DEBOTTLENECKING ECONOMICS - MAXIMIZING PROFITABILITY WITH MINIMUM CAPITAL

by

Donald F. Schneider, PE
Process Engineering Consultant

Stratus Engineering, Inc.
PMB 339
2951 Marina Bay Drive #130
League City, Texas 77573

(281) 335-7138
Fax: (281) 335-8116
e-mail: dfsstratus@aol.com

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Introduction

Market and regulatory pressures continue to reduce the number of Refineries in the United States (Figure 1). Improvements in transportation systems cause niche markets to disappear shutting regional facilities. Tight product margins force low volume locations to close. Environmental requirements, population encroachment, and heightened public quality of life expectations increase the barrier to plant profitability. Finally, many older units simply wear out - it is sometimes more profitable to shift operations to newer plants than to rebuild aging facilities.

Against this backdrop, Petroleum demand in the United States has been increasing steadily since its most recent nadir in 1983 (Figure 2). Nearly continuous economic growth since then resulted in analogous increasing Petroleum consumption.

These two trends, fewer Refineries and increasing Petroleum demand, combine to raise Refinery Capacity Utilization rates to high levels (Figure 3). More product from fewer locations. Increasing production to accommodate demand can be accomplished by building new units or by debottlenecking existing capacity. This paper reviews debottlenecking opportunities and strategies. Emphasis is placed on finding the lowest capital solution which provides the highest payback.

Fig. 1 - Number of U.S. Refineries

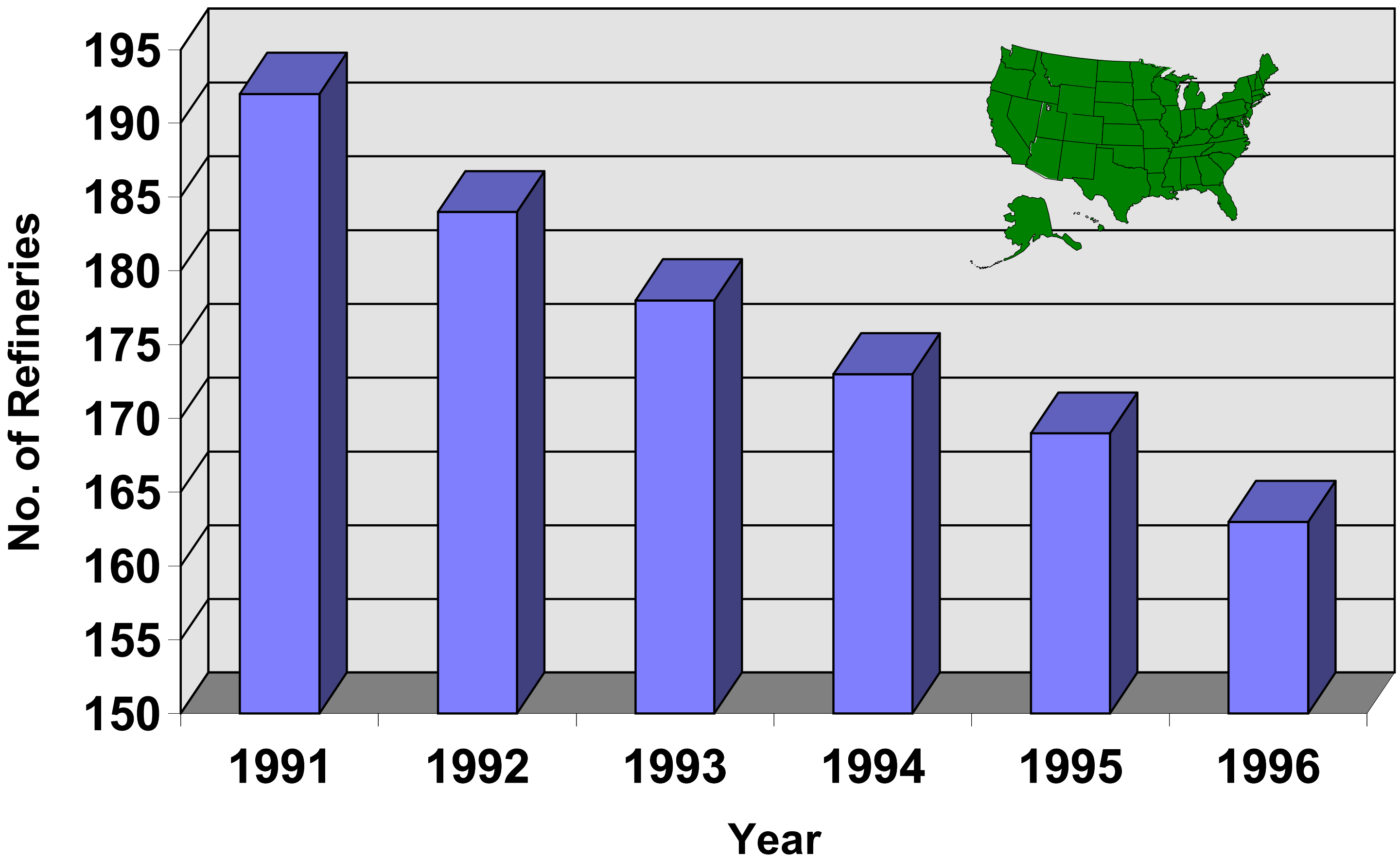


Fig. 2 - U.S. Oil Consumption

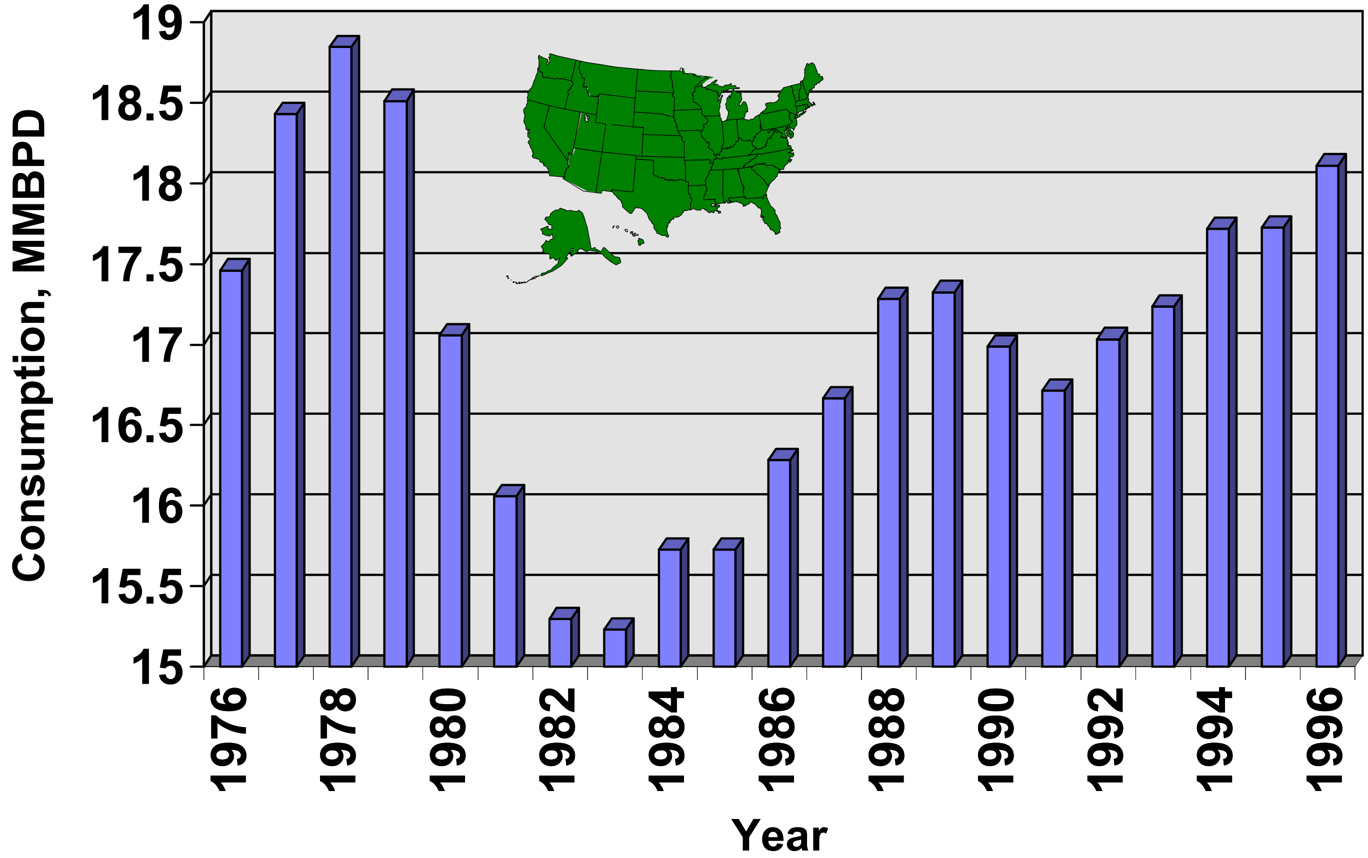
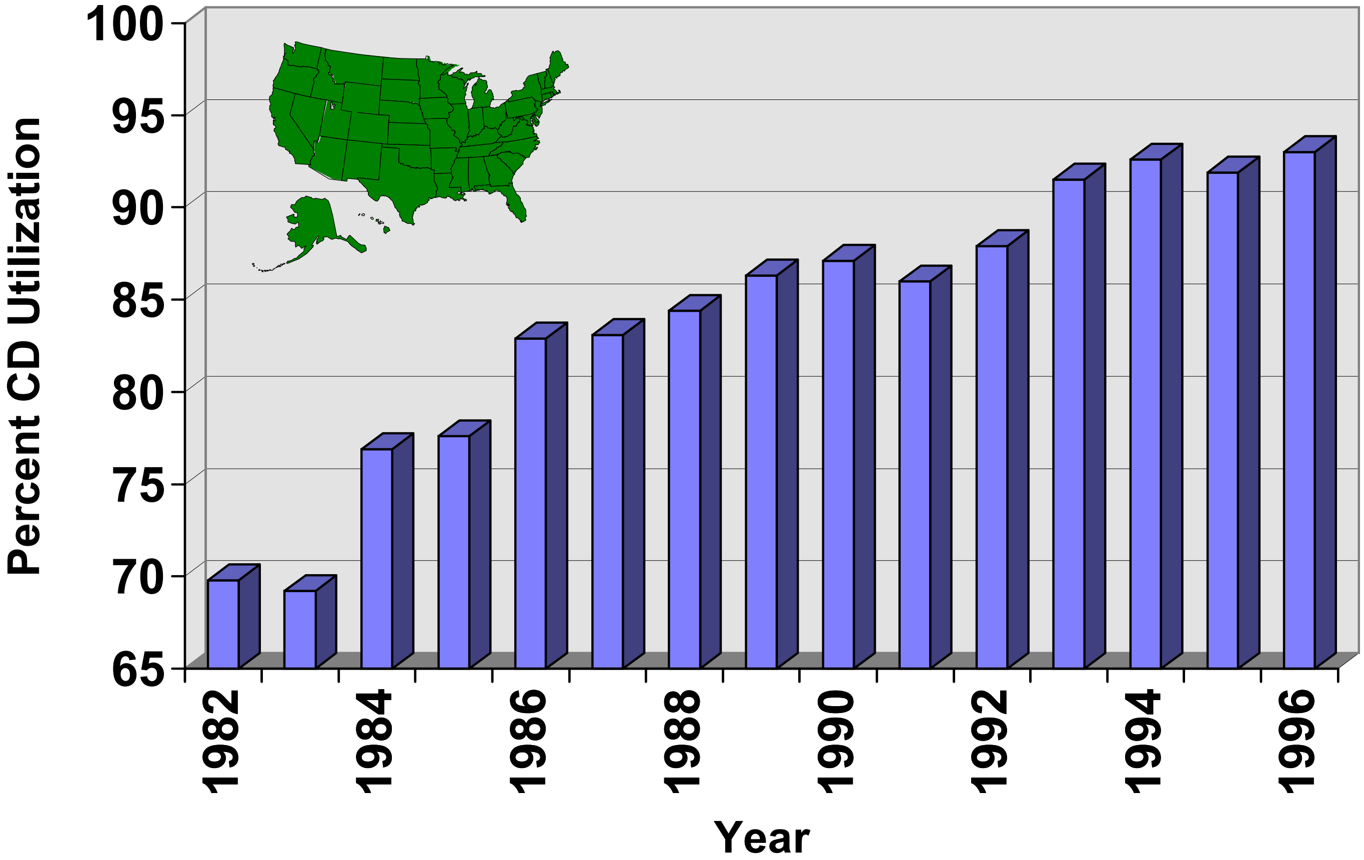


Fig. 3 - U.S. Refinery Utilization



Incremental facility debottlenecking often begins even before a new unit's initial startup is completed and usually continues throughout its lifetime. Debottlenecking typically begins with the desire to achieve plant performance that a unit is deemed incapable of in its current configuration. Throughput increases, yield alterations, and specification modifications are typical debottlenecking goals. Often, debottlenecking takes the form of reliability improvements intended to up the plant's stream factor. Debottlenecking targets often are not firmly established initially because the ultimate plant capability and the cost to achieve it are unknown.

Once a goal is set, a thorough review of the plant, its equipment, and its limits is undertaken. In forming the project foundation, this review is critical to maximizing profitability through informed decisions. Upstream and downstream equipment and facilities, transportation systems, utilities, environmental constraints, manpower impacts, etc. must all be considered in addition to the unit's operating equipment.

A debottlenecking study may result in a range of options with varied costs and benefits for review and evaluation.

Design

Ironically, one of the best opportunities to reduce future debottlenecking costs is during the design of a new facility. Many of the future debottlenecking benefits that can be accrued through judicious design cost very little if implemented before equipment is purchased.

One of the most important areas defined during design is equipment design conditions. Design pressure, and to a lesser degree design temperature, constraints often hamstring debottlenecking efforts. Be sure to consider the impact of higher head pumps that might be used in debottlenecking scenarios. In order to reduce costs, equipment downstream of a pump is often intended to operate only with the original equipment pump - even if that pump has the capability for a larger impeller! Original design conditions which allow room to grow are often a sound investment.

Since higher head pumps often ease debottlenecking, pump installations should specify the use of impellers that are not the maximum size for the selected pump case. Future pump capacity increases are then inexpensive and easy. Also, ensure the pump driver is sized to accommodate maximum impeller horsepower.

Heat exchanger train pressure drop increases with the square of the charge-rate and therefore can quickly restrict throughput. If higher head pumps are not an option, system pressure drop reduction may be required. Depassing of heat exchangers can significantly reduce their pressure drop, at the cost of reduced heat recovery. During heat exchanger design, particular tube pass configurations can be specified, or tube passes can be left open to accommodate future depassing. Without these provisions, complete bundle replacement might be necessary. Additionally, configuring exchanger process design and layout in the initial design so that series exchangers may be switched to parallel operation eases hydraulic constraints at future higher charge rates.

Supplying connections for future tie-ins can reduce direct debottlenecking cost and can reduce lost production due to debottlenecking outages. Candidates for future connections include: pumps (perhaps a third pump to up capacity), compressors, reactors (parallel train), and distillation column overhead condensers.

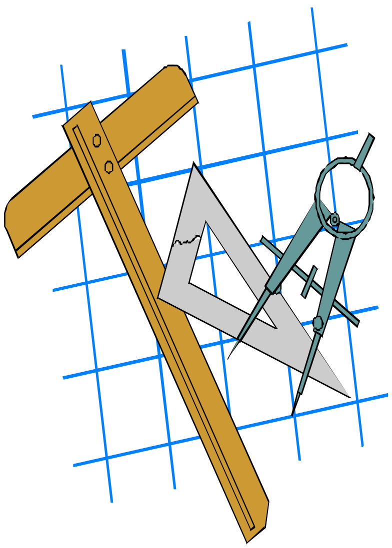
During design, there are often hurdle rates (rate of return or payout requirements) that determine the acceptability of expenditures. These hurdle rates should be reviewed to ensure they account for all costs. For example, new construction energy-efficiency hurdle rates may not be taking into account the cost of environmental and other permitting. The total costs of obtaining environmental permits, and possibly construction permits, for initial construction or future debottlenecking should be factored into hurdle rates and into permitting plans so that some debottlenecking can be accommodated without permitting revision.

New equipment design can also prepare units for future debottlenecking by what is omitted from the design. Use of high capacity technologies for initial designs means these options will not be available when increased capacity is desired. High capacity trays and low-fin heat exchanger tubes should be avoided in initial design if possible so they can be used in the future.

Debottlenecking

- Revised operating target
- Current unit cannot meet goal
- Thorough review
- Options

Design



- Design pressure & temperature
- Pump size
- Heat exchangers
- Future tie-ins
- Hurdle rates & permitting
- High capacity technology

Heat Transfer

Unit heat integration often becomes an issue in debottlenecking. This is especially true in Crude units and Hydroprocessing units such as Hydrotreaters or Hydrocrackers. Often heat transfer debottlenecking issues manifest themselves as a need for additional heat input, e.g. furnace duty, or a as a need for additional cooling utility, e.g. cooling water, or both.

Heat transfer issues can creep up as the unit is incrementally debottlenecked over time. A unit that is designed for 100,000 bpsd, and through skilled operation is running 20% over design, requires 20% more heat transfer surface area to maintain the design energy efficiency. Often what appears as a utility limit, not enough furnace for example, may be mitigated through increased heat transfer surface area. Additional exchangers may cost less than added furnace capacity, and do not require fuel gas and an environmental permit to operate.

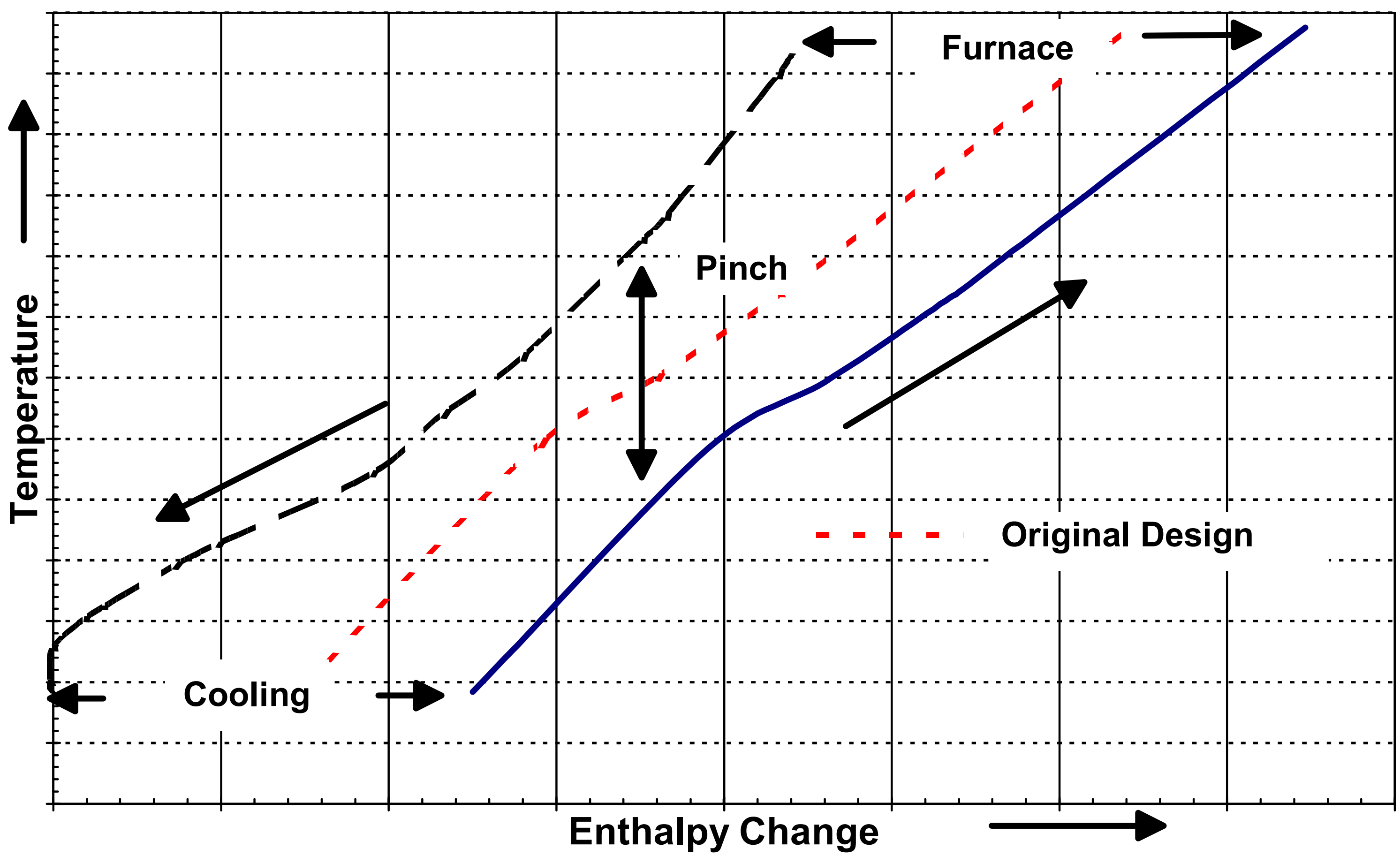
Figure 4 illustrates the composite curves of a pinch analysis for a Crude Atmospheric Distillation unit. This particular unit was limited by furnace capacity and cooling capacity. The unit was already operating at over twice its design rate. From the pinch analysis, it can be seen that there is an opportunity to increase unit heat recovery with additional heat exchange area. Added area would unload the furnace and cooling systems by allowing already hot streams to heat cool ones. Similar situations also occur in other units.

In some cases, heat transfer improvement requirements can be met using technologies such as extended surface (low-fin tubes) or tubulators. Low-fin tubes increase the tube outer surface area and can improve heat transfer where the shell-side transfer coefficient is limiting (and where shell-side fouling is not a concern). Tubulators increase the tube-side transfer coefficient. Fouling services also may justify tube material upgrades. Stainless steel tubes are typically less susceptible to surface fouling when compared to carbon steel.

Heat Transfer

- Efficiency
- More flow requires more area
- Pinch analysis
- Upgrade technologies

Fig. 4 - Pinch Composite Curves



Hydraulics

Pushing more through the pipes is often a debottlenecking goal. A number of items may be reviewed to increase throughput:

- Pump and compressor size can be increased. Perhaps only the impeller need be changed, but design pressure limits may require pressure relief additions. Parallel or double pumping might be practical. Booster pumps may be useful.

- Control valves: Larger control valves may up rates, but might reduce control.

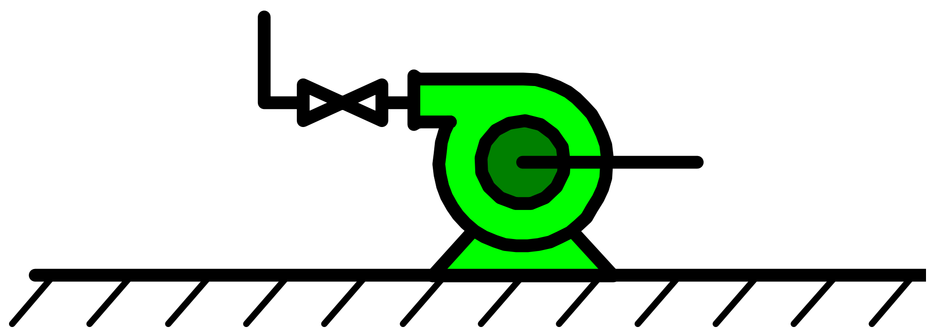
- Line size and layout should be reviewed. Given the same volumetric flow conditions, pipe pressure drop varies with the inverse ratio of the pipe diameters to the fifth power. A recent hydrotreater study revealed that 17% of the unit piping which was one size smaller than the rest was taking 44% of the drop! Use of parallel runs through an out-of-service line might help.

- Feed tanks might be run at higher levels and product tanks at lower levels thereby increasing the apparent pressure driving force.

- Flash Drums. By flashing an intermediate stream in the unit feed train, several hydraulic advantages may be gained. The flashed vapor is separated from the liquid and sent directly to the distillation tower at the feed train terminus. This reduces the hydraulic load on the remainder of the feed train, and reduces vapor loading on the fractionation column. If necessary, the flashed vapor may be rectified in a column before entering the main tower thereby providing improved separation. Moving an existing flash drum earlier in the feed train may increase its contribution to unit capacity through greater fluid bypassing. Flash drum benefits are highly dependent on unit configuration and product slate. However, throughput increases of 20 to 50 % are not uncommon with the addition of a flash drum.

Hydraulics

- Pumps & compressors
- Control valves
- Piping $\left(\frac{D_1}{D_2}\right)^5$
- Tank levels
- Flash drums



Distillation

Increasing fractionation tower capacity is one area that has received significant attention. Various mechanical options are available to add tower capacity tower near their flood point. These include high capacity trays, packing, and multiple pass trays. Installing high capacity contacting devices typically increases a column's capacity by 15 to 20%.

Internals layout modifications, such as reducing reboiler recirculation, may also lead to substantial improvements. Reboiler feed internals may not be suited for operation at current conditions. Ensuring that the reboiler feed temperature is minimized through efficient recirculation can increase column capacity significantly.

Distillation throughput is also often a function of heat transfer limits. Column performance may be improved by altering feed preheat conditions or adding overhead condensing and/or reboil capacity. If the column is flooding below the feed, higher feed preheat may alleviate the problem. If the column is flooding above the feed, reduced feed preheat may be beneficial. Intermediate reboilers can be added which up reboiler capacity and provide an opportunity for energy efficiency increase through using a lower temperature source for reboil.

Operating conditions significantly affect fractionation capability. Adjusting the tower pressure or product specification targets may garner substantial benefits. High column pressures may ease column flooding and overhead condenser restrictions, but at the cost of higher bottoms or feed heat input. For example, increasing a Crude column's operating pressure from 20 to 25 psig reduces its internal vapor volumetric flow approximately 10%!

An engineering and operating review of a column's performance may turn up unexpectedly simple upgrade opportunities requiring little capital.

Distillation

- Contacting devices
- Other internals
- Operating conditions

Reactors

Reactor debottlenecking is more problematic than overcoming other limits. Catalyst modification and parallel train operation are two of the primary methods for increasing reactor capacity. FCC units continue to benefit from riser and feed-nozzle technology improvements which up feed-rates and yields. For fixed bed reactors such as hydrotreaters or reformers, dense catalyst loading and heightened catalyst activities may be used to meet debottlenecking goals. Alkylation plants may have reaction sections that are conservatively designed so that throughput increases have little impact on product octane.

Reactor capacity may also be linked to other unit constraints such as hydraulic or heat transfer limits. Careful reactor performance examination is recommended as these restrictions may be masked by the concern for apparent reactor capacity boundaries.

Advanced Control & On-line Optimization

Implementing advanced control strategies and on-line optimization can have significant operating benefits. Simply studying the possibility of implementing these technologies may return handsome rewards through increased understanding and constraint identification. Advanced control, such as advanced level control or multivariable dynamic matrix control, might be able to provide much smoother operation than standard methods reducing product variance, and may allow operation closer to specification reducing giveaway. Optimization systems can provide a tool for maximizing profitability on a continuous basis even under varied operation.

Perhaps the largest bonus returned from these types of systems is the information and information management capability they provide. The data gathering and historical archiving these technologies provide yield the tools for improved understanding of unit performance and potential.

Out-of-Service Equipment (*The Bone Pile*)

Although OSHA 1910 has eliminated, or at least hampered, mid-night requisitions that previously led to low-cost Unit modifications, out-of-service hardware continues to provide a profitable source of equipment for Unit upgrades.

Proper mothballing of decommissioned equipment is very important in preserving operability. Much sturdy equipment has been rendered worthless by the elements even after withstanding seemingly harsher environments while in operation.

Tracking out-of-service equipment and maintaining its records makes assessments of its potential use much easier.

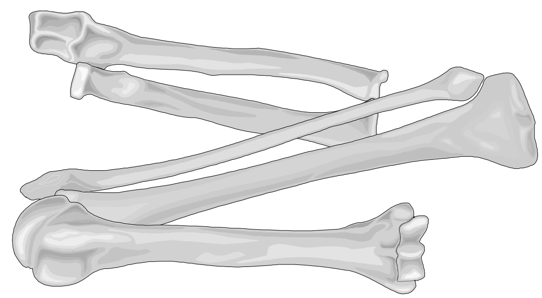
Purchasing an entire plant, moving it, and restarting it is frequently accomplished at significant savings compared with new design and construction.

Duplicate

Stretching the definition of debottlenecking, plant duplication might be considered. A step increase too large for an existing plant debottlenecking calls for new construction. However, duplication of existing facilities can reduce costs and risk. An existing plant in operation probably has many of the kinks worked out and is a known quantity. Equipment procurement, construction, and detailed design costs are reduced through use of previous design information.

Other

- Reactors
- Advanced control & optimization
- The bone pile
- Duplication



Summary

As utilization rates continue to be high, extracting increased unit capacity continues to be profitable. Debottlenecking can provide a cost effective means for upgrading capacity. Beginning with unit design, thorough unit review and proper planning are the two most powerful tools available to achieve existing plant debottlenecking. With the definition of available options and their profitability, a course of action can be discussed. Ultimately, debottlenecking may or may not be selected as the proper course of action. However, the information collected during a debottlenecking study will almost certainly identify improvement opportunities that were unknown, and that may cost very little.

Please contact the author at:

Stratus Engineering, Inc.
PMB 339
2951 Marina Bay Drive Suite 130
League City, Texas 77573
USA

Phone: (281) 335-7138
Fax: (281) 335-8116
E-Mail: dfsstratus@aol.com
Website: www.stratusengr.com

References

1. Burke, B. F., "*Prospects for the U.S. Energy and Refining Industries: Markets, Profitability, and Key Drivers for Change*," Paper AM-96-04, Presented at the 1996 NPRA Annual Meeting.
2. Gonzalez, R. G., Ryan, J., "*R&M Companies Piece Together the Big Picture*," Fuel Technology & Management, Sept./Oct., 1996.
3. Rhodes, A. K., "*Worldwide Refining*," Oil & Gas Journal, December 23, 1996.
4. Rhodes, A. K., "*Worldwide Refining*," Oil & Gas Journal, December 18, 1995.
5. Rhodes, A. K., "*Worldwide Refining*," Oil & Gas Journal, December 19, 1994.
6. Rhodes, A. K., "*Worldwide Refining Report*," Oil & Gas Journal, December 20, 1993.
7. Rhodes, A. K., "*Worldwide Refining Report*," Oil & Gas Journal, December 21, 1992.
8. Rhodes, A. K., "*Worldwide Refining Report*," Oil & Gas Journal, December 23, 1991.
9. Schneider, D. F., Musumeci, J., Chavez, R.,"*Analysis of Alky DIB Exposes Design, Operating Considerations*," Oil & Gas Journal, September 30, 1996.
10. "*Worldwide Report*," Oil & Gas Journal, December 31, 1990.
11. "*Worldwide Report*," Oil & Gas Journal, December 25, 1989.
12. "*Worldwide Report*," Oil & Gas Journal, December 26, 1988.
13. "*Worldwide Report*," Oil & Gas Journal, December 28, 1987.
14. "*Worldwide Report*," Oil & Gas Journal, December 22/29, 1986.
15. "*International Energy Annual 1992*," Energy Information Administration, Department of Energy, USA.
16. "*International Energy Annual 1995*," Energy Information Administration, Department of Energy, USA.
17. "*IEO95: Energy Information Administration (EIA), World Energy Projection System(1995)*," Energy Information Administration, Department of Energy, USA.
18. "*Petroleum Supply Annual 1992*," Energy Information Administration, Department of Energy, USA.
19. "*Petroleum Supply Annual 1993*," Energy Information Administration, Department of Energy, USA.