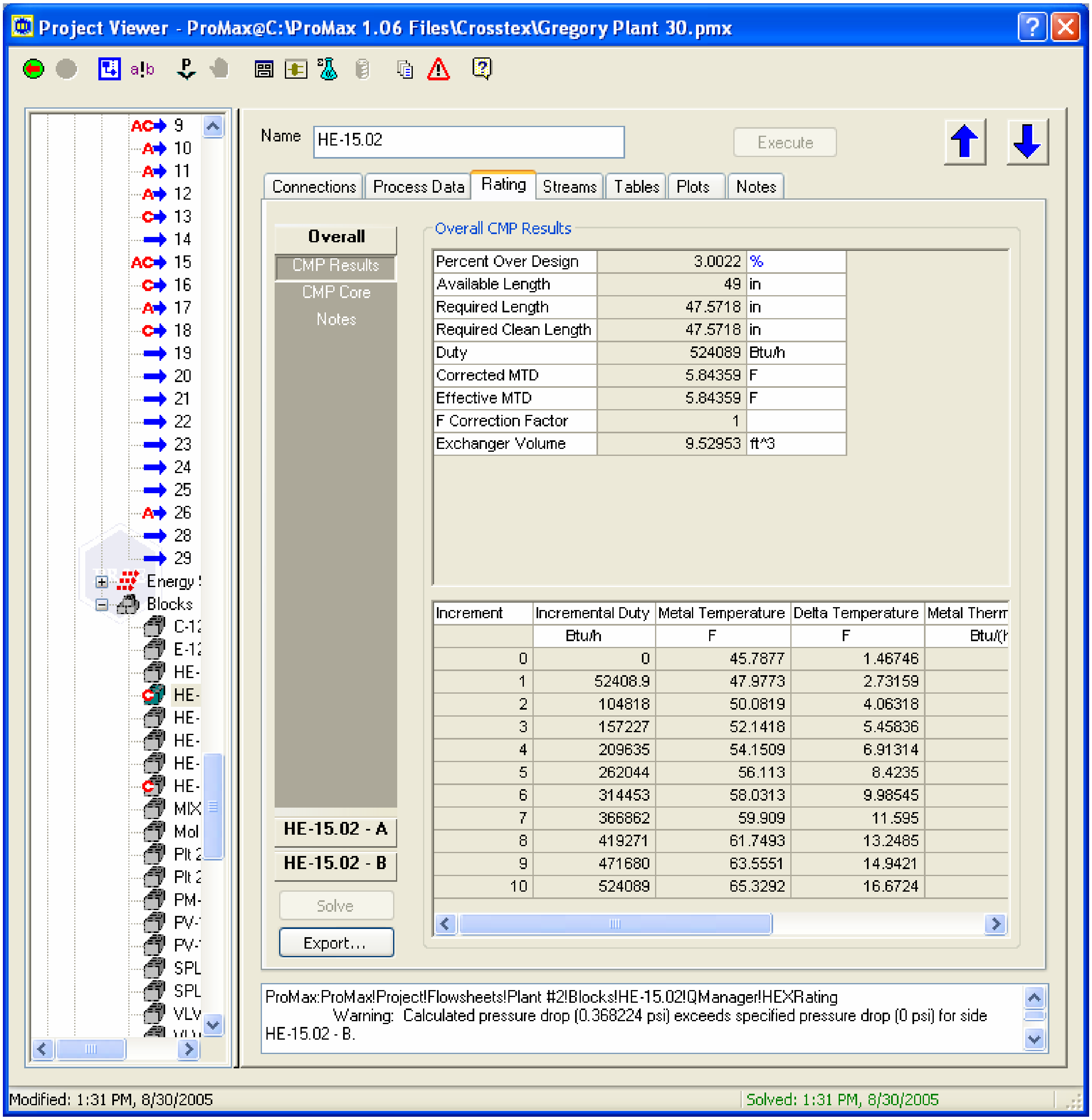



Figure 7 – Plate Fin Exchanger Rating

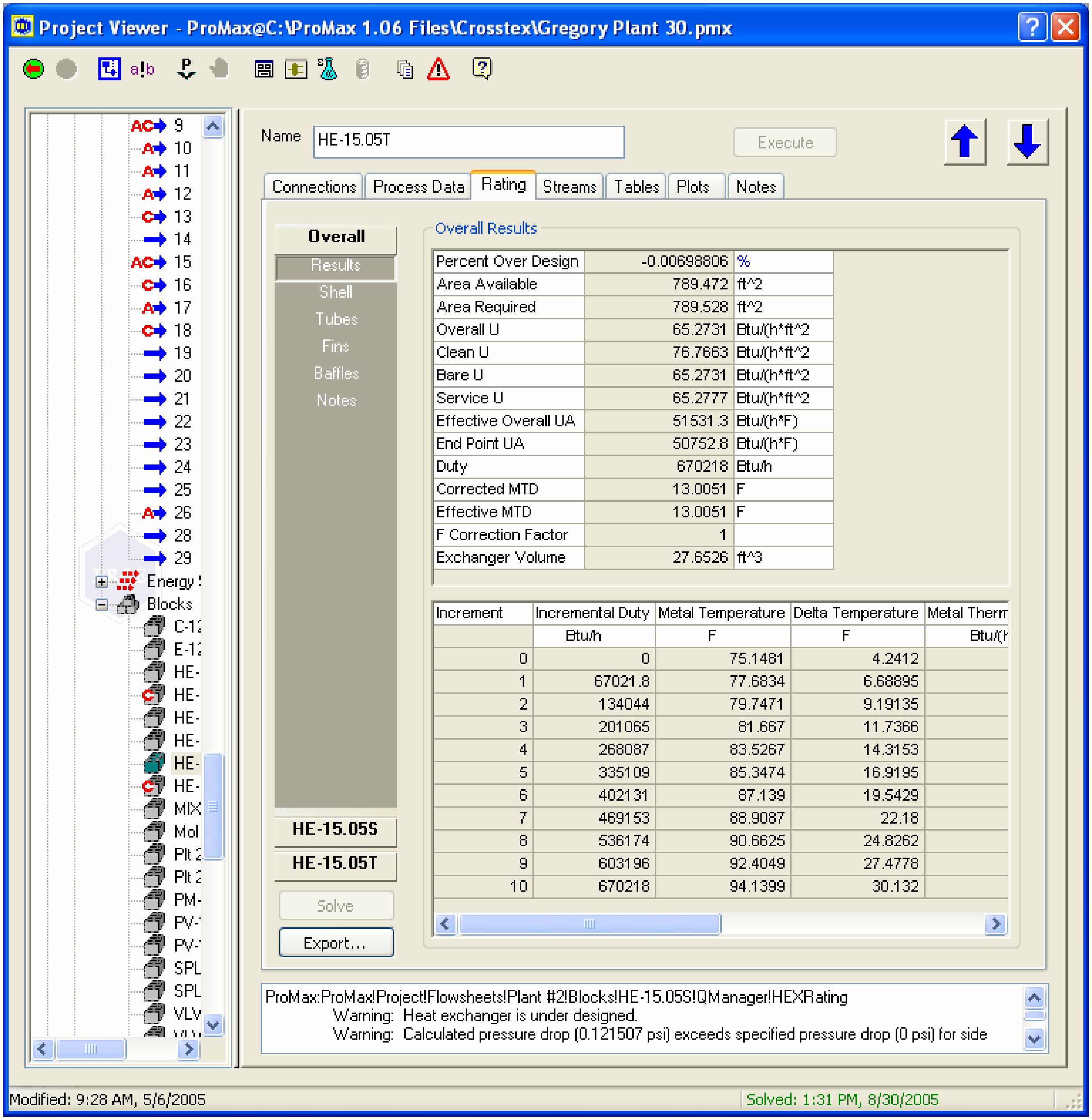



Figure 8 – Shell and Tube Exchanger Rating

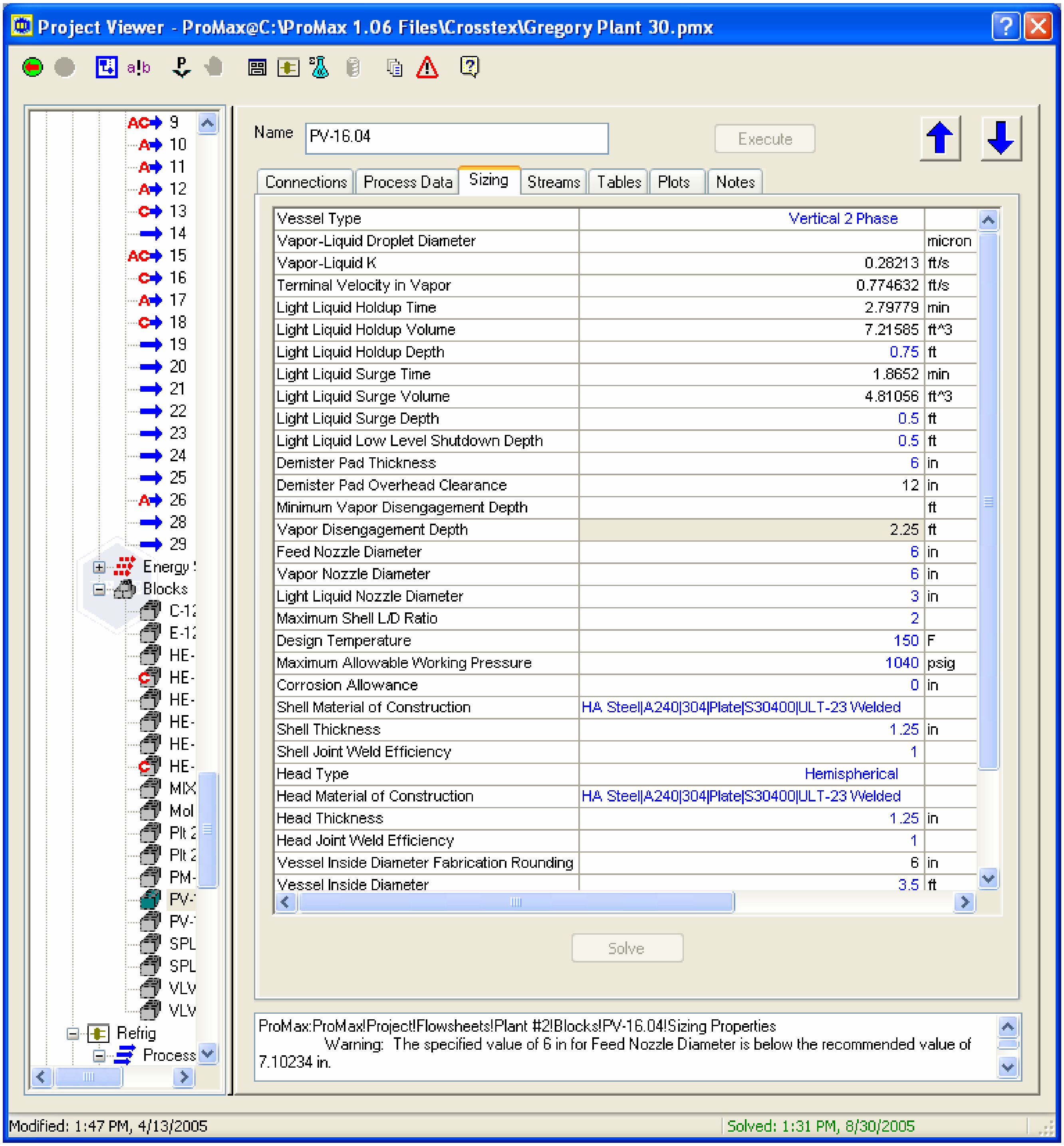
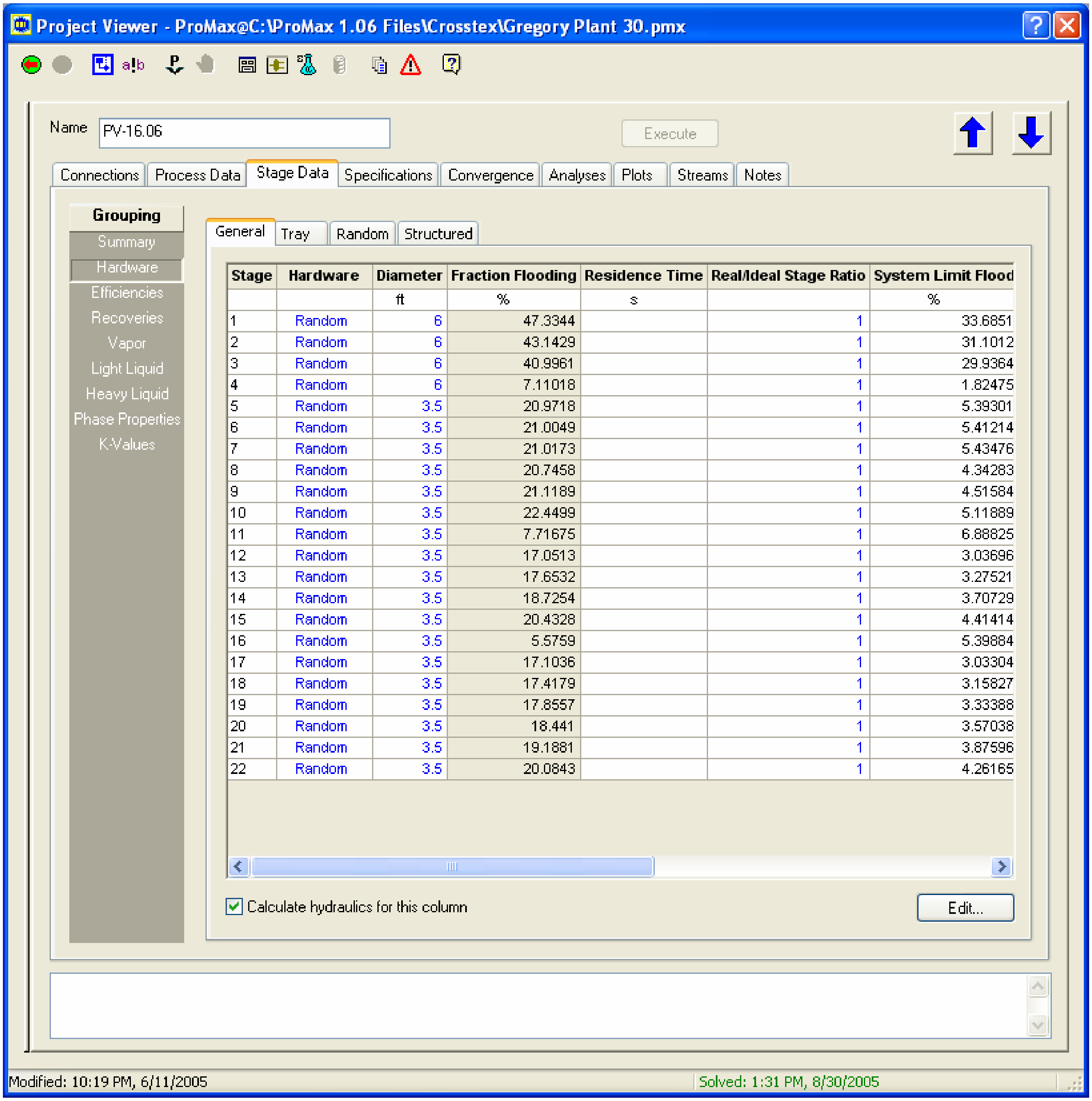



Figure 9 – Cold Separator Rating




| Stage | Hardware | Diameter | Fraction Flooding | Residence Time | Real/Ideal Stage Ratio | System Limit Flood |
|---|---|---|---|---|---|---|
| | | ft | % | s | | % |
| 1 | Random | 6 | 47.3344 | | 1 | 33.6851 |
| 2 | Random | 6 | 43.1429 | | 1 | 31.1012 |
| 3 | Random | 6 | 40.9961 | | 1 | 29.9364 |
| 4 | Random | 6 | 7.11018 | | 1 | 1.82475 |
| 5 | Random | 3.5 | 20.9718 | | 1 | 5.39301 |
| 6 | Random | 3.5 | 21.0049 | | 1 | 5.41214 |
| 7 | Random | 3.5 | 21.0173 | | 1 | 5.43476 |
| 8 | Random | 3.5 | 20.7458 | | 1 | 4.34283 |
| 9 | Random | 3.5 | 21.1189 | | 1 | 4.51584 |
| 10 | Random | 3.5 | 22.4499 | | 1 | 5.11889 |
| 11 | Random | 3.5 | 7.71675 | | 1 | 6.88825 |
| 12 | Random | 3.5 | 17.0513 | | 1 | 3.03696 |
| 13 | Random | 3.5 | 17.6532 | | 1 | 3.27521 |
| 14 | Random | 3.5 | 18.7254 | | 1 | 3.70729 |
| 15 | Random | 3.5 | 20.4328 | | 1 | 4.41414 |
| 16 | Random | 3.5 | 5.5759 | | 1 | 5.39884 |
| 17 | Random | 3.5 | 17.1036 | | 1 | 3.03304 |
| 18 | Random | 3.5 | 17.4179 | | 1 | 3.15827 |
| 19 | Random | 3.5 | 17.8557 | | 1 | 3.33388 |
| 20 | Random | 3.5 | 18.441 | | 1 | 3.57038 |
| 21 | Random | 3.5 | 19.1881 | | 1 | 3.87596 |
| 22 | Random | 3.5 | 20.0843 | | 1 | 4.26165 |

Figure 10 – Demethanizer Column Rating/Sizing

**Implementing the Predictive Model**

Now that the plant model had been built and all available equipment rated, a fully predictive plant model was developed using these ratings and incorporating them into the actual simulation run to be used to adjust parameters (such as Duty or Tower Pressure) to meet specified (or measured) criteria, such as Percent Over Design in heat exchangers or pressure at the discharge of the Booster Compressor. This predictive capability is accomplished using a feature called “Solvers”. For example, a common Solver that was used was the adjustment of an exchanger duty to provide an exchanger with 0% Over Design (i.e. predicted actual performance). Since ProMax allows for direct connect of exchangers to columns (Figure 11), the exchanger and column interaction is accomplished "on-line", in an iterative process that solves the column, then the exchanger, adjusting the exchanger duty for the specified Percent Over Design (POD), then solving the column again with the revised calculated duty (Figure 12). This process continues until there is final convergence for both the exchanger and the column. Solvers were used to determine performance of ***all*** exchangers simultaneously, as well as the tower pressures, expander/compressors and other equipment within the Gregory Plant and, thus, used to optimize performance of the entire plant for a given set of operating conditions. Crosstex was able to determine the accuracy of this model by varying the inlet gas composition and flow and then comparing the actual plant operating data to the results predicted by the simulator; the two sets of data were nearly identical.

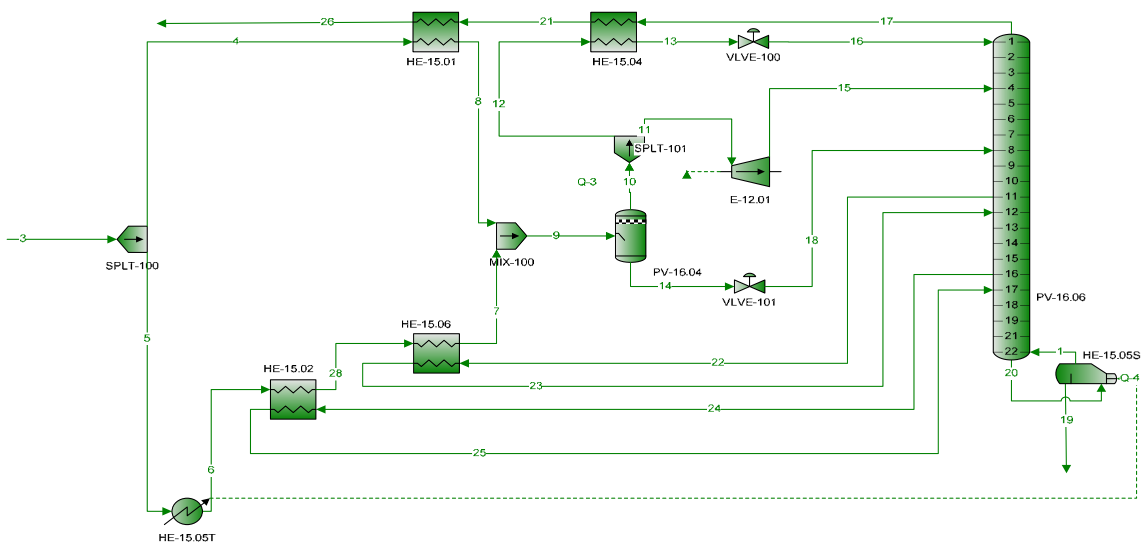



Figure 11 – Direct Connection of Exchangers and Columns

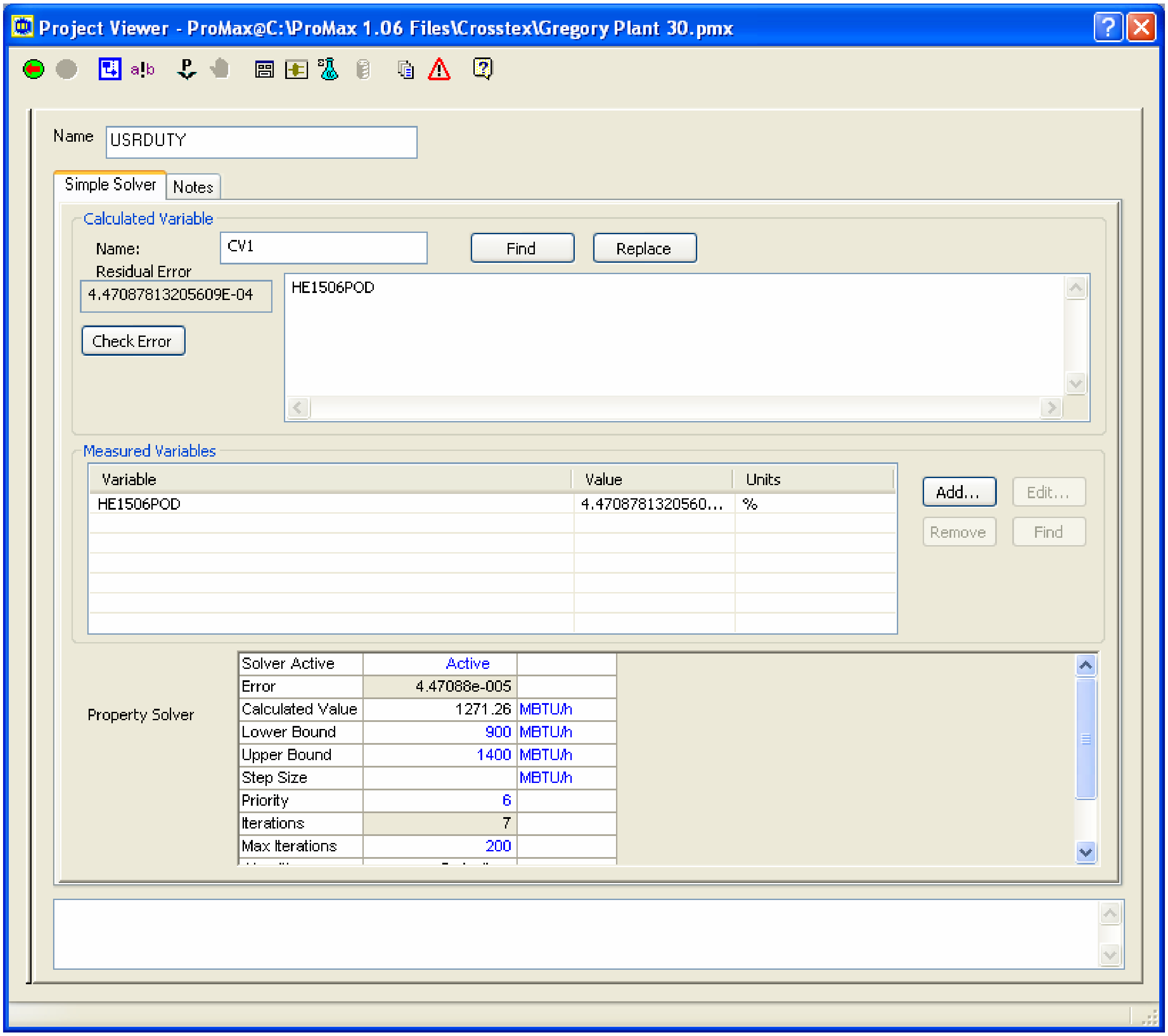



Figure 12 – Solver for Exchanger Duty vs Percent Over Design

**Comparison of Plant Operation Under Varying Conditions**

Unfortunately, plant operating conditions rarely stay constant for any length of time, even though the Plant Operators may try to maintain the same operating guidelines and setpoints for years. The inlet gas to the Gregory Plant has become richer over the years and plant performance has declined. Through use of the simulation model, it was determined that Plant #2 was more affected by the higher ethane-plus content than was Plant #1. However, it was difficult to make side-by-side comparisons of the two plants, while making individual process changes. It was at this time that the ProMax Scenario Tester tool was employed (Figure 13). This tool allows the User to import input data for numerous cases into the simulation model directly from an embedded Excel workbook.

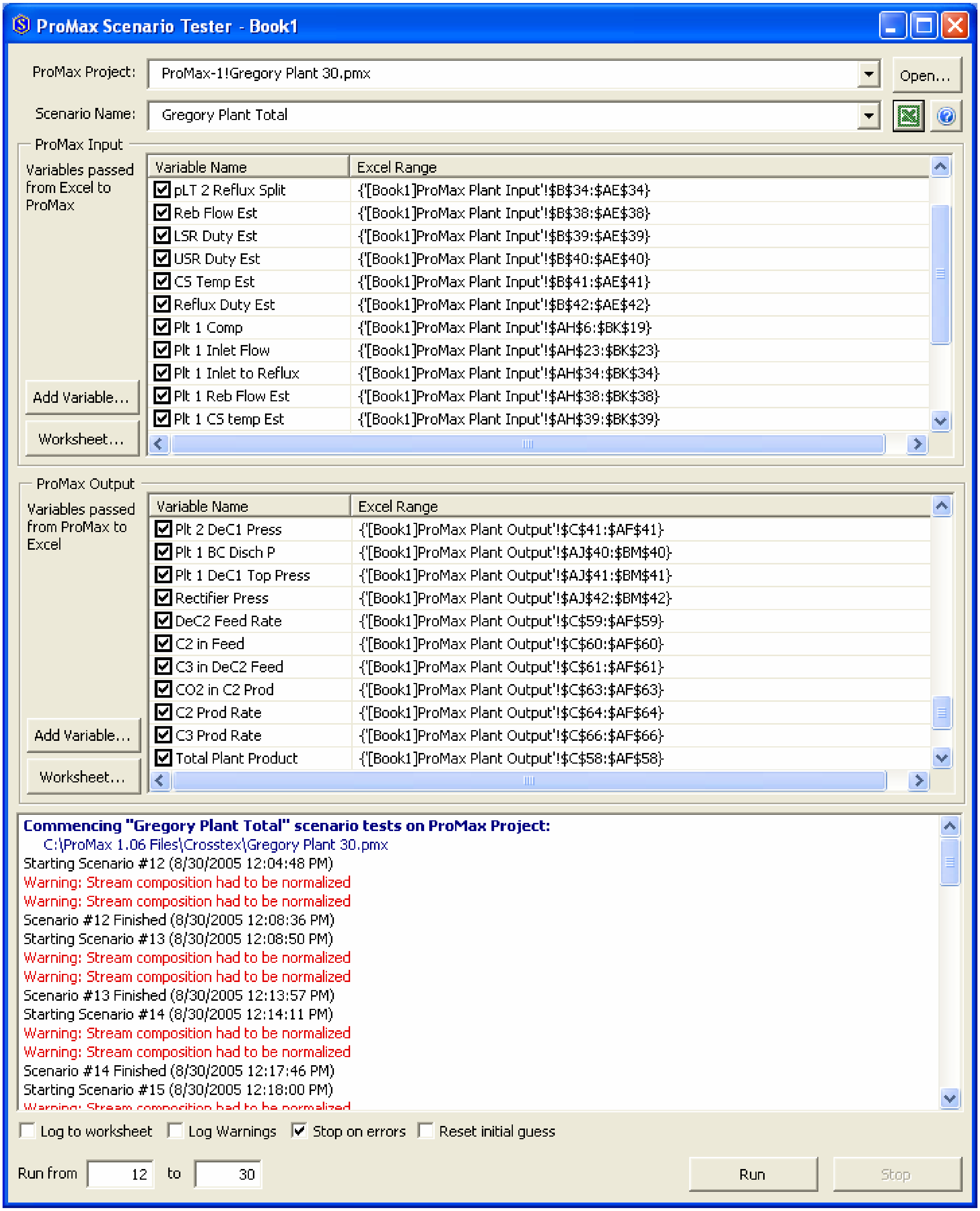



Figure 13 – Scenario Tester Tool

Additionally, output data for these same cases can be exported from the simulation model directly back to Excel. Thus, Crosstex was able to simulate the plant performance under a wide variety of operating conditions and have the output from each simulation run displayed on an Excel spreadsheet, next to the results from the previous and subsequent simulation runs (Figure 14).

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| NGL Prod Rate (gpd) | 113291 | 113862 | 114805 | 115041 | 114912 |
| C2 in NGL (mol/hr) | 228.85 | 231.20 | 234.94 | 235.96 | 235.55 |
| C2 in Residue (mol/hr) | 68.61 | 66.26 | 62.52 | 61.50 | 61.91 |
| C2 in Inlet Gas (mol/hr) | 297.46 | 297.46 | 297.46 | 297.46 | 297.46 |
| **Plant C2 Recovery (%)** | **76.935** | **77.725** | **78.983** | **79.324** | **79.188** |
| Cold Separator Temp (F) | -<br>33.30173 | -30.9617 | -<br>28.85925 | -<br>26.83146 | -<br>25.23441 |
| **HE-15.01 Min App T (F)** | 15.484 | 15.212 | 14.826 | 14.610 | 14.470 |
| **HE-15.01 POD (%)** | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 |
| **HE-15.01 Duty (MMBtu/hr)** | -9.477 | -9.243 | -9.026 | -8.833 | -8.690 |
| HE-15.05 Min App T (F) | 4.094 | 4.091 | 4.096 | 4.088 | 4.080 |
| HE-15.05 POD (%) | -0.002 | -0.005 | 0.001 | -0.027 | -0.004 |
| HE-15.05 Duty (MMBtu/hr) | -0.743 | -0.746 | -0.754 | -0.755 | -0.752 |
| **HE-15.02 Min App T (F)** | 1.967 | 1.942 | 1.934 | 1.915 | 1.889 |
| **HE-15.02 POD (%)** | 3.012 | 2.980 | 2.997 | 3.081 | 2.999 |
| **HE-15.02 Duty (MBtu/hr)** | 583.437 | 581.421 | 583.492 | 580.295 | 575.722 |
| HE-15.06 Min App T (F) | 15.522 | 15.277 | 15.004 | 14.824 | 14.705 |
| HE-15.06 POD (%) | 0.002 | 0.000 | -0.001 | -0.013 | 0.001 |
| HE-15.06 Duty (MBtu/hr) | 1345.378 | 1331.052 | 1317.880 | 1305.575 | 1294.054 |
| **% Gas to Reflux** | **25.000** | **26.000** | **27.000** | **28.000** | **29.000** |
| Reflux Temp (F) | -<br>141.0451 | -<br>140.8876 | -<br>140.7449 | -<br>139.0401 | -<br>135.9067 |
| HE-15.04 Min App T (F) | 1.138 | 1.513 | 2.246 | 3.970 | 6.396 |
| HE-15.04 POD (%) | -0.039 | -0.015 | 0.001 | 0.000 | 0.000 |
| HE-15.04 Duty (MMBtu/hr) | 4.918 | 5.180 | 5.438 | 5.647 | 5.790 |
| Inlet Gas Flow (MMSCFD) | 60.000 | 60.000 | 60.000 | 60.000 | 60.000 |
| **Inlet GPM** | **2.150** | **2.150** | **2.150** | **2.150** | **2.150** |
| Gas Flow to Reb (MMSCFD) | 11.719 | 11.740 | 11.687 | 11.705 | 11.719 |
| Tower Btm Temp (F) | 75.043 | 74.840 | 73.978 | 73.985 | 74.232 |
| C1/C2 Ratio (LV Frac) | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 |
| CO2/C2 Ratio (mol frac) | 0.034 | 0.033 | 0.033 | 0.033 | 0.033 |
| Expander HP | -729.48 | -729.00 | -730.28 | -727.67 | -722.97 |
| Booster Comp Disch P (psig) | 384.52 | 385.07 | 384.15 | 384.47 | 384.55 |
| DeC1 Top Pressure (psig) | 323.92 | 324.42 | 323.57 | 324.07 | 324.57 |

Figure 14 – Output Data from ProMax

Using these results Crosstex was able to compare what type operation provided the highest product recovery and best fuel efficiency, as well as system bottlenecks and limitations. One example of this is the optimization of the reflux rate used in the GSP plant design (Figure 15). As can be seen by the plots, the ethane recovery from the plant is dependent on the reflux rate and has an optimum point for plant performance. You can also see that the optimum reflux rate changes as inlet gas composition changes.

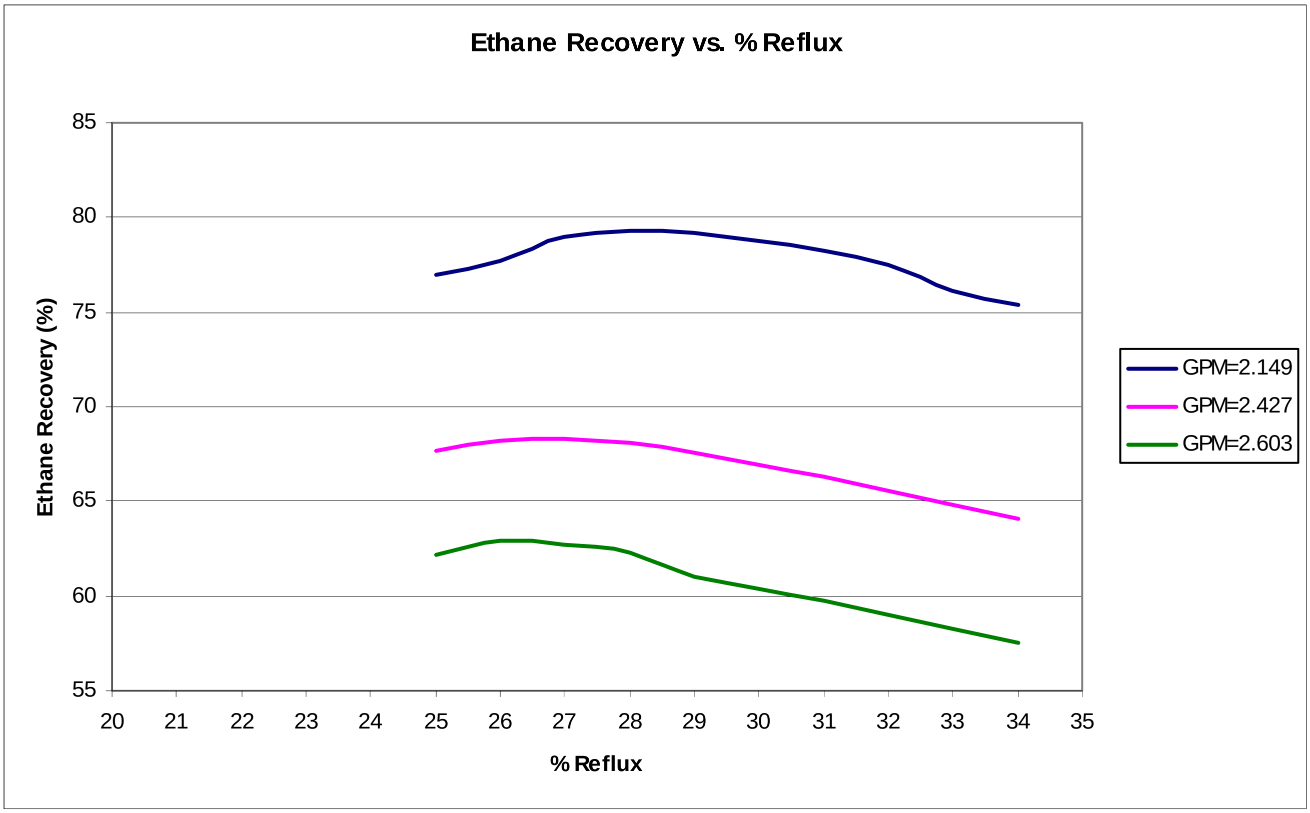



Figure 15 – Ethane Recovery vs Reflux Rate

The results from the different simulation runs were then assimilated and reviewed to determine the best manner to run the plant facility to maximize production and minimize operating costs. Armed with this information, Crosstex went to the field and began to apply the simulation results to actual plant operation. Within a matter of hours, the Engineer had worked with Operations to increase ethane production and reduce the required external heat supply into the plant, while still meeting all product specifications. This was accomplished through a series of steps that included: Lowering the reflux rate from the specified design rate of 34% to 30% and re-distribution of the inlet gas streams feeding Plants 1 and 2, to provide a leaner feed stream to Plant #2 and a heavier feed stream to Plant #1. This resulted in a lower Cold Separator temperature and Demethanizer bottoms temperature. In fact, the actual plant performance almost exactly matched that predicted by the simulation model for the given inlet conditions.

Unfortunately, declining gas rates into the Gregory Plant facility necessitated a temporary shut down of Plant #2 before all optimization measures could be fully implemented. However, the results clearly showed how the simulation tool could be used to accurately model, predict and optimize a plant's operation.

## CONCLUSIONS

Use of a simulation tool can provide an abundance of information to help determine the best way to operate your facilities. If that simulation tool also allows you the ability to run multiple cases in a sequential manner, rate and predict the performance of equipment within the plant and provide appropriate output data for each case, the Operator and/or plant control system can respond to the variation in operating parameters almost simultaneously with the variation. While ProMax is a steady-state simulator, these capabilities bring the simulator to the precipice of dynamic simulation.