TEXAS TECHNOLOGY 2003 Showcase

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Houston, Texas
Energy-Efficient Process Technologies and BestPractices
Chemical and Refining Industries

Valero Energy Corporation

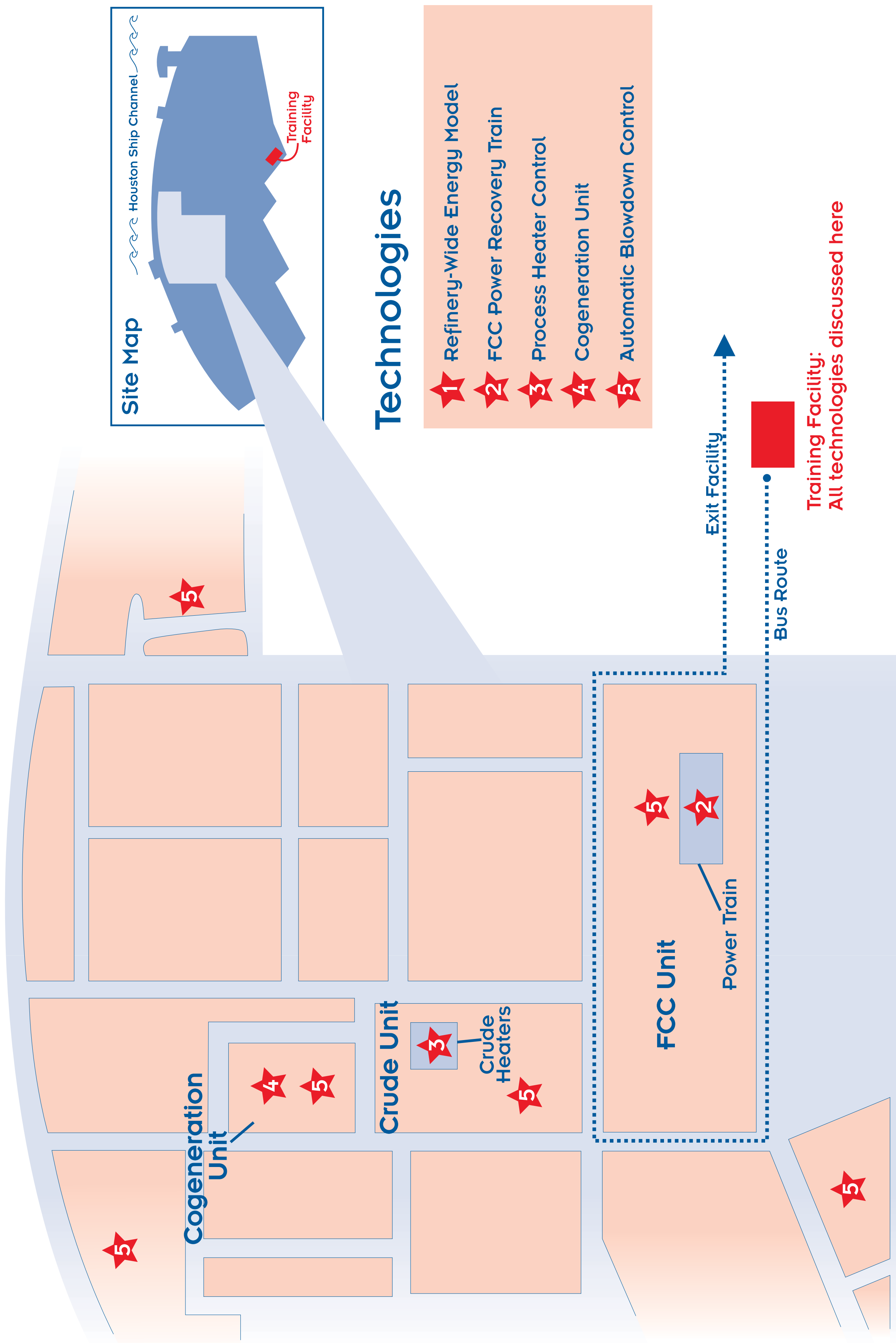
Tour Guide Book
Houston Refinery

U.S. Department of Energy
Energy Efficiency
and Renewable Energy

VALERO REFINING-TEXAS, L.P.

Texas Industries of the Future

Tour Route



Site Map
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Texas Showcase Sponsors:

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Plant Overview

Valero Energy Corporation

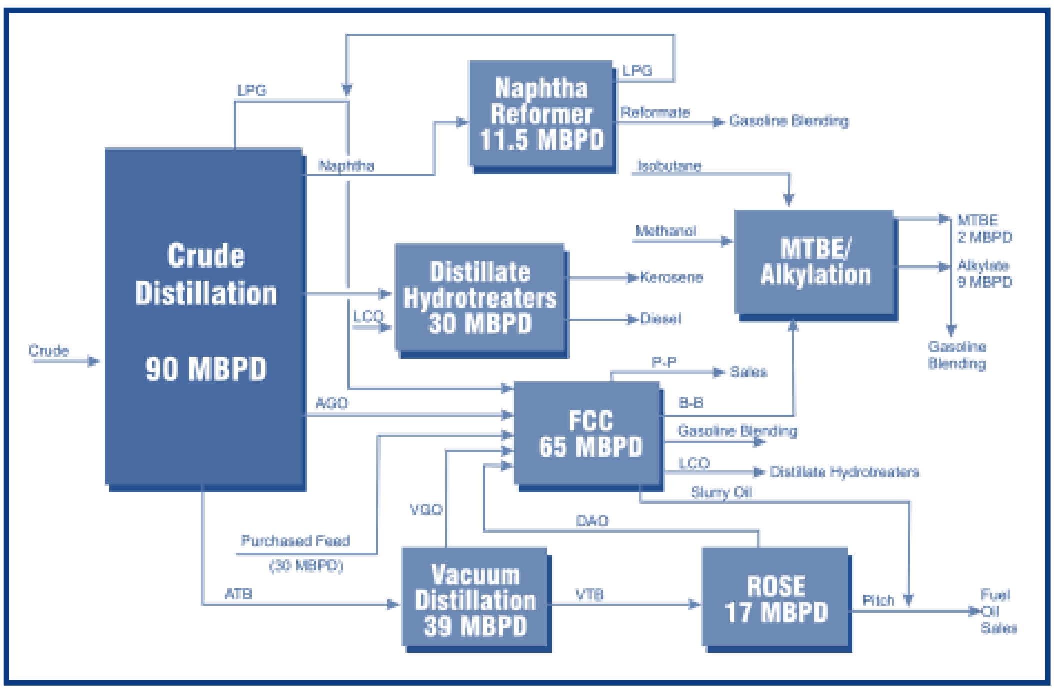
Houston Refinery

Established in 1980, Valero Energy Corporation is the largest independent refining and marketing company in the United States, generating $30 billion in revenues. Valero now owns twelve refineries in the United States and Canada with a total throughput of nearly 2 million barrels per day. *Industry Week Magazine* named Valero one of the "100 Best-Managed Companies" in the world in 2000, and *Fortune Magazine* honored Valero as one of the "100 Best Companies to Work for in America" in 1999, 2000, and 2002 (ineligible in 2001 because of merger with Ultramar Diamond Shamrock).

Valero uses lower-cost, heavy, sour feedstocks to produce a high percentage of premium fuels such as premium gasoline, reformulated gasoline, or CARB (California Air Resources Board) gasoline. Heavy, sour feedstocks account for approximately 75% of the feedstocks processed. Valero acquired its Houston refinery in 1997 from Basis Petroleum, Incorporated. The mid-sized refinery, which began operating in 1940, is located on 303 acres along the Houston Ship Channel and has access to several major product pipelines. The refinery has a feedstock throughput capacity of approximately 136,000 barrels per day.

The refinery is flexible and offers a wide range of products including gasoline, diesel, kerosene, asphalt, jet fuel, fuel oil, sulfur, liquefied petroleum gas, and chemical feedstocks. The refinery employs approximately 325 workers.

Employee safety and the environment are primary concerns for Valero. The company's recordable injury rate is far better than the industry average. The Houston refinery's safety record has been recognized by the City of Houston and Valero management. Valero is also setting high environmental standards as one of the only U.S. refiners to receive a 2000 Environmental Achievement Award at America's Clean Air Celebration and as the only petroleum refiner ever to win the "Texas Governor's Award for Environmental Excellence." In addition, Valero was the first Texas refiner to voluntarily obtain permits for its "grandfathered" refinery emission sources.



Valero Houston Refinery Process Flow Diagram

Refinery-Wide Energy Optimization Model

Case Study

Summary

Valero Energy Corporation is one of the top refiners in the nation. The company owns 12 refineries throughout North America and is the largest independent refining and marketing company on the Gulf Coast. The Valero Houston refinery is mid-sized, with a throughput capacity of approximately 136,000 barrels per day.

In August 2002, the Valero Houston refinery began several energy performance assessments sponsored by the U.S. Department of Energy (DOE). The DOE Industrial Assessment Center at Texas A&M University performed an energy and productivity assessment, and DOE experts conducted a series of targeted energy system assessments. With cost-shared funding from the DOE, the Valero Houston refinery also began a plant-wide energy assessment, which included the development of a refinery Energy Optimization and Management System (EOMS) by Aspen Technology, Inc. (AspenTech). The EOMS will be used in assessing, implementing, and tracking results of the identified opportunities.

All of these assessments identified opportunities for energy performance improvements at the refinery. Plant engineers are reviewing and acting on these opportunities based on potential energy savings and capital availability.

Benefits

- Potential company-wide cost savings of $7 to $27 million per year.

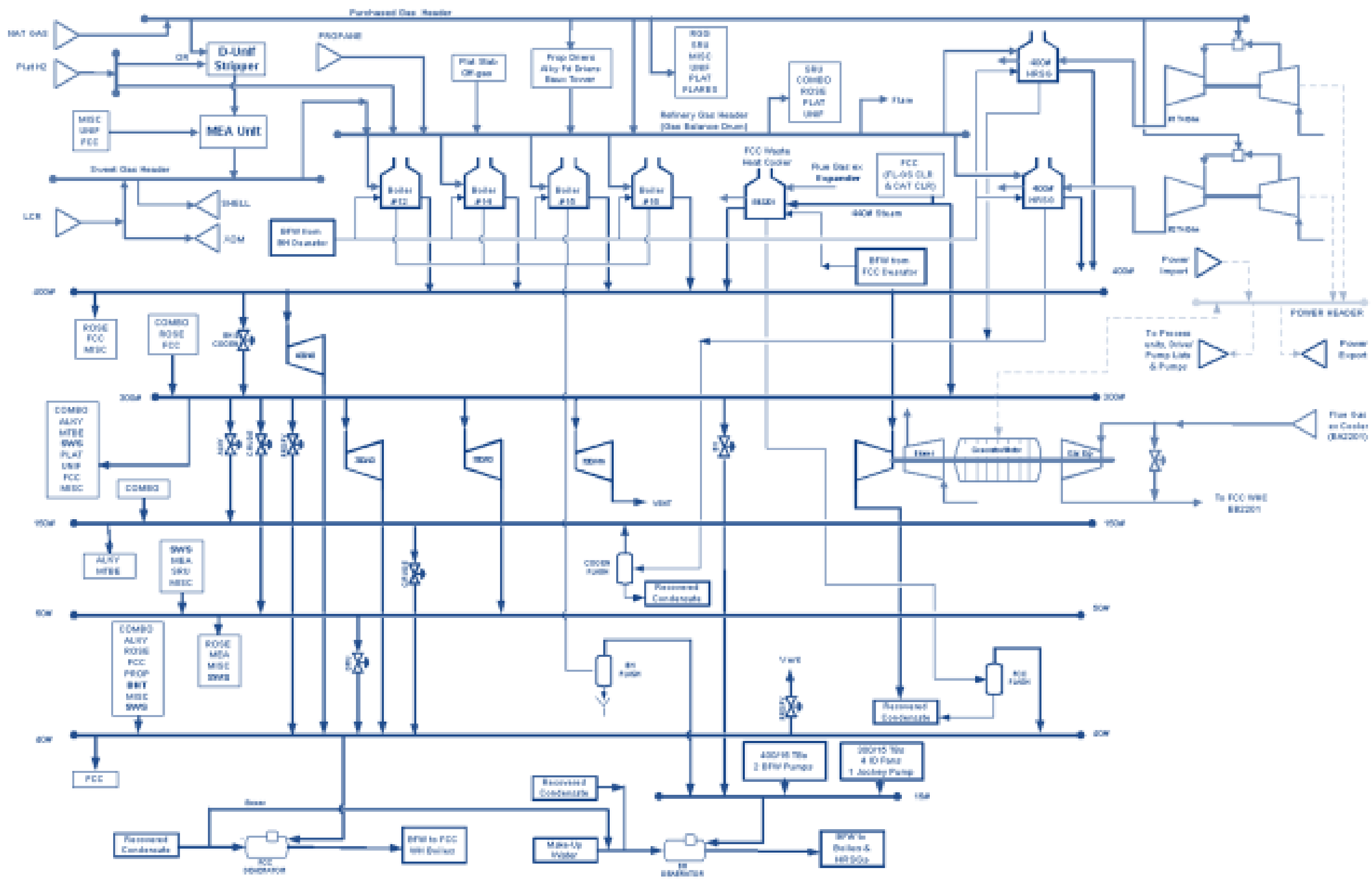
Project Overview

Valero's Houston refinery received cost-shared funding from the DOE to conduct a plant-wide energy assessment as part of the Texas Technology Showcase. To evaluate and track implementation of the identified opportunities, Valero hired AspenTech to design an EOMS, which is based on AspenTech's Aspen Utilities™ software.

Aspen Utilities™ is a model-based, equation-oriented simulation and optimization software tool. Within environmental constraints, it optimizes the purchase, supply, and usage of fuel, steam, and power at an industrial plant site. The software analyzes issues such as supply contract variability; alternative fuels; optimum loading of boilers and turbines; equipment choice; importing, self sufficiency, or export of electricity; and drive choice (motor or turbine).

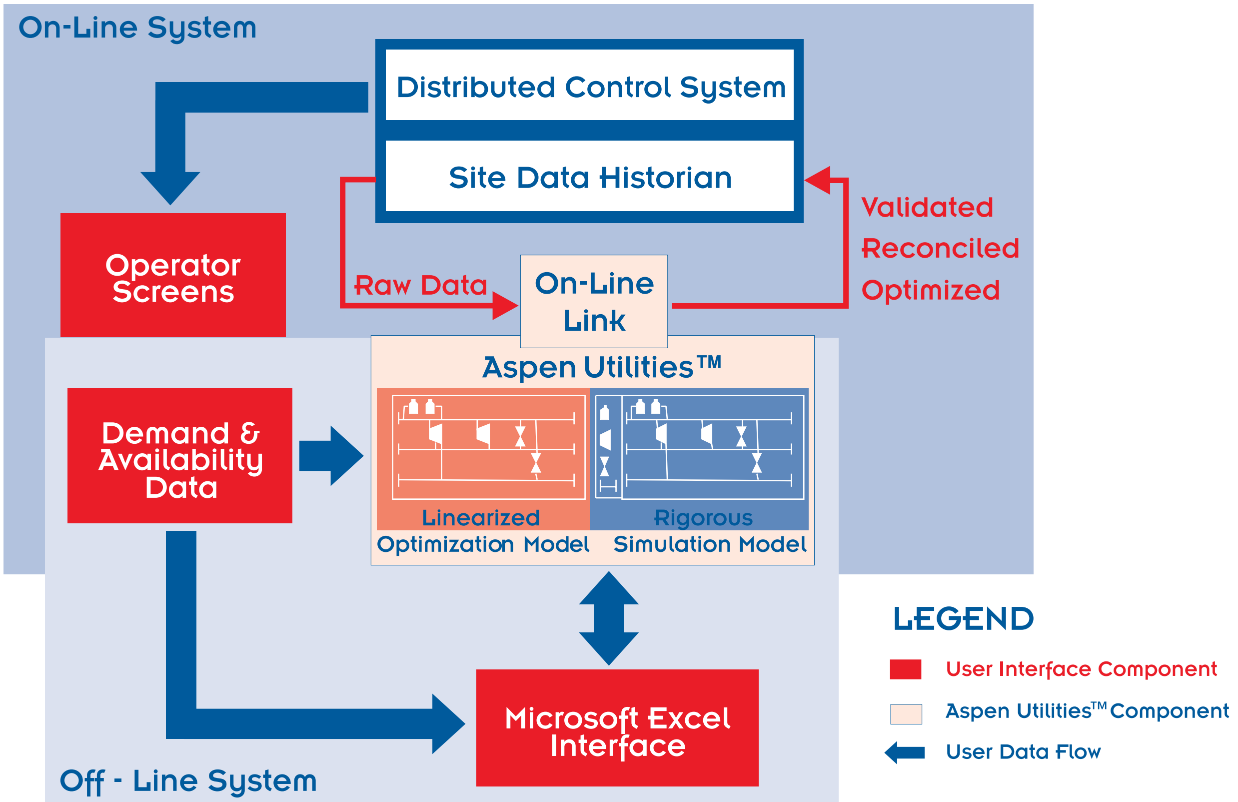
Aspen Utilities™ uses a library of equipment models specifically developed for utility systems, which can be tuned with real-time data to reflect current performance at a specific site. The software integrates production planning, operation optimization, contract structures, and system constraints to construct a refinery-wide flowsheet as a single, rigorous model for use by refinery management. A Houston refinery example flowsheet is shown in Figure 1.

Figure 1: Houston Refinery EOMS Flowsheet



Aspen Utilities™ can be used both off-line and on-line. Off-line, the model is used for budgeting and planning, or for running "what-if" analyses to evaluate process changes or equipment modifications. On-line, the same model runs data validation and reconciliation routines prior to running an optimization sequence to guide operators. The optimizer determines the most economic method for meeting the refinery's steam, fuel, and power demands by calculating the optimum equipment line-up and load, subject to set constraints. Built-in equations provide information that can be used for performance monitoring (e.g., identifying metering problems and quantifying steam leaks). Additionally, the on-line system can provide information such as flow rates of unmetered streams. Figure 2 illustrates the flow of information through the facility and identifies on-line and off-line capabilities.

Figure 2: Energy Optimization and Management System Overview



Overall, the system is designed to perform the following functions:

- Facilitate optimal operations planning of utilities equipment.
- Assist in optimal operation of the utilities plant and associated equipment.
- Provide real-time information on site-wide energy performance, utility costs, and revenue.
- Provide real-time information for use in maintenance prioritization.

The Houston refinery EOMS is designed with the following plant-specific capabilities:

- On-line, open-loop/advisory utilities optimization that gives recommendations on the following:
  - Optimum electric power import/export balancing, including load allocation between the Cogeneration Unit gas turbines and the FCC Unit power train flue-gas expander and steam turbine.
  - Energy recovery from the FCC Unit regenerator flue gas, including optimum trade-off between electric power from the power train expander and steam generation in the waste-heat cooler.
  - Optimum configuration of the fuel-gas system, including selection of hydrogen or natural gas as the stripping gas in the Hydrotreater Unit, as well as recommendation on the use of propane to supplement the refinery gas.
  - Optimum load allocation between heat recovery steam generators and boilers.
  - Selection of steam turbine and electric motor drives.
- Off-line utilities optimization for planning and strategic development.
- Plant data validation and reconciliation with faulty-meter detection and reporting (limited to three steam headers and the fuel-gas distribution system).

Project Team

For the system to deliver sustained benefits to Valero, effective technology transfer from AspenTech to Valero is essential. The project is structured to involve Valero engineers as much as possible. Valero personnel's responsibilities include the following:

- Development of Excel graphics for the off-line model.
- Reviewing the model and testing the system for accuracy.
- Selecting appropriate tags (equipment variables) for reconciliation of data.
- Configuring the on-line version of the software, Aspen Online.

By staying heavily involved in the design of the EOMS, Valero personnel will become proficient in incorporating plant changes as they occur and expanding system capabilities in the future.

Project Implementation

The effort to develop and implement the proposed system will occur in three major stages as defined below.

Stage	Deliverable	Estimated Completion Date
Stage 1	Energy system review and user-requirements specifications	December 2002
Stage 2	Execution and delivery of off-line system	February 2003
Stage 3	Execution and delivery of on-line system	June 2003

To date, Stage 1 and 2 of the project are complete, with a refinery-wide assessment of all the energy-related systems at the refinery and delivery of the off-line system. The assessment provided the necessary information to define and begin development of the Aspen Utilities™ model. The primary use of the off-line system delivered at the end of Stage 2 is off-line planning and configuration of the utilities plant.

Future Plans

Valero's EOMS is designed for future expansion into other process and business areas. Valero plans to extend the EOMS by incorporating such functions as demand forecasting, performance monitoring, emissions monitoring, and cost accounting. Valero is using the Houston refinery to pilot test the energy model methodology and plans to replicate the refinery-wide energy model at its other facilities.

Savings

Valero Houston refinery expects significant economic benefits from refinery-wide implementation of the EOMS. Benefits will be realized through improved energy purchasing with lower contract prices, better adherence to contract terms to reduce penalties, maximized use of the most efficient equipment, accurate selection of fuel type, reduction of standby equipment and steam venting, and faster responses to problems.

Typical cost savings at comparable refineries are in the range of 2 to 8% of energy expenditures. If the EOMS performs as expected in all 12 refineries, it has the potential to save Valero $7 to $27 million per year company-wide.

FCC Power Recovery Train

FCC Unit Process Description

The Fluid Catalytic Cracking (FCC) Unit, sometimes referred to as the "Cat," is one of the key process units in most petroleum refineries. The FCC Unit cracks low-value, heavy hydrocarbons into lighter and more valuable hydrocarbon products such as fuel oils, gasoline, and light olefin-rich products. The process name comes from the high-temperature, fluidized bed of fine catalyst that circulates through the unit and promotes hydrocarbon cracking reactions. The two sections that form the heart of the FCC are the reactor, which is the main vessel in which the oil feedstock is cracked, and the regenerator, the vessel in which carbon (coke) deposits on the catalyst are burned off. (Carbon is deposited on the catalyst during the cracking reactions.)

Refineries have used the FCC process for over 50 years, and the process has undergone numerous improvements. One of the most significant improvements has been the addition of an energy recovery system, or Power Train, to the regenerator flue gas stream. Valero included a Power Train in the Houston refinery FCC Unit design and construction in 1995 to recover energy from the regenerator flue gas stream. The recovered energy is used to drive the regenerator air blower, avoiding the need to build a separate electric motor driver.

Power Train Process Description

FCC regenerator flue gas leaves the regenerator at around 40 psig and 1,350°F and flows to a catalyst separator, where large entrained catalyst particles are removed. The gas then leaves the top of the separator and enters a gas expander through a throttling butterfly valve. The valve controls the back pressure on the regenerator and, if necessary, can redirect a portion of the gas around the expander.

The flue gas in the expander is converted into mechanical power, which drives a 24,000-hp axial compressor. The compressor, commonly referred to as an air blower, provides both combustion and fluidizing air to the regenerator.

The expander exhaust, which is close to atmospheric pressure and around 935°F, flows to the FCC waste heat boiler, where it is used to generate steam. When the exhaust leaves the waste heat boiler, it flows to an electrostatic precipitator to further reduce particulate concentration.

A good control strategy is essential to avoid costly shutdowns. Power Train controls have become more flexible and reliable over the years as electronic controls have replaced relays and pneumatic technologies.

Benefits

- Power savings of up to 22 MW.
- Revenue from sales of up to 4 MW electrical power through occasional excess power generation.
- Safe and reliable operation utilizing modern electronic controls.

Figure 1: FCC Process Unit and Power Recovery Train

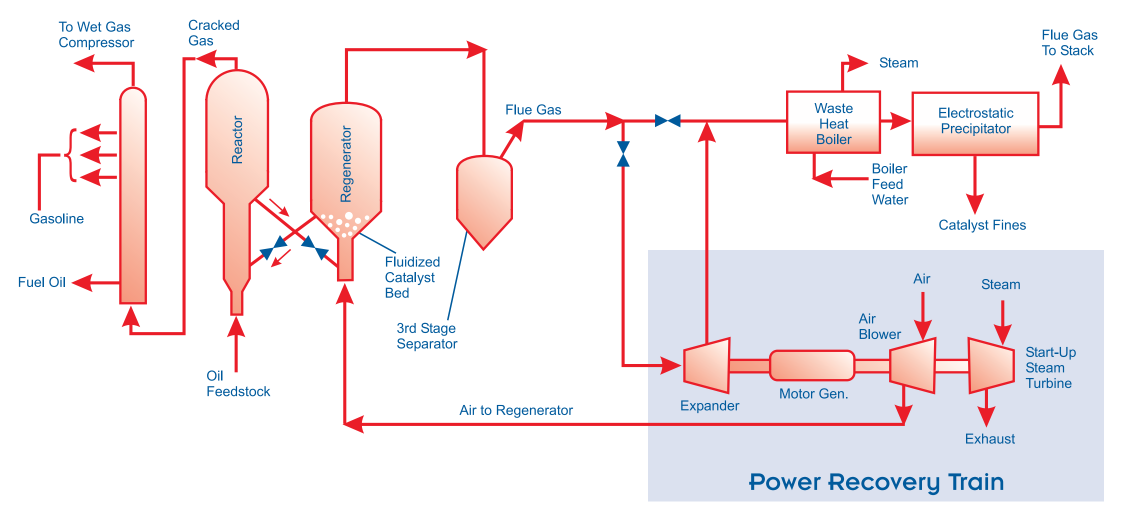


Figure 1 shows a simplified process flow diagram of the FCC Process Unit and the Power Recovery Train.

The Power Recovery Train consists of the following mechanically coupled pieces of equipment:

- Hot gas expander (single-stage gas turbine) — Provides power to drive the air blower.
- Electric motor/generator — Provides additional power when needed to drive the air blower, or serves as a generator when the expander provides excess energy.
- Air Blower (axial compressor) — Provides combustion and fluidizing air to the FCC regenerator.
- Steam turbine — Used during startup to bring the train up to speed before the motor is started.

Savings

By recovering energy from the hot flue gases to drive the 24,000-hp air blower, the refinery is saving up to 22 MW. The Power Train is designed to generate more energy output than the air blower might need and, in certain operating situations, will export additional power (up to 4 MW) for sale to the grid.

Process Heater Low Excess Air Control

Valero's Houston refinery operates three process heaters in its Crude Distillation Unit. In January 2003, the refinery upgraded two of these heaters with an advanced control system that minimizes excess combustion air. The system improves combustion efficiency and reduces oxides of nitrogen (NO_x) emissions.

The control system selected for the upgrades is the CO Control Technology from Bambeck Systems, Inc. (BSI) of Santa Ana, CA. This low excess air control system enables Valero to operate with only 1% oxygen instead of the 3 to 4% that is typical in refinery process heaters. The project has simultaneously reduced fuel gas use in the two heaters and reduced NO_x and carbon dioxide (CO_2) emissions in the heater stack gas.

Benefits

- Fuel gas savings of 3 to 6%.
- 10 to 25% reduction in NO_x emissions.
- Reductions in CO_2 emissions.
- Enhanced heater safety.

Process Description

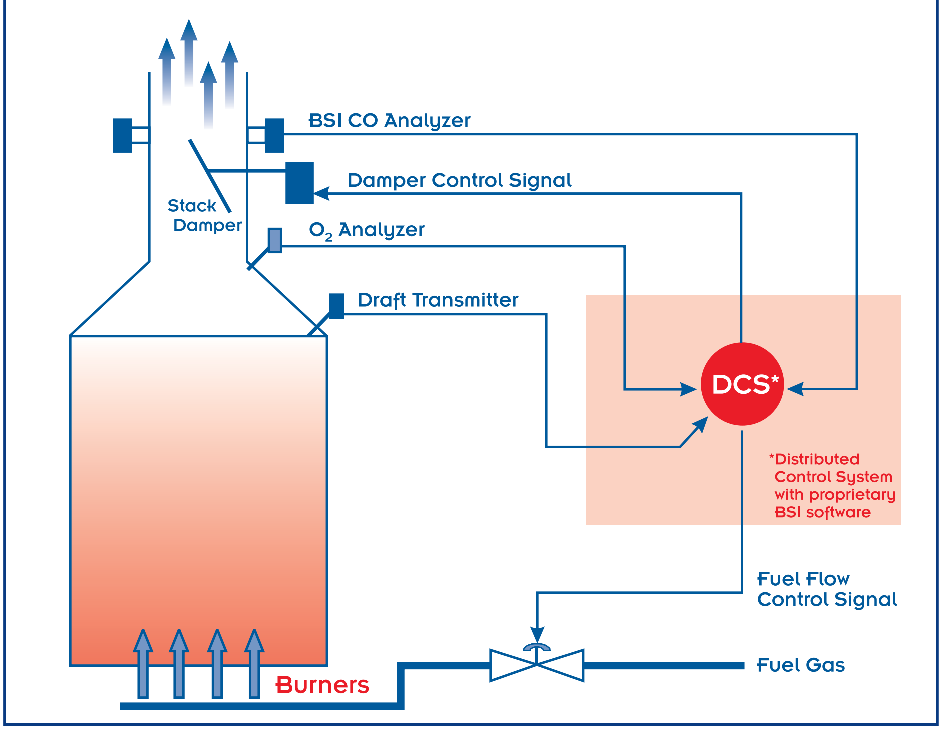
Both heaters are conventional, natural draft, refinery process heaters that fire refinery fuel gas. One heater is equipped with ultra-low NO_x burners. Process operators manually adjust the burner air registers as necessary. The BSI technology is an advanced control system that automatically adjusts the heater stack damper based on carbon monoxide (CO) measurements.

A BSI analyzer (infrared spectrometer) located in the heater stack measures CO concentrations, which are considered more reliable than oxygen (O_2) measurements alone as a basis for efficiency optimization. Figure 1 shows a simplified process heater diagram with an advanced CO control scheme.

Process Control

Although the controls and theory for operating process heaters at optimum fuel efficiency have been around for many years, high fuel costs have only recently stimulated

Figure 1: Process Heater Control Diagram



interest in advanced control systems. The advanced control strategy uses feedback signals indicating stack gas CO, O_2, and heater draft to automatically adjust the stack damper for optimal heater fuel efficiency. (Reducing excess air produces trace amounts of incompletely burned fuel in the form of CO in the stack gas.) The system is designed to be failsafe; the continuous monitoring and fine-tuning of combustion conditions enhance heater safety.

Figure 2: BSI Typical Process Heater Performance Data*

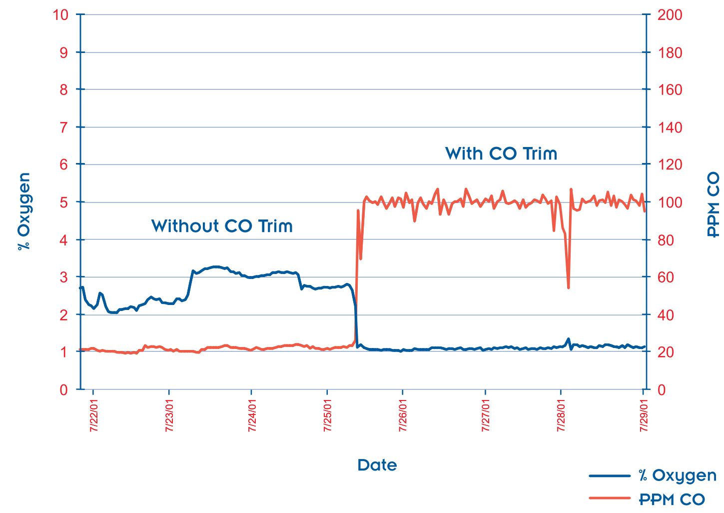
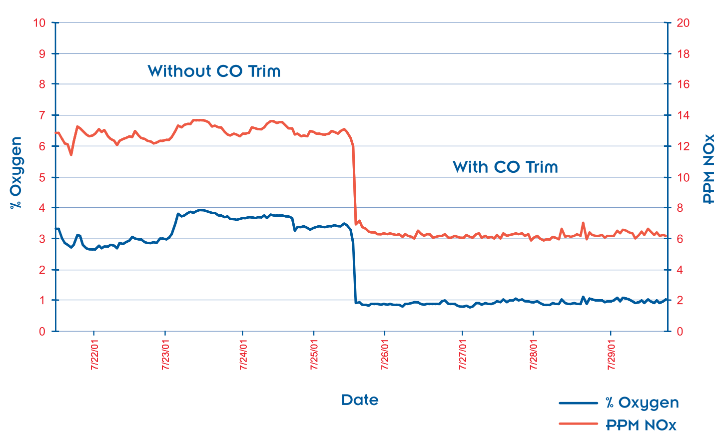


Figure 3: BSI Typical Process Heater NO_x Data*



**Valero Houston refinery performance data not yet available.*

Reducing O_2 from the 3 to 4% range to 1% limits the likelihood of O_2 combining with nitrogen from the excess combustion air to form NO_x. This restriction on oxygen availability reduces NO_x emissions in stack gas by up to 50%.

Figures 2 and 3 illustrate BSI performance data for a typical process heater with CO Control technology. The first diagram shows how CO increases with the decrease in oxygen, while the second shows how closely NO_x reduction is linked to oxygen levels.

Savings

Potential fuel gas savings at Valero's Houston refinery are in the range of 3 to 6%, which equate to over 9.8 MMBtu per hour or an estimated $340,000 per year. These savings should multiply as Valero upgrades additional process heaters with CO Control Technology. This project will help the refinery meet the newly finalized Texas Commission on Environmental Quality NO_x mandates by reducing heater stack gas NO_x emissions by 10 to 25%. CO_2 emissions will also be reduced as a direct result of improved combustion efficiency.

Over the next few years, BSI will be making similar upgrades to 94 process heaters at Valero refineries around the country. Company-wide savings are estimated to be $8.8 million per year.

Cogeneration Unit

In 1990, Valero constructed a 34-MW Cogeneration Unit at its Houston refinery. Cogeneration, a process that converts a fuel into both thermal and electrical energy, is used to produce two forms of useful energy output at the refinery: electrical power and utility steam. Two simple-cycle gas turbines in the Cogeneration Unit generate sufficient electricity to meet the refinery's demands, and occasionally produce excess for export to the local electrical grid.

Benefits

- Reduction of power costs by $40,000 per day.
- Reduction of steam production costs by $15,000 per day.
- Potential to sell to local power grid.

Project Overview

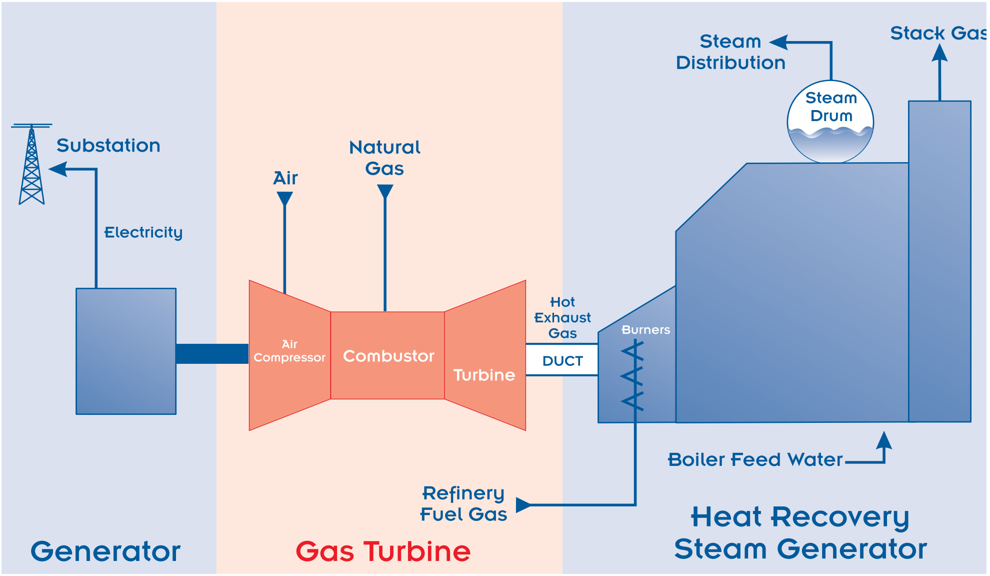
The Cogeneration Unit consists of parallel power equipment systems, with two Siemens-Westinghouse gas turbines and two heat recovery steam generators (HRSGs). The two turbines were purchased used and retrofitted, while the two HRSGs were purchased new. For each system, a generator converts mechanical power from the gas turbine into electrical energy. The HRSG produces utility steam for use throughout the refinery. The fuel source for the Cogeneration Unit is a combination of purchased natural gas and refinery-produced fuel gas. Figure 1 shows a simplified layout of a cogeneration system.

Process Description

Natural gas is supplied to the gas turbines, where it is combusted with compressed air. The combustion products and excess compressed air enter the turbine, where heat energy is absorbed and converted into mechanical work to drive the generator and produce electrical power. Each generator can produce approximately 17 MW of power, which is routed to a power substation for use by the refinery and for sale to the local electric utility.

The exhaust gas from the turbines is ducted to the HRSG at a temperature of approximately 775°F, with additional refinery fuel gas added for supplemental firing. Each HRSG can produce up to 240,000 pounds per hour of 750°F 440-psig steam, which is then directed to the refinery steam system. If one or both of the gas turbines are not running, the HRSGs are capable of operating independently by

Figure 1: Simplified Cogeneration Equipment Layout



automatically engaging a fresh-air fan system and supplemental burners. This flexibility helps Valero maintain balance in its refinery fuel gas and steam systems.

Equipment Description

The Siemens-Westinghouse gas turbine generator systems (W-191G) form a self-contained, combustion turbine-powered, electrical generator station rated at a base load output of 17,700 kW. The gas turbine is the simplest type of power generation apparatus available. It is completely self-contained, burning fuel and converting the heat to mechanical power within a single assembly. The gas turbine consists of a multistage, high-efficiency, axial compressor; a set of six combustors; and a turbine.

The modular HRSG is a horizontal, natural-circulation, forced-draft boiler. The hot turbine exhaust gas is routed to the boiler through a duct equipped with flow-routing dampers. Supplemental, low-NO_x duct burners are located in the boiler ducting to provide additional heat when required.

Savings

By generating its own power, the Valero refinery is enhancing its reliability and avoiding purchase of electricity from an off-site utility provider. Valero estimates savings of approximately $40,000 per day. The refinery has reduced steam production costs by using the hot exhaust gas from the turbine to produce steam. This saves the refinery approximately $15,000 per day.

Electrical power and steam production cost savings are offset by an increase in natural gas purchase for firing the turbines. This expense is dependent on the market price of natural gas. The refinery can also export power to the local grid when the on-site electrical requirement is lower than cogeneration production.

Cooling Tower and Boiler Automatic Blowdown Control

History

In August 2002 a DOE-sponsored Industrial Assessment Center team from Texas A&M University conducted a three-day assessment of Valero's Houston refinery. The faculty-led student group identified opportunities for the refinery to conserve energy and prevent pollution for a total estimated savings of over $3 million per year.

Following the assessment, the refinery implemented five of the recommendations, including two recommendations involving automated blowdown. The refinery contracted with GE Betz to provide and install automatic conductivity controllers on the blowdown streams of four cooling towers and three boilers, replacing the manual systems.

Cooling Water and Boiler Water Systems

Cooling water and boiler water contain numerous impurities that exist in the form of ions. Some common examples are calcium, magnesium, sodium, silica, oxygen, and iron. All ions are electrically charged and, consequently, conductive. Conductivity is directly related to the amount of total dissolved solids within the water. If the total solids level, or conductivity, is too high, deposits form in the water. Over time deposits concentrate in the system, requiring that a portion of the water be removed, or blown down. Fundamentally, water control is necessary to minimize corrosion and fouling, which could otherwise lead to the destruction of process equipment, frequent process unit shutdowns, loss of heat transfer, and reduced process unit efficiency.

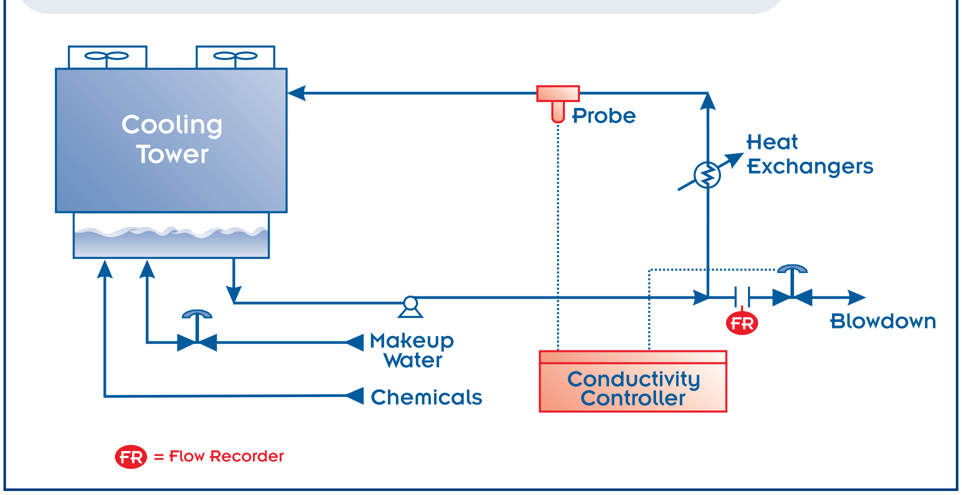
Benefits

- Over $340,000 per year in savings by reducing the amount of purchased makeup water and treatment chemicals, and limiting flow to the water treatment plant.
- More reliable system operation.
- Enhanced corrosion and fouling prevention.

Cooling Towers

The Valero cooling water systems circulate cooling water between process heat exchangers and cooling towers. Heat is removed from the system in the towers through evaporation as water comes into contact with air. Makeup water must be added to the water systems to replace evaporation and drift losses. Blowdown water is increased or decreased to maintain the concentration of dissolved solids at a target level. Makeup water is added to the tower basin and blowdown is discharged from the circulating water. Figure 1 shows a simplified process flow diagram of a cooling tower system.

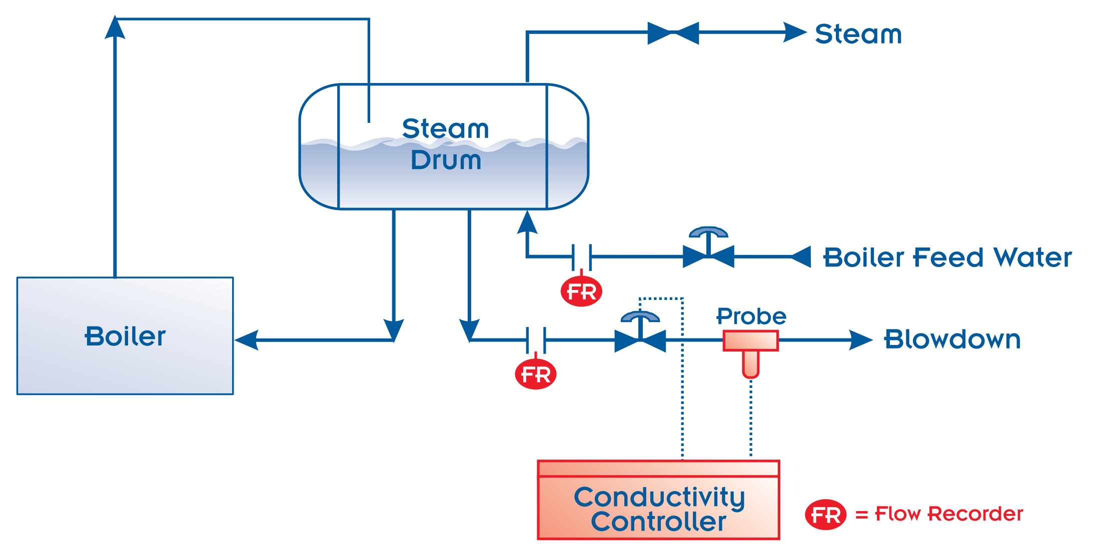
Figure 1: Automatic Blowdown for Cooling Towers



Boilers

While boilers vary considerably in design, all have a steam drum in which product steam is separated from the boiler water and exported to the refinery steam system. Conductivity control in the boiler steam drums differs from conductivity control of a cooling tower in that a different conductivity target is set for each system depending on steam pressure. In Figure 2, the simplified process flow diagram shows where boiler feed water is added and blowdown is discharged.

Figure 2: Typical Boiler Steam Drum System



An on-stream conductivity controller and probe will be installed on each system to maintain target conductivity levels in the circulating water. These controllers and probes will replace portable analyzers, which were used to determine conductivity and set makeup water-flow rates once every 12 hours. Using conductivity measurements on a real-time basis to control the amount of blowdown reduces the amount of purchased makeup water and treatment chemicals and limits the amount of water going to the water treatment plant, providing significant savings.

Savings

Real-time control of conductivity measurements in the four cooling towers will reduce Valero's costs for water, cooling tower chemicals, and water treatment—an estimated savings of $130,000 per year. In the three boiler systems, reduced costs for water, treatment chemicals, boiler makeup water softening, and water treatment will save the company an estimated $213,500 per year.

For more information on these projects, please contact:

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