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Panel Discussion: The Impact of U. S. Environmental Regulations on the Refining Industry

As a follow-up to the formal presentation by the American Petroleum Institute, a panel of representatives from the U.S. refining industry was convened to elaborate on the impact on specific refinery processing. Panel members included Arthur S. Alexander of Chevron USA, Rick Woonik of Conoco, Carlton H. Jewitt of Ashland and Tom A. Verachtert of UOP Inc.

Expanding the discussion beyond the manufacture of reformulated gasoline, it was pointed out that regulations for highway grade diesel fuel will go into effect on October 1, 1993 in 49 states and will require that the sulfur content of this fuel be reduced to a maximum level of 500 ppm, a ten-fold decrease. These stringent limits for sulfur content can prevent refiners from blending other products such as kerosine or jet fuel because the allowable sulfur specification limits for these fuels are higher than 500 ppm. However, such blending is standard practice in areas where winter temperatures fall below the normal cloud point of No. 2 diesel fuel. In addition to this sulfur limit, the State of California is also requiring the same limit for non-road vehicles using diesel fuel and has added a requirement for a 10% maximum limit on aromatic content. To date no refiner has been able to qualify a product to California standards.

One panel member presented the results of a linear programming study involving a typical 100,000 barrel per day refinery. The baseline configuration of such a refinery, listed in Table 1, meets 1990 baseline

TABLE 1 - 1990 BASELINE REFINERY CONFIGURATION

Crude Fractionation
Reformer
Distillate Desulfurizer
Gas Oil Desulfurizer
Fluid Catalytic Cracker
Alkylation Unit
Sulfur Plant

gasoline and diesel quality by the addition of distillate and gas oil desulfurization. The resulting product slate, produced from a mix of sweet and sour crude, is shown in Table 2.

TABLE 2 - 1990 BASELINE REFINERY FEEDSTOCK AND PRODUCT SLATE

Feed Stocks	Barrels/day	m^3/day
Crude Oil (Blend of Sweet & Sour)	100,000	15,900
Isobutane	5,500	875
Products		
LPG	3,500	570
Unleaded Gasoline	40,500	6,440
High Octane Unleaded Gasoline	10,200	1,620
Jet Fuel	12,500	1,990
No. 2 Heating Oil or Diesel Fuel	16,000	2,540
Asphalt and Heavy Fuel Oil	20,500	3,260

To make reformulated gasoline to the 1995 standards, an MTBE (methyl tertiary butyl ether) unit and an isomerization unit have to be added and gas oil desulfurization capacity has to be expanded. The new product slate is summarized in Table 3 and consists of about 50% reformulated gasoline and low sulfur diesel, instead of higher sulfur heating oil. However, the new scheme also dictates procuring isobutane, methanol, MTBE and hydrogen gas from outside the refinery to accomplish the desulfurization demanded by this product slate.

TABLE 3 - REFORMULATED GASOLINE REFINERY FEEDSTOCK & PRODUCT SLATE

Feedstocks	Barrels/day	m^3/day
Crude Oil (Blend of Sweet & Sour)	100,000	15,900
Isobutane	5,300	840
Methanol	300	50
MTBE	2,300	370
Hydrogen	21*	590**
Products		
LPG	3,100	490
Unleaded Gasoline	23,200	3,690
High Octane Unleaded Gasoline	5,400	860
or		
Reformulated Gasoline	20,400	3,240
High Octane Reformulated Gasoline	4,800	760
Jet Fuel	13,800	2,190
Low Sulfur Diesel Fuel	15,000	2,380
Asphalt & Heavy Fuel Oil	20,500	3,260

* Millions of standard cubic feet/day
** Standard cubic meters/day

Table 4 lists the primary 1990 ("base line") versus the 1993 properties of diesel fuel, showing the sulfur reduction and a slight improvement in cetane index.

TABLE 4 - DIESEL FUEL PROPERTIES

	% Sulfur	Cetane Index
1990 Baseline Diesel Fuel	0.20	44.5
Post 1993 Low Sulfur Diesel Fuel	0.05	45.0

The gasoline properties of 1990 baseline versus 1994 conventional and reformulated gasoline are summarized in Table 5. The reformulated gasoline shows a decrease in vapor pressure and reveals a drop in aromatic content from 26 to 16%, small decreases in benzene and olefin levels and the inclusion of sufficient MTBE to obtain an oxygen level of 2.4% in the gasoline.

TABLE 5 - GASOLINE PROPERTIES

	RVP	Octane	%Oxygen	%Benzene	%Aromatics	%Sulfur	%Olefins
1990 BASELINE							
Regular	8.2	87.0					
Premium	8.2	91.0					
Baseline Pool			0.0	0.8	26.0	0.026	13.1
POST 1994 GASOLINE							
Conventional							
Regular	8.7	87.0					
Premium	8.7	91.0					
Conventional Pool			0.0	0.8	24.7	0.025	13.9
Reformulated							
Regular	6.9	87.0					
Premium	6.9	91.0					
Reformulated Pool			2.4	0.5	16.3	0.023	12.7

The EPA draft rules for 1992 also include controls on gasoline volatility and require the addition of enough oxygenated species for a minimum oxygen content of 2.7%. This level is mandated in 41 major US areas which do not meet carbon monoxide air quality requirements. In a typical catalytic cracking refinery, the addition of an MTBE unit based on internally available olefins will only meet 15% of the total oxygenate requirements. If a unit is added to make tertiary amyl methyl ether

(TAME), another 16% of the oxygen demand will be met. In any case between 69 to 85% of additional ether must be purchased to meet the mandated oxygen content of improved gasoline.

The rules for reformulated gasoline in 1995 further mandate reductions in Reid vapor pressure (RVP) and benzene, the addition of oxygenates and the installation of toxic emission controls in nine severe ozone non-attainment areas. RVP reductions by the fractionation of butanes and pentanes may not be feasible because refiners have previously revamped and expanded their facilities and may no longer have the capacity for further expansion. This is due to the fact that the introduction of unleaded gasoline has forced many small refiners out of business and caused large refineries to expand to meet market demand. Meeting benzene reduction targets will force decreases in reforming severity, but this step will reduce hydrogen volumes needed for other essential treating. In some cases, reformate fractionation or extraction of the aromatics for petrochemical use would be a logical course.

To meet the 1997 target for reformulated gasoline a more complex model must be considered. It adds to the 1995 model a reduction in sulfur by hydrotreating the heavy end of fluid catalytically cracked gasoline, a reduction of the 90% distillation point by the fractionation or cracking of the heavy ends and finally an olefin reduction by either fractionation or hydrotreating.

It is obvious that one major problem for all refiners in meeting the 1997 standards is a shortfall of hydrogen gas, normally obtained from reforming, especially because severe diesel fuel desulfurization has to be added to the hydrotreating needs of reformulated gasoline. A second problem lies in the fact that, although carbon monoxide and ozone non-attainment areas often do not overlap, transportation, storage and shipping restrictions may require a refiner to meet all reformulation requirements for the gasolines made at any given plant.

One question posed to the panel concerned the current mix of octane quality which could become more critical when refiners have to meet reformulated gasoline composition. There are clear indications that not all cars are as octane critical as they were because meeting current emission standards has made cars less prone to knock. In reply it was stated that all companies must market at least one grade having a minimum 87 (R+M)/2, but the sale of higher octane grades is generally a marketing decision rather than a technical need. The introduction of a reformulated gasoline grade having an octane below 87 therefore ought to be considered because it would satisfy the octane demand of many cars.

Another question concerned the shortfall of MTBE as an in-house refinery product. Such a shortfall could also be met by the addition of ethyl alcohol instead of MTBE. It was agreed that such alcohol addition is an alternative, but it requires terminal rather than refinery addition because of water extraction. Other oxygenates such as isopropanol and diisopropyl ether are being considered; in fact, the American Petroleum Institute is preparing a white paper examining the availability of these alternatives.