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AM-05-55 A New Proxy for Coking Margins – Forget the Crack Spread

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A New Proxy for Coking Margins – Forget the Crack Spread

The so-called "3-2-1 crack spread" has been used for many years by refining industry analysts as a broad-based indicator of the economic incentive to convert crude oil into finished products. Unless you simply burn it, crude oil in its natural state is of no use to consumers—it must be transformed, through the process of refining, into products that are needed and can be used in the marketplace. In order to cover the costs of that transformation, including the substantial capital costs, there must be a "margin" or "spread" between what the products can sell for and the cost of the crude oil. Over the years, the 3-2-1 crack spread has become institutionalized as a simple, and easily calculated, measure of refining margins. However, some analysts incorrectly equate it to our current industry's refining margins—an assumption that is often far from reality.

The theory behind the crack spread formula is fairly simple. It is grounded in the fact that refineries convert crude oil primarily into two key product classes: gasolines and middle distillates—and very broadly speaking, the demand for these two classes of products is in the ratio of approximately 2 barrels of gasoline to one barrel of middle distillate. Since gasoline and middle distillate together will typically comprise more than 80% of a refinery's yield, a formula that equates each barrel of crude oil to ⅔ barrel of gasoline and ⅓ barrel of middle distillate (3 barrels of crude = 2 of gasoline and 1 of middle distillate) would seem, on the face of it, to offer a simple and reasonable "proxy" for refining margins. The selection of the appropriate crude oil, product grades, and pricing locations to be used in the crack spread formula is not as straightforward as it might seem.

When the crack spread first came into widespread use by refinery analysts, West Texas Intermediate (WTI) crude oil (priced at Cushing, Oklahoma) was one of the most widely traded and price-transparent crude oils in the US marketplace. Thus, WTI-Cushing was a logical choice for the crude oil side of the crack spread formula. Likewise, regular grade unleaded gasoline, which comprised the largest portion of gasoline demand, was a reasonable selection for gasoline in the equation. Finally, diesel fuel and heating oil were typically sold as a single product and represent the lion's share of middle distillate demand. Thus, No. 2 heating oil (also referred to as No. 2 fuel oil) was chosen for the middle distillate portion of the formula. With these inputs, the 3-2-1 crack spread could easily be calculated. The following example shows the calculation based on U.S. Gulf Coast (USGC) product prices and the WTI-Cushing price for August 2004:

	$/Bbl.		
2 Barrels Regular Unleaded Gasoline →	$49.26	x 2 =	$ 98.52
plus 1 Barrel No. 2 Heating Oil →	$47.99	x 1 =	$ 47.99
minus 3 Barrels WTI Crude Oil →	$44.89	x 3 =	$ (134.67)
Total Value Difference on 3 Barrels Crude =			$ 11.84

Calculated Crack Spread = $11.84 / 3 = $ 3.95 per Barrel

The importance of the 3-2-1 crack spread formula as a measure of refinery economics increased in the mid-1980s when refiners started to use the oil futures market to hedge the price risk associated with the difference in the timing of crude oil purchases and finished product sales. Futures contracts for WTI, unleaded gasoline and No. 2 heating oil are all traded on the New York Mercantile Exchange (NYMEX) in 1,000-barrel increments. Thus, the crack spread formula, which involves simple whole number relationships, provides an easy and useful method to cover the pricing risk between WTI crude oil and two of the major refined products, gasoline and No. 2 heating oil. As compared to the crack spread based on USGC prices, the crack spread used by financial analysts is frequently expressed on a traditional NYMEX basis using the following product prices:

- Regular (87 octane) reformulated gasoline (RFG), delivered to New York harbor
- No. 2 heating oil (0.2% sulfur), delivered to New York harbor

The WTI price quoted on the NYMEX is the same as in the USGC formula, i.e., delivered to Cushing, Oklahoma.

The “NYMEX crack” formula is a good example of how there can be different variations on the crack spread that may be—and are—used in different circumstances and for different purposes. Accordingly, one needs to exercise some caution in analyzing or relying on data generically termed the “crack spread.” It is important to understand the underlying statistics used and the specific formula referred to. When used in this paper, the crack spread means the 3-2-1 crack spread using the USGC product prices referred to in the example calculation above.

Typical Cracking Refinery Configuration and Margins

As part of our continuing analysis of refining industry economics on behalf of our clients, Baker & O'Brien regularly monitors both short-term changes and long-term trends in refinery feedstocks, refinery configurations, refined product prices and overall refining industry economic performance. Throughout the years, we have found that the simple 3-2-1 USGC crack spread provides a reasonable proxy for the gross refining margin (i.e., the difference between product revenue and feedstock costs on a unit basis) realized by the typical USGC complex cracking refinery. We define the “typical” USGC complex cracking refinery as one that includes all of the following basic process units:

- Crude Distillation
- Naphtha HDS
- Catalytic Reforming
- Light Naphtha Isomerization
- Vacuum Distillation
- Vacuum Gas Oil HDS
- Fluid Catalytic Cracking
- Distillate HDS
- Kerosene HDS
- C3 / C4 Alkylation

This type of refinery commonly processes a mix of crude oils that we term as “light sour” in quality. Light sour crudes typically have API gravities in the range of 30-35 and sulfur levels in the 1-2% range. We have developed an economic model for the USGC complex cracking refinery based on processing 100% West Texas Sour (WTS) crude oil, which is classified as a light sour crude oil, having a typical API gravity of about 33 degrees and sulfur content of about 1.6%. The price of WTS has been quoted in the spot market since the mid-1980s.

Our cracking refinery model calculates finished product yields from WTS based on employing the process units noted above. The model also purchases outside unfinished feedstocks, as required, to meet prevailing product specifications. Figure 1 shows the WTS cracking refinery yields and a sample calculation of the gross refining margin for the period of

August 2004. Figure 2 shows the results of the same calculation, on a monthly basis, for the last 20 years. The average monthly gross refining margin over this entire period was $3.05 per barrel, with the highest at $9.62 and the lowest at $0.58 per barrel. Although our USGC cracking model is based on 100% WTS, we consider the margins calculated from the model to be representative of the gross margins from a typical USGC cracking refinery processing a light sour crude mix.

Figure 3 overlays the simple 3-2-1 USGC crack spread calculation, also on a monthly basis, onto the data in Figure 2. Figure 3 shows that the 3-2-1 crack spread formula is, and has been historically, a reasonable "proxy" for gross margins achieved by USGC cracking refineries of the kind characterized in our model. This may be somewhat surprising initially, since the unit product revenue side (⅔ gasoline and ⅓ No. 2 heating oil) of the crack spread formula somewhat overstates the unit revenue actually achieved by the model cracking refinery. The latter produces significant volumes of low value heavy fuel oil and light ends. However, this overstatement in revenue is almost entirely compensated for, especially in more recent years, by the price discount that WTS crude oil enjoys over WTI. The average calculated crack spread over the entire 20-year period is $3.33 per barrel, with the highest value at $10.94 and the lowest at $0.39 per barrel.

Applying conventional statistical analysis, it can be shown that, when statistically comparing the crack spread to the WTS cracking margin, the so-called "R-squared" value is 0.80 over the entire 20-year period. This improves to 0.88 when calculated using only the most recent 10-year period. An R-squared value of 0.88 means that 88% of the variation in the WTS cracking margin can be explained by variations in the 3-2-1 crack spread. The improvement in the overall correlation over the last 10 years has been due primarily to the widening differential between the price of WTS and WTI. Recently, this differential has come closer to offsetting the differences on the product value side of the equation. These calculated R-squared values by no means reflect a perfect correlation. However, they do indicate that the simple USGC crack spread is reasonable proxy for USGC light sour crude cracking margins.

Typical Coking Refinery Configuration and Margins

As might be expected, if the traditional USGC 3-2-1 crack spread reasonably reflects cracking margins, it shows much less utility when it comes to more complex refineries that incorporate coking capacity. Thus, we have found that the usefulness of the crack spread, as an indicator of refining industry economic performance, has waned considerably over recent years. The average USGC refinery configuration has shifted substantially toward the complex coking refinery that produces a higher proportional yield of valuable products and processes heavy sour crude oil. Figure 4 shows how the number of cracking and coking refineries on the USGC has changed over the last 20 years. While the number of cracking refineries has fallen by more than half, the number of coking refineries has increased by more than one-third over the same period.

Looking at it another way, Figure 5 shows that USGC coking capacity, as a percentage of crude capacity, has more than doubled over the last 20 years. On the other hand, USGC cracking capacity, measured in the same way, has remained relatively constant during this time period. It follows that USGC refineries with cokers continue to represent an ever larger portion of the market. Today, USGC coking refineries comprise about 90% of total USGC crude capacity and more than 77% of the number of facilities. Unlike cracking refineries, the economics of coking refineries are driven largely by the so-called light-heavy differential—the prevailing difference in price between light sweet crude oils and heavy sour crude oils. The ability to process low cost crude oils must more than compensate for the coking refinery's lower liquid product yield, higher operating costs, and the substantial additional capital investment required. Because the traditional 3-2-1 crack spread does not take the light-heavy differential into account, it is not a very meaningful economic benchmark for these high conversion plants.

Baker & O'Brien tracks the economic performance of the typical USGC coking refinery using an in-house refinery model that incorporates process units similar to those used in the previously described cracking model, with the addition of a delayed coking unit. In the coking model, both the process unit capacities and severities are adjusted to produce a slate of products similar in proportion and quality to the cracking configuration. Of course, the coking refinery produces no residual fuel oil, with the exception of a small amount of decant oil produced from the fluid catalytic cracker. Baker & O'Brien's USGC coking refinery model is based on processing 100% Mexican Maya crude oil. Since the early 1990s, Maya crude oil has been the benchmark heavy sour crude on the USGC. Maya is currently priced by PEMEX for USGC deliveries using the following pricing formula:

Maya, FOB Mexico =

40% WTS, *plus*
40% 3%S No. 6 Fuel Oil, *plus*
10% Louisiana Light Sweet, *plus*
10% Dated Brent, *minus*
Monthly Price Discount from PEMEX

Although most Maya crude oil is purchased under long-term contracts, the Maya formula is used by many industry analysts and traders as being reflective of the current value of heavy sour crude of this quality.

Figure 6 shows the Baker & O'Brien Maya coking refinery yields and a sample calculation of the gross refining margin for the period August 2004. Values for petroleum coke and sulfur are ignored in this calculation for simplicity and because they tend to have minimal economic impact during most time periods. Figure 7 shows the results of the same calculation, on a monthly basis, for the last 10 years. The average monthly gross refining margin for the USGC model coking refinery over this 10-year period was $7.09 per barrel with the highest at $17.14 and the lowest at $2.51. The USGC model coking refinery achieved an average gross refining margin of about $3.45 per barrel more than the cracking refinery during the period 1995-2004.

Figure 7 also shows the wide disparity between the traditional 3-2-1 crack spread and Maya coking margins since 1995. This has been particularly pronounced during the last half of 2004, when the 3-2-1 crack spread and the Maya coking margin diverged from a $4.00 per barrel difference to more than a $13.00 per barrel difference. For the entire 10-year period, the USGC Maya coking margin averaged $3.63 per barrel above the average of crack spread of $3.46 per barrel. This is indicative of the competitive advantage enjoyed by coking refineries processing low cost heavy sour crude oils.

The USGC coking refinery data reinforces the fact that the traditional 3-2-1 crack spread is a poor indicator of refining margins achieved by USGC coking refineries.

A Simple Proxy for Coking Refinery Margins

Baker & O'Brien has developed a relatively simple and reliable substitute for the traditional crack spread, which we term the "coking spread." The coking spread is much more indicative of the gross refining margins achieved by USGC coking refineries that today comprise the bulk of the USGC refining industry. Our primary goals in seeking out a possible substitute for the crack spread were to find an alternative that: (a) reasonably tracked the margins determined in our USGC coking refinery model; (b) was relatively simple from a mathematical standpoint; (c) was based on price quotations readily available from the oil pricing services; and (d) took into account the important crude cost advantage enjoyed by coking refineries.

Our first step in developing the formula was to consider the feedstock side of the equation. Because our USGC coking model uses Maya as its sole crude feedstock, we carefully considered the various components of the Maya pricing formula and analyzed the effects of different feedstock combinations and ratios on the calculated results. Finally, after considering a large number of possibilities and applying some statistical analysis to each, we chose a simple combination of three feedstocks for the crude oil side of the equation: one barrel of WTS; one barrel of Dated Brent; and one barrel of No. 6 fuel oil (3% sulfur). Although No. 6 fuel oil is a product and not a feedstock, it comprises 40% of the Maya pricing formula and many heavy crude refiners are equipped to process it as an alternate feedstock. For the product side of the equation, we followed generally the same pattern in reviewing various product combinations and determining whether or not they improved the accuracy of the formula. Because coking refineries often tend to make proportionally more middle distillate product than cracking refineries, we finally settled on equal volumes of regular unleaded gasoline and No. 2 heating oil for the product side of the equation. The final coking spread formula, based on USGC product pricing, is given below:

Coking Spread ($/Bbl.) =

0.5 x Regular Unleaded Conventional Gasoline, *plus*
0.5 x 0.2% Sulfur No. 2 Heating Oil, *minus*
0.33 x WTS-Midland, *minus*
0.33 x Dated Brent, *minus*
0.33 x 3.0% Sulfur No. 6 Fuel Oil

The following example shows the calculation of the coking spread based on product prices on the USGC and feedstock prices for August 2004:

	$/Bbl.		
0.5 Barrel Regular Unleaded Gasoline →	$49.26	x 0.5 =	$ 24.63
plus 0.5 Barrel No. 2 Heating Oil →	$47.99	x 0.5 =	$ 23.99
minus 0.33 Barrel WTS →	$40.89	x 0.33 =	$ (13.63)
minus 0.33 Barrel Dated Brent →	$43.01	x 0.33 =	$ (14.34)
minus 0.33 Barrel 3%S No. 6 Fuel Oil →	$24.95	x 0.33 =	$ (8.32)
		Calculated Coking Spread =	$ 12.34

Figure 8 compares the monthly calculated USGC coking spread to the USGC Maya coking margin over the last 10-year period. Statistical analysis over this period gives an R-squared of 0.89, which is essentially the same as the result for the crack spread vs. the cracking margin. This means that the coking spread formula, as presented above, appears to be as good a proxy for USGC coking margins as the crack spread is for USGC cracking margins. The average calculated coking spread over the 10-year period is $6.89 vs. $7.09 per barrel for the coking margin—a difference of less than 3%. Also over the 10-year period, the highest calculated coking spread is $17.99 vs. $17.14 per barrel for the coking margins. The lowest coking spread is $2.77 vs. $2.51 per barrel for the coking margins. These results indicate that the coking spread represents an excellent proxy for USGC coking gross margins when processing heavy sour crude oils.

Like the traditional crack spread, one of the benefits of the coking spread formula is that it can also be used for price risk hedging. This is because all of the variables used in the formula have a comparable futures contract that is available through NYMEX.

In summary, USGC refinery economic performance has become increasingly driven by heavy sour crude coking margins—not by the economics of the few remaining cracking refineries. Thus, the traditional 3-2-1 crack spread formula has lost a good deal of its historical utility as an indicator of the economic performance of the refining industry as a whole, or coking refineries in particular. The coking spread formula presented in this paper is a simple, easily applied, and reliable indicator of USGC heavy sour crude coking margins. It should serve as an effective replacement for the crack spread formula and better reflects today's refining industry economics.

Figure 1
WTS Cracking Refinery Gross Margin
August 2004

	Vol.% of Crude	*Price $/Bbl.*	*$/Bbl. of Crude*
Refinery Products			
Fuel Gas, FOE Barrels	1.7	$ 33.09	$ 0.55
Propane	2.4	$ 35.04	$ 0.83
Regular Unleaded Conventional	22.3	$ 49.26	$ 10.98
Regular RFG	22.3	$ 50.69	$ 11.30
Premium Unleaded Conventional	11.1	$ 53.24	$ 5.93
Jet Fuel / Kerosene	8.6	$ 51.43	$ 4.43
0.05%S Diesel	9.9	$ 49.67	$ 4.92
0.2%S No. 2 Heating Oil	9.9	$ 47.99	$ 4.76
3.0%S No. 6 Fuel Oil	18.6	$ 24.95	$ 4.64
Total Products	106.8		$ 48.34
Feedstocks			
WTS, delivered USGC	100.0	$ 41.29	$ (41.29)
Normal Butane	1.1	$ 39.38	$ (0.42)
Isobutane	1.9	$ 38.55	$ (0.72)
MTBE	2.5	$ 67.05	$ (1.64)
Total Feedstocks	105.4		$ (44.07)
WTS Cracking Refinery Gross Margin			**$ 4.27**

SOURCE: Prices based on daily low quotes from *Platts Oilgram Price Report*.

Figure 2
USGC WTS Cracking Margin

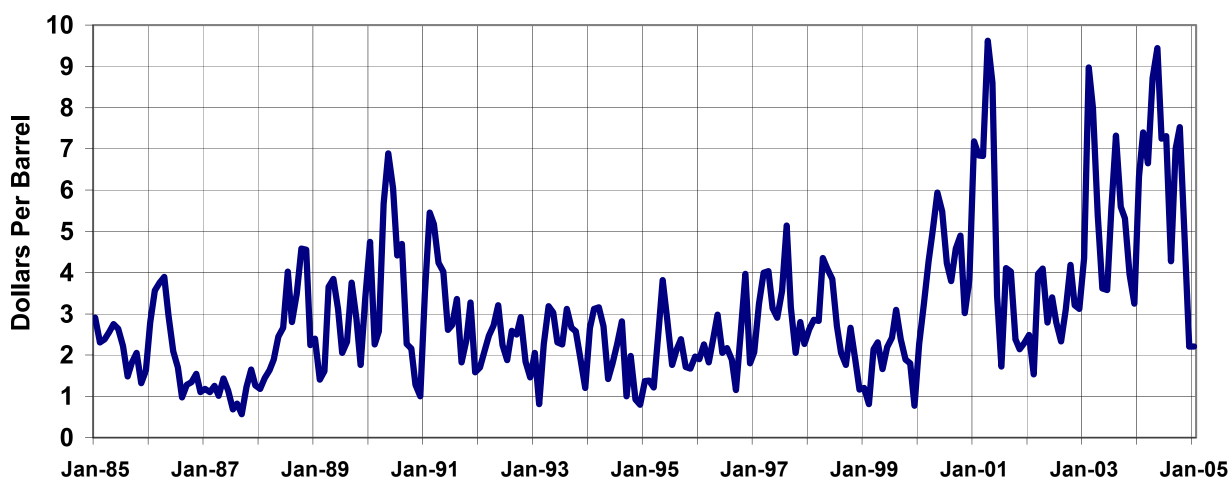

Figure 3
USGC WTS Cracking / WTI 3-2-1 Margins

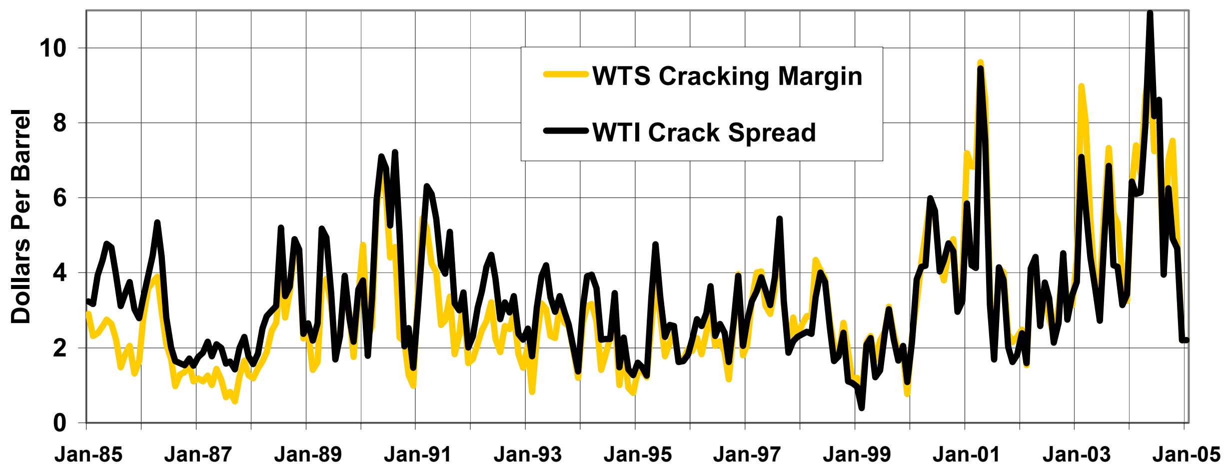

Figure 4
Classification of USGC Refineries

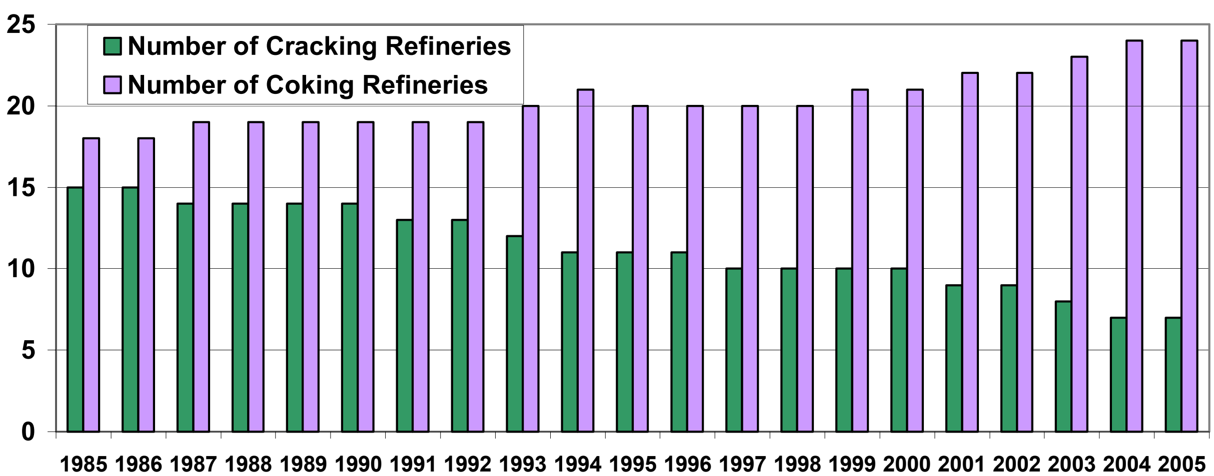

Figure 5
USGC Coking Capacity as a Percentage of Crude Capacity

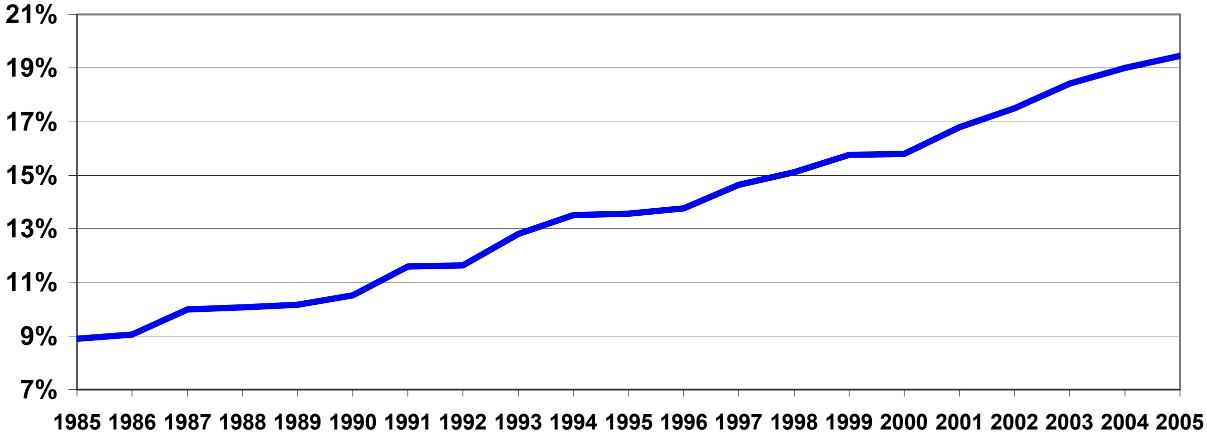

Figure 6
Maya Coking Refinery Gross Margin
August 2004

	Vol.% of Crude	***Price $/Bbl.***	***$/Bbl. of Crude***
Refinery Products			
Fuel Gas, FOE Barrels	4.0	$ 33.09	$ 1.31
Propane	3.2	$ 35.04	$ 1.14
Regular Unleaded Conventional	21.7	$ 49.26	$ 10.66
Regular RFG	21.7	$ 50.69	$ 10.97
Premium Unleaded Conventional	10.8	$ 53.24	$ 5.77
Jet Fuel / Kerosene	6.3	$ 51.43	$ 3.24
0.05%S Diesel	15.0	$ 49.67	$ 7.43
0.2%S No. 2 Heating Oil	15.0	$ 47.99	$ 7.17
3.0%S No. 6 Fuel Oil	2.3	$ 24.95	$ 0.57
Total Products	99.8		$ 48.27
Feedstocks			
Maya, delivered USGC	100.0	$ 32.99	$ (32.99)
Normal Butane	0.8	$ 39.38	$ (0.32)
Isobutane	3.6	$ 38.55	$ (1.40)
MTBE	2.4	$ 67.05	$ (1.60)
Total Feedstocks	106.8		$ (36.30)
Maya Coking Refinery Gross Margin			**$ 11.97**

SOURCE: Prices based on daily low quotes from *Platts Oilgram Price Report*.

Figure 7
USGC Maya Coking Margin vs. Crack Spread

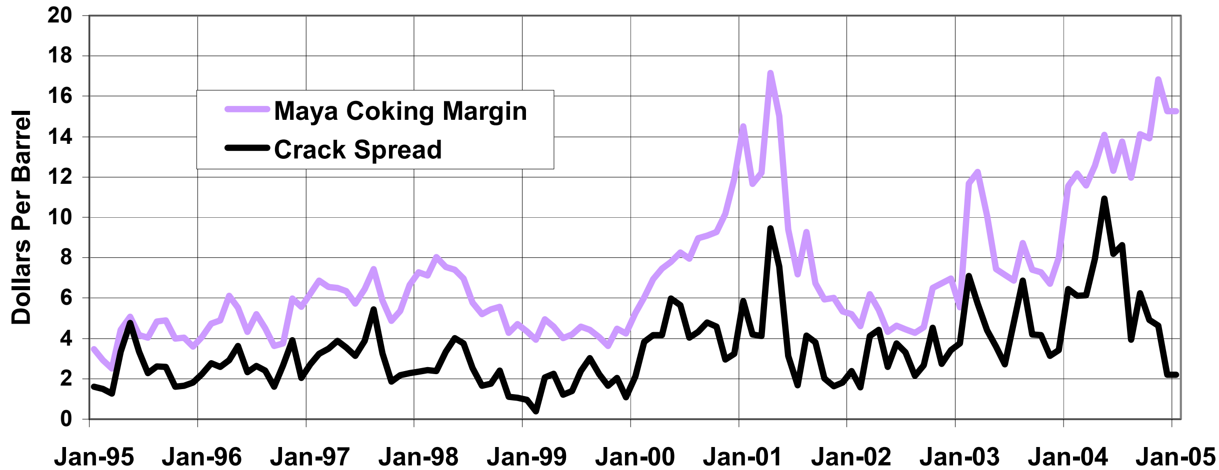

Figure 8
USGC Maya Coking Margin vs. Coking Spread