U.S. Refining Capacity Utilization

by Tancred Lidderdale, Nancy Masterson, and Nicholas Dazzo*

U.S. crude oil refinery utilization rates have steadily increased since oil price and allocation decontrol in 1981. The annual average atmospheric distillation utilization rate has increased from 68.6 percent of operable capacity in 1981 to 92.6 percent in 1994. The distillation utilization rate reached a peak of 96.4 percent in August 1994, the highest one-month average rate in over 20 years. This dramatic increase in refining capacity utilization has stimulated a growing interest in the ability of U.S. refineries to supply domestic requirements for finished petroleum products.

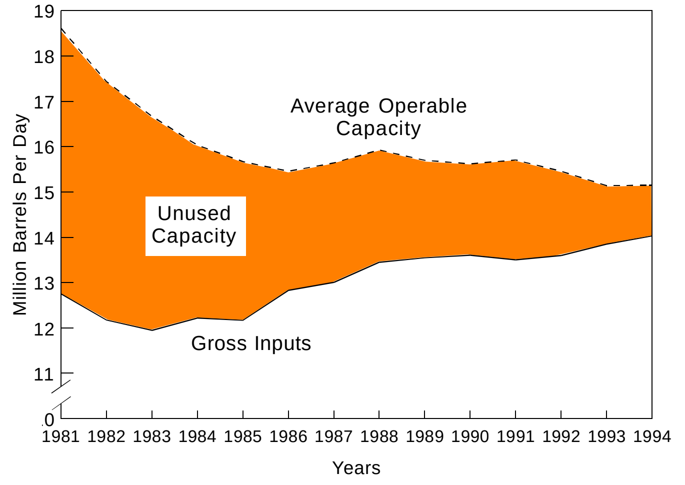
This article briefly reviews recent trends in domestic refining capacity utilization and examines in detail the differences in reported crude oil distillation capacities and utilization rates among different classes of refineries. Comparison of refining margins (profitability) to crude oil distillation utilization rates suggests that an alternative way to measure refining capacity and utilization is needed to properly assess the effect of growing demand on market prices and sources of supply. A focus on downstream processing capacity and utilization may provide a better indicator of potential constraints in refining capacity. A more complex analysis could expand the scope to include foreign refiners in a global view of petroleum markets.

Domestic refining capacity utilization has steadily increased since oil price and allocation decontrol in 1981.

U. S. crude oil distillation capacity grew steadily under the crude oil price and allocation programs set up in 1973 and 1974. The price and allocation programs benefited small refineries, with the result that the number of refineries grew from 268 in 1973 to 324 in 1981.[1] During that same period, average annual operable crude oil distillation capacity grew from 13.6 million barrels per day to its all-time high of 18.6 million barrels per day. With the removal of price controls and allocations in early 1981 and the decline in petroleum demand in the early 1980's, many small refineries that sprang up in the 1970's, as well as older, inefficient plants, began to shut down. Between January 1981 and January 1989, the U.S. refining industry experienced a net loss of 120 refineries and approximately 3 million barrels per day of operable capacity. Thereafter, capacity remained stable until 1992, when, pressured by the costs of environmental regulations and unfavorable refining economics, several marginal refineries shut down, while a few larger refiners idled or permanently shut down crude oil distillation units. By January 1, 1995, U.S. operable refineries numbered 175, with a total crude oil distillation capacity of 15.4 million barrels per calendar day.

While distillation capacity has declined during the last 15 years, refinery gross inputs have risen almost every year since 1983. Average gross inputs increased from 11.9 million barrels per day in 1983 to 14.0 million barrels per day during 1994. This was due to the rise in U.S. demand for petroleum products which began in 1983. U.S. demand has exceeded U.S. crude oil distillation capacity every year since 1985. Total petroleum product demand averaged 15.7 million barrels per day in 1985, 0.4 percent higher than the average operable crude oil distillation capacity. By 1994, total petroleum demand exceeded operable capacity by 17 percent, as demand grew to 17.7 million barrels per day and operable capacity averaged 15.2 million barrels per calendar day. With declining capacity and rising gross inputs, the amount of unused crude oil distillation capacity has shrunk significantly since 1981 (Figure 1). Approximately 5.9 million barrels per day of available crude oil distillation capacity was not used in 1981, but by 1994

Figure 1. Gross Inputs to Crude OIl Distillation Units and Average Operable Capacity, 1981-1994



Note: Capacities are the average of reported monthly capacities.
Sources: 1981 and 1982: Energy Information Administration,(EIA), Integrated Petroleum System, Form EIA-810, "Monthly Refinery Report," data base; 1983 through 1988: EIA, *Petroleum Supply Annual*, DOE/EIA-0340, Volume 1, Table 11; 1989 through 1994: EIA, *Petroleum Supply Annual,* Volume 1, Table 16.

*Nicholas Dazzo is an Associate, Commodities Economics Research, J.P. Morgan and Co.

[1]Energy Information Administration, *Annual Energy Review 1994*, DOE/EIA-0384(94) (Washington, DC, July 1995), p. 155.

the difference between available capacity and gross inputs had narrowed to approximately 1.1 million barrels per day.

Consequently, operable utilization rates for crude oil distillation units have experienced a fairly steady upward trend since 1981. Utilization rates increased nearly every year from 1981 to 1994, growing from an average of 68.6 percent in 1981 to 92.6 percent in 1994, the highest annual level since 1973. The refinery utilization rate reached a peak of 96.4 percent August 1994, the highest one-month average rate in over 20 years. Since then, monthly utilization rates have remained within a range of 87.7 percent (February 1995) and 95.6 percent (June 1995).

Refinery investment in downstream processing capacity has been more robust.

Since 1980, the refining industry's emphasis shifted from growth of operable crude oil distillation capacity to investment in downstream (secondary) processing units, thereby increasing the overall level of refinery complexity. This transition began several years before the passage of the Clean Air Act Amendments in 1990 and was due to heightened demand for lighter, cleaner products that were being produced from increasingly heavier and more sour crude oils. Secondary processing units can significantly improve the yields of light products. For example, the straight distillation yield of motor gasoline from Oseberg crude oil is about 17 percent. A refinery with a delayed coker, catalytic cracker, and hydrocracker can increase the motor gasoline yield to 64 percent.[2]

In contrast to utilization rates for crude oil distillation, utilization rates for secondary processing units have increased only slightly or even declined between 1987 and 1994 (Table 1). The average calendar day utilization rate for catalytic cracking increased every year through 1993 before dropping slightly to 92.2 percent in 1994. Cokers have had the highest utilization rate of the secondary processing units. In 1994, the average annual calendar day utilization rate for cokers was 93.0 percent compared to 92.3 percent in 1987. Hydrocracking utilization rates have consistently been less than those of catalytic crackers and cokers. Average annual capacity for hydrocracking increased 14.6 percent between 1987 and 1994, while average annual inputs to hydrocrackers grew about 6.3 percent during these years.

Reported capacity utilization rates can be misinterpreted

Capacity utilization rates may be calculated on the basis of either "stream day" or "calendar day" capacity. Stream day capacity represents an engineering design rate that a production unit is capable of when operating. Calendar day capacity represents an *annual average* capacity that accounts for expected and unexpected production unit downtime.[3] The ratio of calendar day to stream day capacity is the refinery operating (or on-stream) factor:

Calendar day capacity = Operating factor x Stream day capacity

Table 1. Average Annual U.S. Refinery Inputs, Charge Capacity, and Utilization Rates, 1987-1994
(Thousand Barrels per Calendar Day, Except Where Noted)

	Atmospheric Crude Distillation	Cokers	Catalytic Crackers (Fresh)	Hydro-crackers
Inputs[1]				
1987	13,003	1,265	4,370	946
1988	13,447	1,364	4,514	931
1989	13,551	1,345	4,576	929
1990	13,610	1,356	4,694	941
1991	13,508	1,429	4,784	1,010
1992	13,600	1,456	4,817	1,032
1993	13,851	1,514	4,926	1,064
1994	14,032	1,540	4,850	1,006
Average Charge Capacity[2]				
1987	15,642	1,370	5,070	1,076
1988	15,927	1,394	5,106	1,098
1989	15,701	1,409	5,113	1,134
1990	15,623	1,462	5,225	1,165
1991	15,707	1,479	5,304	1,202
1992	15,460	1,507	5,295	1,242
1993	15,143	1,595	5,258	1,247
1994	15,150	1,656	5,262	1,233
Utilization Rate (percent)[3]				
1987	83.1	92.3	86.2	87.9
1988	84.4	97.8	88.4	84.8
1989	86.3	95.5	89.5	81.9
1990	87.1	92.7	89.9	80.8
1991	86.0	96.6	90.2	84.0
1992	87.9	96.6	91.0	83.1
1993	91.5	94.9	93.7	85.3
1994	92.6	93.0	92.2	81.6

[1]Represents gross inputs to atmospheric crude oil distillation units and fresh feed inputs to cokers, catalytic crackers, and hydrocrackers.

[2]Capacities for atmospheric disillation are the average of reported monthly operable crude oil distillation capacities. Capacities for cokers, catalytic crackers, and hydrocrackers are the average of January 1 stream day capacities for the indicated year and the following year. Stream day capacities were adjusted to calendar day capacities by calculating calendar day capacities at 92 percent, 95 percent, and 90 percent of stream day capacities for cokers, catalytic crackers, and hydrocrackers, respectively.

[3]Utilization rates are expressed as percentages and represent inputs divided by the average annual capacity.

Source: The Energy Information Administration, *Petroleum Supply Annual*, 1987-1994, Table 16 and Table 45.

[2]Robert E. Maples, *Petroleum Refinery Economics* (Tulsa, OK: PennWell Books, 1993), pp. 332-335.

[3]Expected downtime includes scheduled plant "turnarounds," during which equipment is shut down for cleaning and repair. Unexpected downtime accounts for unit shutdowns because of accident, fire, inventory containment problems, (arising from conditions other than low product demand), etc. Allowance for unexpected downtime is conditional upon past plant and industry experience.

Table 2. Calculated Atmospheric Distillation Operating Factors, January 1, 1995

Calculated Operating Factor (Percent)	Gasoline-Producing Refineries: Number of Refineries	Gasoline-Producing Refineries: Distillation Capacity (thousand barrels per day) Calendar day	Gasoline-Producing Refineries: Distillation Capacity (thousand barrels per day) Stream day	Non-Gasoline-Producing Refineries: Number of Refineries	Non-Gasoline-Producing Refineries: Distillation Capacity (thousand barrels per day) Calendar day	Non-Gasoline-Producing Refineries: Distillation Capacity (thousand barrels per day) Stream day
100 %	2	206	206	2	8	8
98.0 - 99.9	14	1,206	1,223	0	0	0
96.0 - 97.9	41	5,234	5,397	2	88	91
94.0 - 95.9	35	4,005	4,216	7	87	92
92.0 - 93.9	17	1,972	2,127	10	155	167
90.0 - 91.9	10	862	949	5	94	104
90 %	12	1,360	1,560	11	158	186
Totals	**131**	**14,845**	**15,679**	**37**	**589**	**647**
Average Operating Factor		**94.7%**			**91.0%**	

Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, *Petroleum Supply Annual 1994*, DOE/EIA-0340(94)/1 (Washington, DC, May 1995), pp. 84-98.

A refinery atmospheric distillation unit that is capable of processing 100,000 barrels of crude oil when it operates has a stream day capacity of 100,000 barrels per day. A refinery that operates for 11 months and shuts down for cleaning for 1 month every year has an expected operating factor of 91.7 percent (operates 11 months out of 12), and a calendar day capacity of 91,700 barrels per day. If this refinery processed an average 91,700 barrels per day of crude oil over the course of a year, it would have operated at 100 percent of calendar day capacity but only 91.7 percent of stream day capacity.

Atmospheric crude distillation utilization rates reported by the Energy Information Administration (EIA) are calculated on the basis of calendar day capacities. Some refining industry analysts have made the mistake of citing utilization rates reported by EIA and assumed that "utilization rates on the order of 94 to 95 percent probably are the best the industry can do on a sustained basis." The correct statement should be that "utilization rates on the order of 100% probably are the best the industry can do on a sustained basis." The error may arise when reported utilization rates are incorrectly assumed to be based on stream day capacities.

Operating factors assumed by refineries are not identical.

While stream day capacity should be an objective design measure of a refinery's processing capability when operating, calendar day capacity is a subjective measure that depends on an *assumed* operating factor. Operating factors for domestic atmospheric distillation units were calculated from the calendar day and stream day capacities reported by EIA in the *Petroleum Supply Annual* (Table 2). Most gasoline-producing refineries assume operating factors for atmospheric distillation of between 94 and 98 percent. Calculated operating factors for non-gasoline refineries (refineries that produce only asphalt, lube oil, waxes, and other heavy petroleum products) are generally less than 94 percent.

Refineries that produce gasoline operate at significantly higher utilization rates than non-gasoline-producing refineries.

The lower operating factors assumed by non-gasoline-producing refineries may be due to the different quality of crude processed and higher frequency of turnarounds. But, we also find that non-gasoline-producing refineries operate at significantly lower atmospheric distillation utilization rates than gasoline-producing refineries (Table 3). During 1994, gross inputs to atmospheric distillation units at non-gasoline-producing refineries averaged 52 percent

Table 3. Average 1994 Atmospheric Distillation Capacity and Utilization Rate by Refinery Type

	Number	Average 1994 Capacity (thousand barrels per day) Calendar day	Average 1994 Capacity (thousand barrels per day) Stream day	Average 1994 Utilization Rate (percent) Calendar day	Average 1994 Utilization Rate (percent) Stream day
Gasoline producers:					
Complex refineries	117	14,099	14,873	95.3	90.4
Topping refineries	14	452	475	62.0	59.0
Non-gasoline producers	37	585	639	51.7	47.3
Total U.S. refineries	168	15,137	15,987	92.7	87.7

Notes: Capacity = day-weighted annual average. • Average 1994 utilization rate = average 1994 gross inputs/atmospheric distillation capacity. Excludes 3 refineries that shut down during 1994.
Sources: Energy Information Administration Form EIA-810, "Monthly Refinery Report."

Measurement of Gross Refining Margins

There are many ways to estimate the profitability of crude oil refineries. A common measure is gross refining margin, or total product market value less raw material costs. One example is the widely used "3-2-1 crack spread," which assumes that 3 barrels of crude oil can be processed into 2 barrels of gasoline and 1 barrel of distillate fuel oil. More rigorous refining margin calculations account for differences in the types of crude oil, which have different potential product yields; the complexity of a refinery or group of refineries, which determines the capability of achieving a given product yield; and product market conditions, which influence the refiner's objectives in maximizing the yield of particular products to coincide with seasonal demand changes.

The sample margin calculation (Table 7) begins by applying U.S. Gulf Coast wholesale market product prices to the estimated gasoline maximizing yield from West Texas Intermediate crude oil at a sophisticated refinery. The delivered cost of crude oil is then subtracted from the estimated revenue to arrive at a gross margin estimate. The margin calculation is instantaneous to the extent that it does not consider the passage of time between the purchase of crude inputs and the sale of product outputs. The margin calculation also ignores refinery operating costs. Although estimated cracking margins for complex refineries are generally $2 to $3 per barrel higher than topping margins, the operating costs of secondary processing units may result in cracking being less profitable than topping.

Table 7. Sample Refinery Gross Margin Calculation

Crude oil: **West Texas Intermediate crude oil**
Refinery: **Complex (cracking) refinery**
Time period: **August 1995, summer motor gasoline season**

Product	Yield (Fraction)	Price ($/gallon)	Value ($/barrel)
Regular unleaded gasoline	0.562	$0.5040	$11.90
Midgrade unleaded gasoline	0.141	0.5189	3.07
Jet fuel	0.160	0.4968	3.34
Number 2 oil	0.122	0.4933	2.53
Fuel oil (1% sulfur)	0.000	0.3155	0.00
Totals	1.020		$20.84
Less:	**Spot price of crude oil**		**$18.04**
	Crude oil transport cost		**- 0.60**
Gross refining margin			**$ 2.20**

Sources: Yields - J.P. Morgan Co. and Pace Consultants, Inc., Prices -McGraw-Hill, Inc., *Platt's Oilgram Price Report* Vol. 73, No. 169 (New York, NY, September 1, 1995), pp. 7, 8, and earlier issues.

of calendar day capacity compared to 94 percent at gasoline-producing refineries. Because of the low utilization rates at non-gasoline-producing refineries, these refineries are excluded from the analyses that follow in this report.

Gasoline-producing refineries can also be disaggregated according to refinery complexity. A "complex" refinery refers to a refinery with secondary heavy oil upgrading units downstream of atmospheric distillation. These secondary units include catalytic crackers, catalytic hydrocrackers, and fluid cokers. A "topping" refinery refers to a refinery with no secondary heavy oil upgrading units. Topping refineries are also found to operate at low utilization rates (Table 3).[4] Further disaggregation of complex refineries by type of secondary processing units (e.g., "coking" and "cracking" refineries) reveals no significant differences in utilization rates. (These results are not reported here.)

Seasonality of industry average utilization rates does not necessarily reflect trends at individual refineries.

The average industry distillation utilization rate is highly seasonal, with peak rates occurring during the high demand

[4]The significant difference in capacity utilization rates between the different refinery configurations suggests differences in the economics of running the different types of refineries; i.e., the cost penalty for operating at a low capacity utilization rate at a non-gasoline-producing or topping refinery may be much smaller than the cost for a complex gasoline-producing refinery.

Table 4. Monthly Utilization of Atmospheric Distillation Capacity, 1994. Gasoline-Producing Refineries

Month	Operable Capacity (thousand barrels per calendar day)	Gross Inputs to Distillation (thousand barrels per day)	Average Industry Operating Rate	Number of Refineries	
				Operating at maximum rates	Operating at minimum rates
Jan	14,457	13,290	91.9%	4	12
Feb	14,427	13,072	90.6%	6	18
Mar	14,427	12,893	89.4%	8	20
Apr	14,577	13,718	94.1%	16	10
May	14,577	14,111	96.8%	13	10
Jun	14,577	14,188	97.3%	8	5
Jul	14,577	14,158	97.1%	10	4
Aug	14,577	14,297	98.1%	13	6
Sep	14,619	14,010	95.8%	19	9
Oct	14,624	13,313	91.0%	11	16
Nov	14,629	13,779	94.2%	12	13
Dec	14,639	13,862	94.7%	9	8

Note: Refineries that operated 2 or more months at maximum or minimum rates are not included in the counts.
Source: Energy Information Administration Form EIA-810, “Monthly Refinery Report.”

summer motor gasoline season. The maximum monthly average utilization rate in 1994 occurred in August (Table 4). However, only 15 (of 129) individual gasoline-producing refineries reported maximum utilization rates for 1994 in August. Less than two-thirds of the domestic refineries reported maximum 1994 operating rates during the summer months (between April and September). The minimum industry atmospheric distillation operating rate in 1994 was recorded in March. Again, only about 15 percent of domestic refineries operated at minimum rates during March. About two-thirds of the domestic refineries reported minimum 1994 operating rates during the winter months (between October and March).

Almost 40 percent of the gasoline-producing refineries reported maximum (one-month average) atmospheric distillation utilization rates in excess of 100% of stream day capacity.

Because refineries are less likely to take turnarounds during the high demand summer motor gasoline season, it is not surprising to find that many refineries operate at rates in excess of reported calendar day capacity during this period. Over two-thirds of the gasoline-producing refineries reported gross inputs to atmospheric distillation that exceeded their reported calendar day capacity (Table 5). What is surprising is that almost 40 percent of the domestic refineries reported a one-month distillation utilization rate that exceeded their reported stream day capacities.

The observation that almost 40 percent of the domestic refineries reported a one-month utilization rate in excess of 100 percent of reported stream day capacity implies that the industry distillation capacity may be understated. A “pseudo” capacity number could be derived by using actual observed processing rates for refineries that operated over 100 percent of stream day capacity. The reported capacity of refineries operating at maximum rates of less than 100 percent of stream day capacity would not be changed. The pseudo capacity of domestic atmospheric distillation is estimated to be about 236 thousand barrels per day higher than the reported stream day capacity (Table 6).

Higher distillation capacity utilization rates have not been associated with higher refinery margins.

Table 5. Maximum 1994 Utilization Rates for Gasoline-Producing Refineries
(Capacity in Thousand Barrels per Day on 1/1/95)

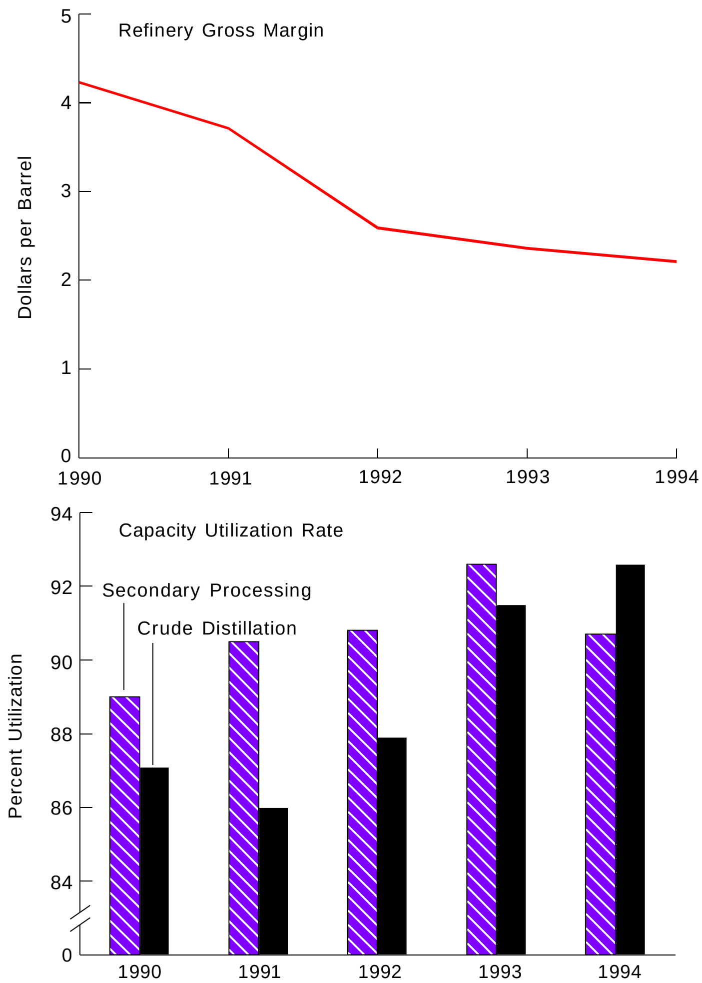
Maximum One-month Operating Rate (percent)	Calendar Day Capacity		Stream Day Capacity	
	Number of Refineries	Reported Capacity	Number of Refineries	Reported Capacity
≥ 110.0 %	**14**	**1,948**	**-**	**-**
105.0 - 109.9	**39**	**4,498**	**11**	**1,157**
100.0 - 104.9	**38**	**4,766**	**41**	**5,807**
95.0 - 99.9	**18**	**2,071**	**39**	**5,118**
90.0 - 94.9	**7**	**605**	**16**	**1,782**
< 90.0 %	**15**	**951**	**24**	**1,815**
Totals	**131**	**14,845**	**131**	**15,679**

Source: Energy Information Administration Form EIA-820, “Annual Refinery Report.”

Gross margins for complex refineries have been relatively flat over the last several years even as domestic distillation utilization rates have increased. (Refer to the shaded box titled “Measurement of Gross Refining Margins” (pg. xxxvi) for an explanation of gross margins.) Typically, we would expect higher capacity utilization to be associated with higher margins.[5] To explain this

[5]In the conventional economic short-run profit maximization model of competitive markets, the marginal cost of production and gross margin increase with capacity utilization.

Figure 2. Refinery Gross Margin and Capacity Utilization Rates



Note: Refinery gross margins are based on U.S. market prices. Capacity utilization rates are based on calendar day capacity. Secondary processing includes catalytic cracking, coking, and hydrocracking combined.

Sources: Gross margin: refer to box "Measurement of Gross Refining Margins." Capacity utilization: the Energy Information Administration, *Petroleum Supply Annual*, 1990-1994, Table 16 and Table 45.

inconsistency we must look beyond the standard measure of capacity utilization--crude distillation--toward a measure of refinery activity that more closely reflects the industry's economics.

Conventional measures of capacity utilization are based on crude distillation capacity because it is still by far the largest component of the typical refinery's capacity. Even in the United States, where refiners have added most to secondary processing capacity, atmospheric distillation is still equivalent to almost 300 percent of catalytic cracking capacity. In Europe and the Far East, atmospheric distillation capacity is over 700 percent of catalytic cracking capacity.[6] For this reason, inputs to distillation units provide a useful indication of refinery output despite the advance of refinery complexity.

Table 6. Estimation of "Pseudo" Atmospheric Distillation Capacity for Gasoline-Producing Refineries, 1994
(Barrels per Stream Day)

Maximum One-month Operating Rate on a Stream Day Basis	Number of Refineries	Reported Capacity	Calculated "Pseudo" Capacity
> 100%	52	6,964	7,200
< 100%	79	8,715	8,715
Total U.S Refineries	131	15,679	15,915

Note: Pseudo" capacity = Reported capacity times maximum utilization rate for refineries that operated at maximum rates in excess of 100 percent of stream day capacity plus reported capacity for refineries that operated at maximum rates of 100 percent or less.

Source: Energy Information Administration Form EIA-810, "Monthly Refinery Report."

The problem with crude distillation is that it is no longer sufficient for analyzing refinery profitability. As transportation fuels grow to represent an ever-larger slice of the petroleum demand pie, so must the relative complexity of refineries. Domestic refineries have also had to comply with governmental regulations on fuel quality, further encouraging growth in secondary processing capacity that in recent years has exceeded demand growth. As a result, while distillation capacity utilization has risen, secondary processing capacity utilization has been relatively flat.

When the recent trends in refinery margins are compared to trends in distillation capacity utilization versus secondary processing capacity utilization, it appears that a focus on secondary processing capacity may be more appropriate for analyzing refinery profitability (Figure 2). However, while distillation capacity utilization is a poor predictor of refinery profitability, it should be noted that total secondary processing capacity utilization is not much better. Monthly comparisons of gross margins for U.S. Gulf Coast and West Coast refiners are poorly correlated with both measures of utilization in PADD III and PADD V, respectively. One important explanation for this is the importance of foreign trade. Because the U.S. is just a part--albeit a large one--of the broader Atlantic Basin market for petroleum products, domestic refiners are subject to supply/demand balances outside U.S. borders.

Significantly, Western European refiners raised their catalytic cracking capacity sharply in the past two years (between January 1, 1993 and January 1, 1995).[7] This increase in European conversion capacity implies that refiners expected

[6]Energy Information Administration, *International Energy Annual 1993*, DOE/EIA-0219(93) (Washington, DC, May 1995), pp. 54-55.
[7]PennWell Publishing Co., *Oil and Gas Journal*, Vol. 92, No. 51. (Tulsa, OK, December 19, 1994), pp. 54, 55, and earlier issues.

European motor gasoline demand to grow at close to the 2.7 percent per year average of the previous five years.[8] This forecast has proven overly optimistic, and a resultant increase in exports (or even just the availability of exports) to the U.S. has been a depressing factor on U.S. Gulf Coast refinery profitability.[9]

What is the true refinery capacity constraint?

We have shown that measures of refinery capacity utilization have several shortcomings and that 100 percent stream day capacity on atmospheric distillation units is not a clear limit of U.S. refinery throughputs. Moreover, 100 percent stream day capacity does not represent a wall one cannot surpass, but a slope of increasing steepness. Capacity constraints relate to cost functions: how fast do marginal costs of production (either operating costs or product quality degradation) increase as you raise operating rates? Thus, rather than focus on reported utilization rates, it may be more useful to study how marginal costs increase as utilization rates rise. Marginal costs should dictate gross margins for crude oil refining and market prices for petroleum products.

The marginal costs of increasing throughputs in secondary processing units, such as fluid cokers and catalytic crackers, is likely to be greater than in atmospheric distillation units. It is due to the high marginal cost of running secondary processing units that these units generally represent the constraining capacity in complex refineries. Thus, in the U.S., cracking margins should provide the first signal that a refining capacity constraint is being reached. The trend in cracking margins over the last 5 years does not indicate that an industry capacity constraint has been reached. However, the analysis of the relationship between domestic secondary processing capacity utilization and refinery gross margins may be problematic because of the important role foreign refiners serve in supplying U.S. petroleum product markets.

[8]Energy Information Administration, *International Energy Annual 1993*, DOE/EIA-0219(93) (Washington, DC, May 1995), p. 51, and earlier issues.

[9]U.S. net imports of motor gasoline in 1994 were almost double those of the previous year and represented a turnabout from a steady 5-year decline. Energy Information Administration, *Petroleum Supply Annual 1994*, DOE/EIA-0340(94)/1 (Washington, DC, May 1995), p. 17.