Maximize Process Energy Efficiency–Pinch Screening Analysis

Marathon Ashland Petroleum LLC-Catlettsburg, Kentucky

TR-114085

Final Report, November 1999

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American Electric Power Service Co.
1125 Sixth Avenue
Huntington, WV 25701

EPRI Project Manager
K.R. Amarnath

EPRI • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

ORGANIZATION(S) THAT PREPARED THIS DOCUMENT

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This report was prepared by

Veritech, Inc.
22960 Shaw Road, Suite 620
Sterling, VA 20166

Principal Investigator
B.L. Pretty
M.A. Rutkowski

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REPORT SUMMARY

EPRI and its subcontractor, Veritech, were commissioned to conduct a strategic analysis of the steam utility system at the Marathon Ashland Petroleum LLC (MAPLLC) Catlettsburg refinery. During the strategic analysis, we determined the marginal costs of steam and the marginal costs of steam-derived power. We also developed a preliminary steam model to evaluate energy cost reduction opportunities.

Background

Two stages of analysis have been completed to date, the first focusing on the site steam system characteristics and savings potential, and the second focusing on energy savings potential achievable within process units through improved heat integration. The results of these studies have enabled the development of a clear strategy for achieving substantial energy use and cost reduction. A combination of condensing turbine drive replacement with electric drives, steam system infrastructure improvements and improved heat integration will maximize total energy cost savings potential.

Objective

- To identify utility system opportunities to reduce energy use and costs, and to provide a basis for evaluation of selected process modification, for possible future implementation.

Approach

We recommend that highest priority be given to condensing turbine drive replacement with electric motor drives. Our Phase 1 analysis identified stand-alone turbine drive replacement annual savings after adjusting for the summer base case operation. This involved 35,000 hp of process compression in four 450 psig condensing turbines and one 150 psig condensing turbine. Of these opportunities, two turbines, 2-1-GB-10 FCC Main Air Blower and 2-112-G-27 MRS Wet Gas Compressor, offer particularly promising conversion economic potential, as both turbines are in need of overhauls. Together, these two conversions would decrease boiler load while incurring a power demand increase of around 13.6 MW. Expected paybacks, without considering the credit from avoiding turbine overhaul costs, are typically in the 2-3 year range.

The recommended approach to identifying the optimal selection of energy cost reduction projects which addresses the remaining steam savings scope is to first develop a much more definitive list of high rate-of-return infrastructure improvement projects. These are the most likely to have the lowest capital requirements and highest investment return rates. They must, however, be quite specific projects with well-defined savings analyses to ensure that real savings are actually achieved.

Once the infrastructure savings potential is well defined, further pinch analyses should be undertaken for the six units that show potential for steam load reduction projects through improved process integration (FCC/Crude3/Vac4, Furfural, Cumene, MEK, FCC Gas Con., and Sulfolane units). The specific objective of these studies would be to identify the one or two highest rate of return projects in each unit.

The infrastructure projects, process integration projects and turbine conversion projects should then be sorted and ranked based on criteria such as economic performance, capital requirements, likelihood of achieving the projected savings, operability issues and other criteria that MAPLLC regard as significant in the evaluation of project characteristics for investment purposes.

Results

Further turbine conversions are still possible, to the point where the site boiler load is taken down to a practical minimum. However, these conversions compete with both infrastructure improvements and improved heat integration savings opportunities for the remaining boiler load reduction potential. They must be assessed against these competing alternatives on a stand-alone basis with expected paybacks of 2-3 years.

Opportunities for additional savings from improved process integration in six units should be considered in conjunction with the recommended turbine conversions. Savings were found through pinch screening analyses in the FCC/Crude3/Vac4, Furfural, Crude5/LVT/LEP, VGO, SDA and Sat. Gas units. These savings consider only stand-alone fired heater savings and/or steam system impacts that have minimal boiler load reduction impact or which serve to increase boiler load (in a trade-off with fired heater duty reductions). Projects developed in these units will not compete with other steam load reduction opportunities for the remaining boiler load reduction potential.

Further pinch analysis of the FCC/Crude3/Vac4 and Crude5/LVT/LEP units in particular is strongly recommended, as the potential atmospheric furnace duty reduction in these units may enable unit throughput increases. Improved process integration in these circumstances is a very cost-effective approach to unit debottlenecking.

EPRI Perspective

Apart from the opportunity benefit offered by the potential to avoid significant overhaul costs, these projects offer opportunities for discussions with AEP on the basis of mutual economic benefits. This may lead to financial assistance to ensure that the projects meet MAPLLC economic performance objectives.

TR-114085

Keywords

Process Industry		Heat Recovery
Pinch Technology	Energy Efficiency

EXECUTIVE SUMMARY

This Pinch Screening Analysis Project was completed for Marathon Ashland Petroleum LLC (MAPLLC) at the Catlettsburg Refinery in Catlettsburg, Kentucky.

Two stages of analysis have been completed to date, the first focusing on the site steam system characteristics and savings potential, and the second focusing on energy savings potential achievable within process units through improved heat integration. The results of these studies have enabled the development of a clear strategy for achieving substantial energy use and cost reduction. A combination of condensing turbine drive replacement with electric drives, steam system infrastructure improvements and improved heat integration will maximize total energy cost savings potential.

We recommend that highest priority be given to condensing turbine drive replacement with electric motor drives. Our Phase 1 analysis identified stand-alone turbine drive replacement annual savings after adjusting for the summer base case operation. This involved 35,000 hp of process compression in four 450 psig condensing turbines and one 150 psig condensing turbine. Of these opportunities, two turbines, 2-1-GB-10 FCC Main Air Blower and 2-112-G-27 MRS Wet Gas Compressor, offer particularly promising conversion economic potential, as both turbines are in need of overhauls. Together, these two conversions would decrease boiler load while incurring a power demand increase of around 13.6 MW. Expected paybacks, without considering the credit from avoiding turbine overhaul costs, are typically in the 2-3 year range.

While serious consideration has been given only to the above turbines, the RCC Transport Air Turbine, which uses 150 psig supply steam, should also be considered for conversion. This machine produces 1150 hp or 860 kW of shaftwork. Conversion to electric motor drive would realize additional savings.

Apart from the opportunity benefit offered by the potential to avoid significant overhaul costs, these projects offer opportunities for discussions with the sponsoring utility on the basis of mutual economic benefits. This may lead to financial assistance to ensure that the projects meet MAPLLC economic performance objectives.

Further turbine conversions are still possible, to the point where the site boiler load is taken down to a practical minimum. However these conversions compete with both infrastructure improvements and improved heat integration savings opportunities for the remaining boiler load reduction potential. They must be assessed against these competing alternatives on a stand-alone basis with expected paybacks of 2-3 years.

Opportunities for additional savings from improved process integration in six units should be considered in conjunction with the recommended turbine conversions. Savings were found through pinch screening analyses in the FCC/Crude3/Vac4, Furfural, Crude5/LVT/LEP, VGO, SDA and Sat. Gas units. These savings consider only stand-alone fired heater savings and/or steam system impacts that have minimal boiler load reduction impact or which serve to increase boiler load (in a trade-off with fired heater duty reductions). Projects developed in these units will not compete with other steam load reduction opportunities for the remaining boiler load reduction potential.

Further pinch analysis of the FCC/Crude3/Vac4 and Crude5/LVT/LEP units in particular is strongly recommended, as the potential atmospheric furnace duty reduction in these units may enable unit throughput increases. Improved process integration in these circumstances is a very cost-effective approach to unit debottlenecking.

The remaining opportunities for energy cost reduction all compete for the remaining boiler load reduction potential down to a minimum site boiler load. Assuming the two turbine conversions recommended above are implemented and the process integration savings for the six key units discussed above are realizable and are implemented, then the remaining boiler load reduction potential opportunities are

- Steam load reduction potential, through improved process integration, increased steam generation or reduced steam demand, in the FCC/Crude3/Vac4, Furfural, Cumene, MEK, FCC Gas Con., and Sulfolane units.
- Steam system infrastructure savings, through reduced steam leak losses, improved condensate recovery and return, through improved steam header pressure control and steam distribution management to reduce consequent steam venting losses to atmosphere, and through increased raw water makeup heating to reduce deaeration steam demands.
- Shaft power cost reduction through conversion of the remaining steam condensing turbine drives to electric drives.

The recommended approach to identifying the optimal selection of energy cost reduction projects which addresses the remaining steam savings scope is to first develop a much more definitive list of high rate-of-return infrastructure improvement projects. These are the most likely to have the lowest capital requirements and highest investment return rates. They must, however, be quite specific projects with well-defined savings analyses to ensure that real savings are actually achieved.

Once the infrastructure savings potential is well defined, further pinch analyses should be undertaken for the six units that show potential for steam load reduction projects through improved process integration (FCC/Crude3/Vac4, Furfural, Cumene, MEK, FCC Gas Con., and Sulfolane units). The specific objective of these studies would be to identify the one or two highest rate of return projects in each unit.

The infrastructure projects, process integration projects and turbine conversion projects should then be sorted and ranked based on criteria such as economic performance, capital requirements, likelihood of achieving the projected savings, operability issues and other criteria that MAPLLC regard as significant in the evaluation of project characteristics for investment purposes.

CONTENTS

1
INTRODUCTION

Strategic Analysis

EPRI and its subcontractor, Veritech were commissioned to conduct a strategic analysis of the steam utility system at the Marathon Ashland Petroleum LLC (MAPLLC) Catlettsburg refinery. During the strategic analysis, we determined the marginal costs of steam and the marginal costs of steam-derived power. We also developed a preliminary steam model to evaluate energy cost reduction opportunities.

We recommended a hybrid approach to energy cost reduction that included improved operations, conversion of condensing turbine drives to electric drives, and improved process heat integration through pinch analysis. The success of energy cost reduction efforts depends on a cohesive strategy that implements compatible solutions, simultaneously considering the interactions between power, fuel and steam requirements.

Pinch Screening Analysis

Using the results of the strategic analysis, we conducted a pinch screening analysis of several key process units at the refinery. During the screening analysis, we determined the energy use targets and the potential energy savings that process heat integration provides, and evaluated the impacts of improved operations, conversion of condensing turbines to electric drive, and process heat integration on an improved steam model. We identified the process units that MAPLLC should consider for detailed evaluation.

2
PINCH SCREENING ANALYSIS

EPRI and Veritech have completed the pinch screening analysis of the process units defined in the scope of work, which is summarized below. The analysis indicates that many of the units use more energy than necessary. The potential energy cost reduction is significant with improved heat integration.

The FCC/Crude 3/Vac 4 process units have the largest potential for energy cost reduction. The Furfural unit and the Crude 5/LVT/LEP units also have large potential cost reductions. We strongly recommend the continued evaluation the FCC/Crude 3/Vac 4, Furfural, and Crude 5/LVT/LEP units for heat integration.

The VGO, Cumene, SDA, FCC Gas Con, and Sulfolane, units also have significant potential for energy cost reduction. We also recommend the continued evaluation of these units for integration. The MEK and Sat Gas units have significant potential cost reductions, however, more definition of the heat and material balances is required to confirm this conclusion.

The LP CCR, HP CCR, and Aliphatics units do not have any significant energy cost reduction potential to warrant further analysis. Any energy savings would probably be uneconomical to pursue. The RCC/RCC Gas Con units are properly integrated as designed and have no scope for additional energy savings.

For the analysis, heat and material balances were developed from actual operating data and from design data as needed. From the heat and material balances, process composite and grand composite curves were prepared. These curves show the heat flow characteristics of a process and are used to establish its minimum energy consumption. The balances used in this analysis must be developed to a higher level of confidence before continuing to the design stage.

To identify cross-pinch heat transfer penalties, heat exchanger network designs of the existing processes were reviewed. In several cases, we also prepared revised heat exchanger network designs that eliminate the cross-pinch penalties and approach the specified energy targets. The revised networks are only illustrations and have not been evaluated for cost effectiveness or operating feasibility. Evolved networks are generally simpler at the cost of some lost energy savings. We recommend that the revised designs be considered with the objective of assessing the feasibility and level of complexity of the changes required. If there is a consensus to evaluate the energy savings potential for a unit further, more detailed engineering and economic evaluations can be undertaken.

Process integration techniques also incorporate pre-design capital-energy targeting techniques which can establish the optimum level of energy savings under specified energy cost and equipment cost constraints. These techniques should be applied as the next step in the analysis so that definitive equipment design changes can be developed to enable +/-30% cost estimates. Evaluation of the capital-energy trade-off for these units can be effectively addressed using pinch technology techniques.

Although we have not evaluated the economic feasibility of the potential energy cost reductions, we have determined the energy targets of the process units with DTmin values that yield economic paybacks in the range of two to three years. With our conservative approach, the economic feasibility of the energy cost reduction opportunities identified in this screening analysis will probably be confirmed in later evaluations.

Pinch Screening Analysis of FCC/Crude 3/Vac 4 Process Units

Key Points

Significant energy savings potential

Reduced crude furnace duty

Increased HP steam generation

Decreased MP steam generation

Extensive heat exchanger network revamp, however, proven results for crude unit applications

The FCC, Crude 3 and Vac 4 units are integrated extensively in their present configuration, however, pinch analysis indicates that the units still use more energy than necessary. The potential energy cost reduction is significant with improved heat integration.

An extensive heat exchanger network revamp is required to properly integrate the FCC/Crude 3/Vac 4 units. Because the integration of crude units is common and routine in the refining industry, the integration of the FCC/Crude 3/Vac 4 units involves only the usual risks associated with projects of this scale. The large extent of inter-unit integration between the FCC and Crude3/Vac4 units already in place demonstrates the feasibility of further improved integration, and the willingness of MAPLLC to consider such efficiency improvement opportunities. We strongly recommend the continued evaluation of the FCC/Crude 3/Vac 4 units for further analysis and project definition.

With improved heat integration, the absorbed duty for the crude atmospheric furnace is reduced from its present configuration resulting in an increased furnace preheat temperature. Furnace duty reduction potential through reduced exchanger fouling has not been separated out from improved heat integration benefits. The absorbed duty for the generation of high pressure steam can also be increased while the generation of medium pressure steam is decreased.

Pinch Screening Analysis of Furfural Process Unit

Key Points

Significant energy savings potential

Reduced furnace duties

Reduced HP and LP steam use

Increased LP steam generation

Pinch analysis indicates that the Furfural unit uses more energy than necessary. The potential energy cost reduction is significant with improved heat integration.

With improved integration, the absorbed duties of the unit furnaces are reduced from the present configuration. In addition, the use of high and low pressure steam is reduced and the generation of low pressure steam is increased.

A significant heat exchanger network revamp is required to properly integrate the Furfural unit. A revised network could include seven or more new heat exchange services, new surface area for existing services, and several flow splits. Since no unusual risks are involved, we strongly recommend the continued evaluation of the Furfural unit for integration. A simpler retrofit design could be developed requiring fewer design modifications, but this would be at the expense of some energy savings. Assessing the capital cost/complexity/energy savings relationship would be the focus of further studies for this unit.

Pinch Screening Analysis of Crude 5/LVT/LEP Process Units

Key Points

Significant energy savings potential

Reduced crude furnace duty, eliminates DeC6 fired reboiler

Decreased MP steam use

Increased MP steam generation

Decreased LP steam generation

Extensive heat exchanger network revamp, however, proven results for crude unit applications

The Crude 5/LVT/LEP units are partially integrated in their present configuration, however, pinch analysis indicates that the units still use more energy that necessary. The potential for energy cost reduction is significant.

With improved integration, the absorbed furnace duties are reduced resulting in an increased crude preheat temperature. In addition, the use of medium pressure steam is reduced, the generation of medium pressure steam is increased, and the generation of low pressure steam is decreased.

An extensive heat exchanger network revamp is required to properly integrate the Crude 5/LVT/LEP units. Because the integration of crude units is common and routine in the refining industry, the integration of the Crude 5/LVT/LEP units involves only the usual risks associated with projects of this scale. We strongly recommend the continued evaluation of the Crude 5/LVT/LEP units for integration.

Pinch Screening Analysis of VGO Process Unit

Key Points

Significant energy savings potential

Reduced furnace duties

Slightly decreased MP and LP steam generation

Pinch analysis indicates that the VGO unit uses more energy than necessary. The potential energy cost reduction is significant with improved heat integration.

With improved integration, the absorbed duties of the unit furnaces are reduced from the present configuration. In addition, the generation of medium and low pressure steam is decreased slightly.

A heat exchanger network revamp is required to properly integrate the VGO unit. A revised network could include four or more new heat exchange services, new surface area for existing services on the charge oil stream from the stripper bottoms and the separator overhead. Since no unusual risks are involved, we strongly recommend the continued evaluation of the VGO unit for integration.

Pinch Screening Analysis of Cumene Process Unit

Key Points

Significant energy savings potential

Increased LP steam generation

Pinch analysis indicates that the Cumene unit uses more energy than necessary. The potential energy cost reduction is significant with improved heat integration.

With improved integration, the generation of low pressure steam is increased. Integration does not alter the use of hot utilities. Given the local header balance problems in the LP system which lead to atmospheric venting, additional LP steam generation benefits need to be assessed in the context of local header balance considerations as well as the site context. Despite the apparent ability of the site to absorb additional LP steam generation, local header issues may prevent these savings from being realized. The cost of the local header balance problems needs to be assessed both in terms of lost LP steam generation potential and the cost of venting steam to atmosphere.

A heat exchange network revamp is required to properly integrate the Cumene unit. A revised network could include five or more new heat exchange services and new surface area for existing services. Since no unusual risks are involved, we strongly recommend the continued evaluation of the Cumene unit for integration.

Pinch Screening Analysis of MEK Process Unit

Key Points

Significant energy savings potential

Heat balance difficulties

Decreased steam use

Decreased refrigeration use

Full savings may be difficult to realize

The analysis for the MEK unit was developed from two separate cases – the actual operation and the design operation – with 100N feedstock. The energy consumption data for the actual operation proved unreliable, requiring estimates of the steam and refrigeration use. So, we used the design data to qualify the estimates of the savings. The results for the two cases vary significantly, just as the operating conditions for the MEK unit vary with feed type and rate.

Pinch analysis indicates that the MEK unit uses more energy than necessary. The potential energy cost reduction is significant.

With improved integration, steam use is reduced. Refrigeration use is reduced. The reduction in refrigeration use represents a significant compressor load reduction.

A heat exchanger network revamp is required to properly integrate the MEK unit. A revised network could include seven or more new heat exchange services and new surface area for existing services. Refrigeration savings rely on the optimization of the approach temperature in the double pipe exchangers and the propane chillers. Given the specialized nature of the equipment in the MEK unit, the fully integrated refrigeration savings may be difficult to realize in practice.

Pinch Screening Analysis of SDA Process Unit

Key Points

Significant energy savings potential

Reduced furnace duties

Reduced HP and MP steam use

Slightly decreased LP steam generation

Similar concept to MEK and Furfural units

Pinch analysis indicates that the SDA unit uses more energy than necessary. The potential energy cost reduction is significant.

With improved integration, the absorbed duties of the unit furnaces are reduced from the present configuration. In addition, the use of high and medium pressure steam is reduced, while the generation of low pressure steam is decreased slightly.

A significant heat exchanger network revamp is required to properly integrate the SDA unit. A revised network could increase heat recovery through the improved use of the driving forces from the solvent flash towers. This is very similar in concept to opportunities found in the Furfural and MEK units. Since no unusual risks are involved, we strongly recommend the continued evaluation of the SDA unit for integration.

Pinch Screening Analysis of FCC Gas Con Process Unit

Key Points

Significant energy savings potential

Reduced steam use

Simple heat exchanger network revamp

Pinch analysis indicates that the FCC Gas Con unit uses more energy than necessary. The potential energy cost reduction is significant.

With improved integration, steam use is reduced.

A relatively simple heat exchanger network revamp would be required to properly integrate the FCC Gas Con unit. Since no unusual risks are involved, we strongly recommend the continued evaluation of the FCC Gas Con unit for integration.

Pinch Screening Analysis of Sulfolane Process Unit

Key Points

Significant energy savings potential

Reduced steam consumption

Moderately simple heat exchanger network revamp

Pinch analysis indicates that the Sulfolane unit uses more energy than necessary. The potential energy cost reduction is significant with improved integration.

With improved integration, the consumption of high and low pressure steam is reduced while the consumption of medium pressure steam is increased. The net steam consumption is reduced.

A moderately simple heat exchanger network revamp is required to properly integrate the Sulfolane unit. A revised network could include four or more new heat exchange services, new surface area for existing services, and several flow splits. Since no unusual risks are involved, we strongly recommend the continued evaluation of the Sulfolane unit for integration.

Pinch Screening Analysis of Sat Gas Process Unit

Key Points

Significant energy savings potential

Reduced furnace and hot oil duties

Slightly increased steam consumption

Heat balance data is "rough"

Pinch analysis indicates that the Sat Gas unit uses more energy than necessary. The potential energy cost reduction is significant with improved integration.

With improved integration, the absorbed duties of the furnaces and hot oil units are reduced from the present configuration. In addition, the use of medium and low pressure steam is increased slightly.

The Sat Gas process unit appears to have scope for significant energy savings, however, the results may be unreliable because the analysis is based on incomplete and inconsistent design data. To improve the reliability of the results, an improved heat balance is necessary.

Pinch Screening Analysis of LP CCR Process Unit

Key Points

Small stand-alone scope for increased MP steam generation

Unchanged hot utility use

Moderately increased MP steam generation

Possible integration with downstream units

Except for a moderate increase in medium pressure steam generation, the LP CCR process unit has no significant scope for energy savings. The increase in steam generation would probably be uneconomical to pursue. The LP CCR unit could possibly be integrated with downstream units for increased energy savings.

Pinch Screening Analysis of Aliphatics Process Unit

Key Points

No scope for energy savings as a stand-alone unit

Possible integration of excess below-pinch heat with nearby units

Small overall heat flow

The Aliphatics process unit has no scope for significant energy savings through unit integration. The Aliphatics unit could effectively use waste heat through inter-unit integration. However, the heat duties involved are small and could not justify a significant capital expenditure.

Pinch Screening Analysis of RCC/RCC Gas Con Process Unit

Key Points

Properly integrated as designed

Excellent integration between RCC, RCC Gas Con, and Crude 5

No scope for additional energy savings

The RCC/RCC Gas Con process units are properly integrated as designed and have no scope for additional energy savings. The RCC/RCC Gas Con units are currently designed for maximum energy efficiency.

Pinch Screening Analysis of HP CCR Process Unit

Key Points

Thermodynamically similar to LP CCR

Insignificant scope for increased MP steam generation as a stand-alone unit

Possible integration with downstream units

Although the HP CCR process unit is larger than the LP CCR unit, it is thermodynamically similar. The most notable difference between the units is that the HP CCR unit integrates a debutanizer reboiler with the convection section of its reformer furnace, however, this difference does not affect its energy savings potential.

Because of the similarity of the two units, the HP CCR process unit is just as unlikely to have a significant scope for energy savings. Any energy savings would result from a small increase in the amount of medium pressure steam generation, which would probably be uneconomical to pursue. The HP CCR unit could possibly be integrated with downstream units for increased energy savings.

The heat and material balances of the HP CCR unit were not developed for this analysis.

3
SITE STEAM BALANCE

Sensitivity of Site Steam Models

Several suitable steam models were prepared to illustrate the sensitivity of the utility to heat integration. All models were derived from the summer base model since it represents the limiting case for minimum boiler load.

- Base model
- Steam models with pinch savings
- Condensing turbine conversion
- Improved condensate return
- Improved condensate return and condensing turbine conversion
- Improved condensate return, condensing turbine conversion and turbo-generator

Base Steam Model

The base steam model for summer indicates that there are large steam letdowns from the 450 psig level to the 150 psig level, from the 150 psig to the 50 psig level, and from the 50 psig to the 25 psig steam level. The large letdowns indicate that there are no vents to the atmosphere caused by inherent steam imbalances across the site. Rather, the current level of atmospheric venting is caused by local pressure control problems and local header balance restrictions, which prevent steam distribution from areas of excess supply to areas of net demand.

The model for winter indicates the same characteristics. The winter model is provided only for completeness. All comparisons are made to the summer model.

Steam Models with Pinch Savings

For the summer case with extensive pinch savings, the full potential savings of the top ten process units were used. For the summer case with partial pinch savings, only 75% of the full potential savings of the top five process units was used.

For the summer case with extensive pinch savings, steam production from the boilers is reduced, steam generation from the process is increased, and heating steam consumption is reduced.

The site steam balance also features large steam letdowns between the 450 psig level and the 150 psig and 50 psig levels. This is a consequence of the integration opportunities in the FCC/Crude3/Vac4 area, shifting steam generation from the 150 psig level to the 450 psig level. A turbo-generator operating between the 450 psig and 150 psig levels could generate shaftwork or electrical output using available letdown. A 450 psig to 50 psig turbo-generator could produce electrical output using available letdown. As stand-alone turbo-generators, these projects are not economically attractive against the low power cost at the Catlettsburg site. However, as backpressure replacement drives for condensing turbines, they may exhibit favorable economics.

For the summer case with partial pinch savings, steam production from the boilers is reduced, steam generation from the process is increased, and heating steam consumption is reduced. This balance also features large letdowns to the 150 psig and 50 psig steam levels which could be exploited using backpressure turbo-generators or replacement drives for condensing turbines.

Condensing Turbine Conversion

For the summer case with the conversion of two condensing turbines drives to electric motor drives, the turbines chosen for conversion were the FCC main air blower, 2-1-GB-10, and the MRS Wet Gas Compressor 2-112-G-27. These were selected based on indications by MAPLLC staff that they may be facing expensive overhaul costs and thus present opportunities for favorable drive replacement economics.

The conversion of 2-1-GB-10 produces significant annual energy savings by replacing the power derived from the condensing turbine with imported electric power. Similarly, the 2-112-G-27 conversion produces significant annual savings. Condensing turbines can also be replaced with backpressure turbines rather than electric motors. However, since the differential cost of power is less and the installed cost is greater, backpressure turbine replacements yield longer payback periods.

For the summer case with the turbine conversion, steam production from the boilers is reduced, and steam generation from the process and heating steam use are unchanged.

Process letdown to 150 psig or 50 psig could be exploited by a backpressure turbo-generator or turbine drive. As discussed above, for utilization of this letdown to be economically pursued in a low power cost environment, opportunity replacement of a condensing turbine drive such as 2-112-G-29 is required.

For the summer case with condensing turbine conversions and partial pinch savings, the steam production is reduced, the steam generation is increased, and heating steam consumption is reduced. Boiler load is reduced to a level that is likely to be near the minimum for the site. Significant 450 psig steam letdowns to the 150 psig steam level or 50 psig steam level are still present for power recovery in turbo-generation or condensing turbine replacement.

This represents one of the key strategies to achieving maximizing overall energy savings within the constraints of minimum site boiler load.

Improved Condensate Return

Significant steam savings could be realized if condensate return throughout the Catlettsburg complex could be improved. For the summer case with improved condensate return, steam production from the boilers is reduced, while steam generation from the process and heating steam use are unchanged. Flash steam increases as more condensate is recovered (this is dependent on the pressure level at which condensate is recovered), while the steam to the deaerators decreases.

An alternative to improved condensate return is increased makeup water preheat. This could reduce deaerator steam demand. Usual heat sources for preheat are large condenser duties such as the Crude Tower Overheads or the FCC/RCC Fractionation Column Overheads. Recovering the heat from process units is usually focussed on one or two key condensing services. Distributing the hot makeup water to the deaerators may be more of a logistical problem in a site with boilers as geographically distributed as Catlettsburg. However, makeup water preheat should be considered seriously in any strategy to reduce deaerator steam demands.

A feature of interest in these strategies is that the site letdowns all begin to reduce. The balance at the 25/20 psig level, in particular, becomes quite “tight” (i.e. the letdown becomes small). To prevent additional venting of steam to atmosphere, it might be necessary to switch, or convert, some 450-25 psig or 150-25 psig backpressure turbines to electric drives.

The summer case with improved condensate return and partial pinch savings is similar to the improved condensate case above, except that the 450-150 psig letdown is somewhat larger with partial pinch savings implementation. Previous arguments for utilization of the large letdowns in backpressure turbines for turbo-generation or replacing condensing drives also apply in this scenario.

For the summer case with improved condensate return and partial pinch savings, the steam production is reduced, the steam generation is increased, and heating steam consumption is reduced.

Improved Condensate Return and Condensing Turbine Conversion

For the summer case with improved condensate return and 2-1-GB-10 and 2-112-G-27 condensing turbine conversions, steam production from the boilers is reduced, while steam generation from the process and heating steam use are unchanged. The boiler load is reduced, which is at or around the assumed practical minimum site load.

This is another key strategy for reducing the site boiler load to its practical minimum.

For the summer case with improved condensate return, condensing turbine conversions, and partial pinch savings, steam production is critically reduced. If implemented without regard to the impact on the overall site steam balance, this strategy would result in a boiler load which is below the minimum maintainable boiler load.

It is clear from this scenario that the interaction between pinch savings, infrastructure projects such as improved condensate return, and condensing turbine drive replacement must be understood before project implementation decisions are made.

Improved Condensate Return, Condensing Turbine Conversion and Turbo-generator

For the summer case with improved condensate return, condensing turbine conversions and a backpressure turbo-generator, a turbo-generator is used to exploit the 450-50 psig letdown to produce electrical output or equivalent shaftwork. The steam production from the boilers is reduced, while steam generation and heating steam use are unchanged. The boiler load is slightly higher due to the impact of the new extraction turbine. This removes energy from the steam system to produce power. The boilers are, however, operating close to the practical minimum site load. Discussions on the economic viability of a new backpressure turbine have been covered above and apply equally to this scenario.

4
UTILITY STRATEGY SUMMARY

Aggregate Potential Energy Savings from Pinch Analysis

Significant energy savings are indicated by pinch analysis. Heat integration results in steam and fuel savings in the boilerhouse and throughout the site.

Utility Steam Balance Sensitivity Profiles

The model impacts the utility steam balance significantly. Several characteristics of each of the ten steam models presented were profiled as changes from the summer base model. The profiled characteristics include the change of boiler steam production, the change of process heating steam use, the change of process steam generation, the change of boiler fuel consumed, and the change of total shaftwork production from condensing and backpressure turbines.

Total Fuel Profile

The steam model impacts the total fuel consumption significantly. The change of total fuel consumed in the boilers and process furnaces, is profiled as a change from the summer base model.

Energy Savings Characteristics

There are three broad categories for energy savings opportunities at the MAPLLC Catlettsburg refinery:

1. Infrastructure improvements such as improving condensate return, reducing steam losses, reducing atmospheric venting due to control and distribution constraints, and increasing deaerator makeup water preheat.

2. Condensing turbine drive conversion to electric motor drives.

3. Furnace firing and steam savings due to improved process integration.

At a certain level of savings, these three strategies begin to compete for the available scope for steam savings. It has been assumed that steam cannot be exported from the site.

The key to a successful energy cost reduction strategy is to combine the opportunities from the three categories above into a cohesive set of economically viable, practical projects which maximize the true energy cost savings potential for the site.

Infrastructure Project Characteristics

These are likely to be the lowest capital, highest return projects: the so-called “low-hanging fruit”. They are however, poorly, or at best, very generally defined at this stage. There is a general sense from engineering personnel that significant savings can be achieved through improved condensate return, reducing steam leaks and losses, and reducing the site atmospheric vents. These must be quantified so that they can be compared to other savings opportunities in terms of savings magnitude, capital requirements, and return on investment. Detailed studies of the steam distribution system are required to quantify these savings.

Condensing Turbine Conversions

These are well-defined opportunities. Though some further development of the capital implications is required, the energy cost savings and the impact on the site steam system are well defined. Two conversions have been included in the sensitivity analyses, namely 2-1-GB-10 and 2-112-G-27, because of their apparent need for expensive overhauls. This provides a cost avoidance opportunity to help improve the economics of the turbine conversion projects.

These projects also present opportunities to enter into negotiations with the sponsoring utility on the basis of the mutual economic advantages inherent in condensing turbine conversions. MAPLLC will benefit from significant operating cost reductions while the sponsoring utility will benefit from a load growth opportunity.

The two turbine conversions considered would have a combined impact on boiler load reduction. This still leaves room for significant steam use reductions from either infrastructure improvements or improved process integration.

It is also strongly recommended that the RCC Transport air turbine, operating with a supply pressure of 150 psig be considered for conversion.

Pinch Savings

Pinch savings opportunities can be divided into three categories:

1. Those that have no impact on the site steam system, such as savings that arise from fired heater duty savings.

2. Those that have little or beneficial impacts on the site steam balance as they tend to increase steam demand. Savings are achieved through a trade-off with fired heater duty reductions.

3. Those that rely directly on steam use reductions and/or steam generation increases to generate reductions in boiler steam load.

Some projects in the FCC/Crude3/Vac4, Furfural, Crude5/LVT/LEP, VGO, SDA, and Sat. Gas units fall into categories 1 and 2. These should be pursued independently of the steam system considerations.

Other units showing potential for energy savings primarily impact the steam system directly. These are the additional steam generation opportunities in the FCC/Crude3/Vac4, Furfural and Cumene units, and steam use savings in the MEK, FCC Gas Con., and Sulfolane units. The Furfural and Cumene savings rely on increased LP steam generation to generate savings. The risk inherent in these projects is that the current LP steam venting may be aggravated by additional generation, if it is not in the right geographic areas. This requires further detailed analysis, as venting is caused by local header pressure control and distribution issues, not by site-wide steam imbalances.

Steam savings at the 150 psig and 450 psig header levels compete directly with infrastructure improvement savings potential for the remaining boiler load reduction opportunity, assuming condensing turbine conversions are pursued.

It is arguable that the process integration projects, with a little further analysis of each unit showing potential, can be well defined in both project and economic terms. A clear and concise set of economic projects for implementation can be developed. In this sense, this category is more definitive than the infrastructure initiatives as these are currently defined.

It is likely, however, that implementing process integration projects will be more capital intensive than the implementation of infrastructure improvements, assuming the latter can be well defined. In a capital-scarce environment, the forward path should first focus on infrastructure opportunities. If it is clear that implementable, high rate-of-return projects can be defined, and that these are sufficient to drive the boilers to minimum load, then this should be the preferred implementation route.

There is, however, a clear path forward with process integration projects. If competition with high rate-of-return infrastructure projects is the governing economic criteria, the next phase of unit pinch analyses can be focussed on identifying the one or two most economically attractive project opportunities within each unit. The analysis procedure is well defined to enable quick and accurate definition of the savings potential and economic performance of such projects.

5
NEXT STEPS

Many opportunities have been identified to reduce energy costs at the Catlettsburg refinery. In addition to the opportunities provided by heat integration, there are opportunities through power conversion and through improved operations. As the next steps are taken to reduce energy costs at the refinery, it is important to develop a cohesive strategy that implements compatible solutions, simultaneously considering the interactions between power, fuel and steam requirements.

The key advantage of heat integration is that it provides direct energy savings: lower energy requirements translate to lower energy costs. For power conversion, expensive energy is replaced with cheaper energy, however, the energy requirements are unchanged. Heat integration is compliant with long-term asset development plans since its purpose is to lower costs through lower energy requirements. The disadvantage of heat integration is that it requires capital projects and the associated engineering effort to fully define a project and to assess its economic merit.

Although power conversion does not lower energy requirements, it does lower costs. A cohesive strategy to reduce energy costs at the refinery should incorporate the conversion of condensing turbines with electric motors or even backpressure turbines, as justified. A strategy should also incorporate further economic assessment of the use of backpressure turbo-generators to effectively utilize letdown steam between steam headers.

Improved operations are significant for reduced energy costs. What good is a highly integrated process when the utility distribution system is inefficient and loss-ridden? A strategy for reducing energy costs should start with improvements to the utility system, paying particular attention to condensate return, deaerator feedwater heating, local venting, hydraulic restrictions, and control limitations.