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The World Refining System and the Oil Products Trade

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The OIES Series of Papers on Gulf and World Oil Issues

The purpose of this series of eight papers is to analyse a number of oil issues - political, economic and industrial - which have always been important but which have acquired additional significance during the current Gulf crisis.

The analysis in each paper attempts to explain the nature of the problem at hand, the behaviour of economic agents in times of crisis and to draw policy implications for both governments and industry.

The series begins with a paper providing a political analysis of the Gulf crisis and of possible future developments. The other papers are concerned more specifically with oil and gas issues. The papers will appear weekly beginning on 3 October 1990 in a sequence in which problems with greater significance for the short term are dealt with first. The series then moves to issues with a long-term dimension (world economy, substitution of oil by gas, demand, environment).

The series extends significantly the work presented at a very early stage of the crisis (mid-August) in the Institute's study *The First Oil War.* Many new topics have been researched, and those addressed in *The First Oil War* developed in greater depth.

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1. INTRODUCTION

The principal feature of the "1990 oil price shock" is that it is a crisis not only of crude oil supplies but also of oil products. The invasion of Kuwait and the subsequent embargo of Iraq and Kuwait have resulted in the loss of between 4.5 and 5.16 mb/d of crude oil supplies (see OIES, The First Oil War, August 1990). In terms of actual product supplies the invasion of Kuwait has only removed between 650 and 750 thousand b/d of combined Kuwaiti and Iraqi export capacity. This represents around 1 per cent of total world product consumption, certainly less than the crude oil shortfall caused by the crisis and yet, in absolute terms, the price differential between crude oil and many of the lighter products has increased. The product price shock indicates that there is a perceived inflexibility in the world refinery system regardless of whether lost crude oil supplies can be replaced.

From the oil well to the petrol pump, the refining process is the most technical and least understood stage in the exploitation of our crude oil resource. The current panic buying in petroleum product markets, therefore, raises questions about the nature of these technical constraints which require explanation.

First, has the world refinery system become more inflexible during the 1980s or are oil product traders' perceptions unfounded? To answer this we analyse the shifts in world demand for the various products and the structural changes in the world refining system these shifts have made necessary.

Secondly, if oil traders' perceptions are correct how is this growing inflexibility manifested in today's oil price shock? Here we review the two product price spikes that occurred in 1989 in order to test their relevance to the 1990 price shock and assess the vulnerability of product supplies today.

Thirdly, what investment is now planned to restore flexibility in the refining system in the medium-term future? In this section we assess the various factors that may shape the future path of world product demand in order to determine whether current refinery investment will be sufficient. We also look at the geographical distribution of this planned investment to see how new product supplies may affect the pattern of oil products trade.

2. WORLD PRODUCT DEMAND AND THE STRUCTURAL CHANGE IN THE WORLD REFINING SYSTEM DURING THE 1980s

Two principal changes in the world refining system have been brought about by the decline in the absolute demand for petroleum products in the years 1980-5 and shifts in demand for the relative quantity and quality of these products throughout the 1980s. The first has been the decline of atmospheric distillation capacity and the second the increasing profitability of the more complex refiner processes.[1] In this section we review the changes in world demand and the consequent structural transformation of the world refining system.

2.1 The Decline in World Distillation Capacity

The decline in total OECD and developing countries petroleum product demand in the first half of the 1980s faced refiners with the problem of excess distillation capacity that had built up during the 1970s. This decline from around 2.5 billion tons per annum in 1979 to 2.2 billion tons per annum in 1985 (see Table 1) was due primarily to the reduction in primary energy consumption[2] and inter-fuel substitution achieved in the OECD countries. Similarly, the decline in world distillation capacity from 80 million barrels per calendar day (b/cd) in 1979 to 73.8 million b/cd in 1985 (see Table 2) occurred mainly in those OECD countries where the fall in product demand was most significant.

Refiners are naturally inclined to rid themselves of excess capacity. During a period of excess capacity high throughputs result in a glut, with the result that the market is uncompetitive and it is impossible for many refiners to pass on their costs to the consumer. This situation prevails until some refiners are forced out of the market, thereby redressing the balance between supply and demand. The speed at which the balance is resumed is a measure of the competitiveness of that market.

The process of disinvestment in idle OECD distillation capacity did not start until 1981-2, and in Western Europe and Japan excess distillation capacity still exists. In Japan unused capacity was mothballed - that is the careful preparation of distillation

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[1]Atmospheric distillation involves the simple separation of a mixture of compounds found in crude oil into purer fractions by using the differing boiling points of those compounds. This is the fundamental unit for all refineries. If no other adjective is attached to the phrase "the capacity of a refinery is ..." then the "capacity" refers to the maximum crude oil processing capability of the refinery's atmospheric distillation unit.

All other units within the refinery system involve further processing the yield of the atmospheric distillation unit. The cracking process breaks heavy hydrocarbon molecules into smaller and lighter ones thereby increasing the refinery yield of lighter products such as gasoline and heating oil. Octane-enhancing processes, such as catalytic reforming units and alkylation units, are used to improve the quality of gasoline either for environmental reasons or to improve automotive efficiency.

[2]"Primary energy includes that used in the same form as in its naturally occurring state, for example crude oil (and its products), coal, natural gas, and indicates the total fund of energy available before conversion, for example into electricity by burning", P. Brackley, Energy and Environmental Terms: A Glossary, 1988.

capacity so that it can be brought back into operation after a long idle period - and excess capacity was kept in use as a result of product trade restrictions. In certain Western European countries inefficient distillation capacity was kept in operation through state subsidy. These areas with spare distillation capacity are now able to capitalize on the upsurge in product demand spurred by the current Gulf crisis, although these circumstances may well not persist.

2.2 The Growing Importance of Cracking Capacity

This decline in total OECD and developing countries product demand was associated with a significant change in the relative demand for petroleum products which had serious implications to the profitability of certain refinery yields. Fuel oil consumption was hit hardest by the downturn in demand, losing around 10 per cent of its market share from 28 per cent in 1979 to 18 per cent in 1989 (see Table 1). Gasoline and the middle distillates on the other hand have increased their respective market shares to 29 and 35 per cent in 1989 from 26 and 30 per cent in 1979. These opposing trends in the consumption of different petroleum products can be ascribed to their relative substitutability. Whereas fuel oil can be switched for other energy sources such as gas there are, as yet, no economically viable alternatives to the petroleum-based transportation fuels. This change in the composition of demand increased the light to heavy product price differential inducing refiners to maximize light product yields in order to maintain or improve profit margins.

The importance of matching refiner yields to relative product demand led refiners to invest in cracking processes that break down heavy hydrocarbon molecules - thereby increasing the per barrel yield of light products. In order to maximize light product yields the only available option for refiners without cracking facilities is to buy a lighter crude feedstock. Of course an increase in the price differential between light and heavy crudes can soon make such a strategy economically prohibitive, once again introducing strong incentives to invest in cracking processes.

Different types of cracking processes produce light yields of differing qualities which are not necessarily suitable for blending to obtain light end-products of the required specification. The importance of this point will become clear in the analysis of relative product supplies in today's markets (Section 3). Three broad types of cracking exist: thermal cracking, catalytic cracking and hydrocracking. Thermal cracking and catalytic cracking are both suited to the production of gasoil (often used for heating) and gasoline. These processes are able to switch between high gasoline and high gasoil production to match increased demand for gasoline in the summer and for heating oil in the winter. Hydrocracking is a relatively new process and has the added advantage of being able to produce yields suitable for jet fuel/kerosene (the two products are interchangeable) blending. Hydrocracking also involves refinery processing gains and produces higher quality yields.

Despite the obvious advantages of the hydrocracking process its relative youth and expense has led refiners to favour catalytic cracking. In the non-communist world, catalytic cracking capacity expanded from 7.5 million b/cd on 1 January 1979 to 10 million b/cd on 1 January 1990 and the proportion of catalytic cracking to distillation capacity from 12 per cent to 18 per cent. Thermal cracking capacity, which includes thermal cracking, vis breaking and coking, is currently 3.9 million b/cd and hydrocracking capacity stands at 2.6 million b/cd (see Table 3). Limited hydrocracking capacity means that any surge in jet fuel/kerosene demand can only be supplied by increasing distillation throughput which in turn results in a surplus of fuel oil. The invasion of Kuwait has taken 7.3 per cent of world hydrocracking capacity out of production and has in no small way contributed to high kerosene prices in the Far East and high jet fuel prices in the West (see Figure 1).

2.3 The Quality of Gasoline

Increasing demand for cleaner and better quality gasoline implies a greater need for refinery investment. These demands have originated in the OECD countries where over 80 per cent of combined OECD and developing countries gasoline demand is located (see Table 1) and thus have a significant effect on world gasoline markets. From a refiner's point of view these demands are mutually opposing, as environmental restrictions on lead and gasoline volatility reduce octane quality[3] while motorists demand higher octane gasoline for more efficient engine performance. This dual pressure has increased the need both for greater cracking capacity to maintain gasoline supplies and also for greater octane-enhancing capacity to maintain gasoline quality.

The phasing-out of lead in the USA, Japan and Western Europe has increased the cost and restricted the supply of gasoline. Lead served as an inexpensive gasoline additive that in small quantities increased octane quality without detriment to other quality requirements such as volatility. In order to maintain gasoline octane quality refiners have been forced either to invest in processes to enhance traditional gasoline-blending components, such as naphtha, or to obtain expensive non-hydrocarbon substitutes, such as methyl-tertiary-butyl-ether (MTBE). The catalytic reforming unit (CRU) has remained the most popular octane-enhancing process. Although world CRU capacity did not increase greatly between 1979 and 1990 the severe condition at which these units are now operated to increase the octane number of naphtha has resulted in diminished yield - thereby constricting the supply of gasoline and increasing refiner costs.

The Japanese gasoline market is now lead-free and in North America refiners have adjusted to unleaded production. West European refiners still in the process of adjustment, however, are experiencing a decline in indigenous supplies resulting in a smaller surplus of gasoline for export to the USA (recently Europe has even been buying US gasoline cargoes).

Further environmental restrictions on US gasoline in 1989 have increased octane concerns and had a devastating effect on world markets (see Section 3.2). The lowering of the maximum gasoline volatility specification over the crucial summer months, as with

[3] The octane number of gasoline is a measure of its propensity to ignite under compression. The higher the octane number the less flammable a gasoline is. As the gasoline engine relies on a spark plug to ignite the petrol fumes in the compression chamber the less flammable the gasoline the better the engine performs.

lead phase-out, has decreased supplies and increased costs. The volatility specifications mean that much butane, a cheap high-octane but volatile gasoline component, has to be removed from the gasoline mix (butane previously constituted 5 per cent of US gasoline supplies) and investment made to enhance the octane of other gasoline components.

Also, the US Congress is expected to reformulate gasoline specifications in the forthcoming revision of the 1970 US Clean Air Act. The reformulation is likely to impose a minimum oxygen content, maximum aromatics content and a reduction of certain emissions. If passed, these regulations will probably result in the increased use of MTBE (MTBE may soon account for 15 per cent of volume of US gasoline in certain areas), changes in the use of CRUs and increased investment in alternative octane-enhancing processes such as alkylation and isomerization. The net result to US refiners will be an increase in gasoline yield and increased costs which it may not be possible to push through to the consumer.

Octane concern has been reinforced by the demand at the pump for better performance fuels. This trend in both Western Europe and the USA implies a decline in gasoline supplies. The average octane number of US gasoline supplies has increased from 83 in 1980 to 88.4 in 1988. In Western Europe the 1989 average octane rating was 92 and this is expected to increase to 93 by 1995.

Surplus distillation capacity exists in world refining but investment is needed in cracking and octane-enhancing processes. The world refining system is still adjusting to the shift in demand towards the lighter end of the product barrel and supplies of these light products are tight. The gasoline and jet fuel/kerosene markets seem the most vulnerable to a price spike because of continual environmental regulation of gasoline and limited hydrocracking capacity. However, despite good refiner margins over the past three years this necessary investment may not be forthcoming. The experience of the 1980s has left refiners investment-shy, most especially in the OECD countries where product demand is so price-responsive and environmental restrictions both on product specification and refinery construction show no signs of abating. Coupled with this, the construction industry servicing the refinery sector has dwindled, especially in the USA where it is at 50 per cent of its capacity in 1980. In short, refinery construction in the 1990s will be predominantly based in developing countries.

3. THE VULNERABILITY OF PETROLEUM PRODUCT SUPPLIES TODAY

Since 1986-7 light product prices have been on an upward trend, further differentiating them from heavy products, and since the beginning of 1989 light product markets have been subject to sudden shocks causing prices to rise significantly, albeit for a short period of time (see Figures 1 to 4). Investment in cracking facilities has not responded to this growing imbalance between light and heavy product demand as refiners are now wary of the cyclical nature of profit margins and uncertain of future environmental regulation (see section 2.3). In this section we look at the reasons for the price "spikes" that have occurred in the last two years and the signals for investment that these market developments are sending refiners.

3.1 The Gasoline Price Spike of Spring 1989

The gasoline-led price spike in the USA that brought prices in North West Europe up from $169.5 per ton on 1 March to a peak of $271.5 per ton on 26 April (see Figure 3) was not due to a sudden fall in supplies but to uncertainty over the sufficiency of supplies for the coming summer gasoline season. This fear was not necessarily unfounded. Between 1980 and 1988 US imports of gasoline more than tripled from an average of 140,000 b/d to around 440,000 b/d. This suggests that US domestic refineries were too outstretched to be able to supply small incremental quantities of gasoline of the required quality. Coupled with this import growth, the change in specifications reducing the summer volatility of US gasoline from 11 to 10.5 Reid Vapour Pressure (RVP) through federal regulation, and to 9 RVP in the large north-eastern market through state regulation, implied a restriction both on the quality and quantity of indigenous and imported US supplies. The loss to the gasoline market was estimated at between 2 to 3 per cent of total supplies or around 100-150,000 b/d. Not only had these supplies to be replenished from a highly competitive gasoline export market but octane lost from the removal of butane (a high octane but highly volatile gasoline component), had to be compensated for when utilization rates of octane-enhancing processes were at the maximum. In the event, low gasoline demand that summer, 7.5 mb/d in June 1989 compared with 7.8 mb/d in June 1988, and the inventory build of 9 RVP gasoline in the spring prevented any supply disruptions.

Despite the fact that a gasoline supply disruption never materialized over the summer, possibly a result of the spring and summer price rises themselves, the gasoline price spike that threw prices around $90 per ton above the previous two years summer peak held one clear message (see Figure 3). Without considerable investment in octane-enhancing processes it will be difficult to maintain the quality of gasoline in the face of environmental restrictions on the use of high octane gasoline components such as lead and butane. This fact is illustrated by the fall in naphtha prices in the spring of 1989 while gasoline prices were rising. The reason for this was that octane-enhancing processes in Europe and the USA were fully utilized, with the result that spare naphtha supplies could not be blended into gasoline because they were of insufficient quality.

3.2 The Heating Oil Price Spike of Winter 1989

The price spike that occurred in the winter of 1989 and brought prices of gasoil in North West Europe to a peak of $248 per ton on 4 January 1990, compared to $160 per ton the same date a year before, was not the result of traders' fears but of an actual supply disruption combined with a surge in the demand for heating oil. In 1989 the US Gulf Coast experienced its coldest winter for 50 years and as a result 1.8 million b/cd of distillation capacity was incapacitated between 22 and 29 December - 1.2 million b/cd of which remained closed for the first half of January 1990. The price of gasoil doubled on the US Gulf Coast during this short period and most other products followed its lead across world markets.

Despite unremarkable winter demand the price of jet fuel on the US Gulf Coast followed that of gasoil during the demand surge of mid-December and then rose above it after the refinery closures of 22 December (see Figures 1 and 2). The reason for this is to be found in the inflexibility of the world refining system today. The lack of spare world hydrocracking capacity has meant that jet fuel must compete with gasoil for simple distillation yield (see Section 2.2 above). Therefore, any surge in demand for gasoil will push jet fuel prices higher in order to maintain normal supplies. The price spike in jet fuel was exaggerated further in this case because the US Gulf Coast refineries had considerable hydrocracking capacity.

Although this supply disruption was greater than that of the current Gulf crisis it was also short lived. The price implications of a cold winter and refinery closures this year are serious as this would amplify the problems caused by lost Kuwaiti capacity, especially hydrocracking capacity.

3.3 The Gulf Crisis and the Implications of a War Scenario

The invasion of Kuwait and the embargo that followed have resulted in a significant loss of products to the world markets and have clearly shown the tightness of world supplies at the lighter end of the products barrel. The shortfall in light products was added to by the initial diversion of all Saudi Arabian light and middle distillate exports to fuel the US military build-up. This factor has been mollified as Saudi Arabia has resumed the export of 200,000 tons of kerosene and gasoil to Japan this October. However, in terms of Saudi Arabia's light and middle distillate exports of 1988 (see Table 5)[4] this represents only 9 per cent of their usual monthly exports. In addition, Saudi Arabian and Venezuelan replacement supplies for lost Kuwaiti and Iraqi crude oil exports have been on average 2.4 degrees API heavier, resulting in a fall in the lighter product yield of many refineries.

Although Kuwait and Iraq exported more heavy fuel oil than any other product - some

[4]Tables 5 and 6 have been compiled from the recent OAPEC publication Prospects of Arab Petroleum Refining Industry. Unfortunately because OAPEC was based in Kuwait the recent sad political developments have halted the dissemination of the publication. We have taken this opportunity to present some of the impressive data in detail especially given its added relevance at this time.

13 million tonnes per annum (see Table 5) or 237,000 b/d in 1988 - the price differential between fuel oil and the lighter products has increased dramatically during the crisis. The product prices most affected by the shortfall in supplies are naphtha and kerosene/jet fuel. In Japan the price differential between kerosene/jet fuel and heavy fuel oil has increased from $62 per ton in the first week of July to $311 per ton for the week ending on 28 September. The reason for this is that although there is spare distillation capacity in the world sufficient to meet world demand for light products, there is insufficient cracking capacity to turn unwanted fuel oil into those products. In order to make a return on the yield of a distillation unit, usually 25-50 per cent fuel oil depending on the lightness of the crude, refiners would have to expect light product prices to make up for the increased deficit encountered when selling surplus heavy fuel oil. Hence, distillation capacity is termed inefficient as its yield does not match the pattern of demand for petroleum products. The loss of Kuwaiti refinery capacity is important because it held 451,000 b/d of cracking capacity (Fluid Catalytic Cracking (FCC) equivalent[5]) to 826,000 b/d of distillation capacity (see Table 6), some 25 per cent above the world average cracking to distillation capacity ratio of 30 per cent. Included in this Kuwaiti cracking capacity was over 7 per cent of world hydrocracking capacity which placed Kuwait in a unique position to supply the middle distillate needs of the Far East, especially those of Japan.

Traders' reaction to the crisis has been coloured not only by the loss of product supplies but also by concerns over how temporary the loss of refinery capacity will be. A refinery requires constant supervision and maintenance if it is to operate smoothly and even then unpredictable weather (see Section 3.2) can close it overnight. Refineries that are not in operation must be carefully prepared, or mothballed, if the facilities are to remain usable. It is unlikely that the Kuwaiti refineries have been mothballed and so, even if they have not sustained any war damage, rusted portions of the refineries will need replacing. Moreover, it was reported in Energy Compass (21 September, 1990) that refinery spare-parts have been looted from Kuwait. Consequently, even if the Gulf crisis ended tomorrow without the refineries having been attacked, we can assume that Kuwaiti refineries will not be back in operation before the end of this winter. It should also be remembered that when and if the conflict ends all parts of the Kuwaiti economy will require investment and that the restoration of refineries may not be the first priority.

In a non-war scenario there is no reason why Iraqi or, more importantly, Saudi Arabian product export capacity should not be resumed in full. In a war scenario there is a possibility that both may be endangered. The Iraqi refineries would obviously be prime military targets for an air strike in the event of war. The airborne capability of Iraq will not be sufficient to penetrate Saudi Arabian airspace or, therefore, to inflict damage on many of their refineries. The Saudi Arabian refineries that lie within 400 miles of the Kuwaiti border, however, may be vulnerable to Iraqi scud missiles. Two refineries,

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[5]Cracking processes have differing values to refiners (see Section 2.2). The capacities of the various processes have been ascribed the following numerical values: FCC = 1, hydrocracking = 1.3, visbreaking = 0.33, coking = 1.7, thermal cracking = 0.65. As FCC is used as the reference point the final result is termed FCC equivalent.

Mina Saud[6] and Khafji, lie within 10 miles of the border and it is thought that these could be easily threatened. Ras Tanura lies 160 miles from the border but the probability of Iraq achieving a direct hit is very small. The damage that would be inflicted by the destruction of the first two refineries is slight as they have only a combined distillation capacity of 88,000 b/d and in 1988 produced 84 per cent fuel oil. However, any damage that might be done to Ras Tanura, perhaps through the explosion of its LPG storage facility (see The Economist, 29 September-5 October, 1990, p. 93), will be significant not only for the product markets but also for the crude market (see Table 6).

The Jubail refinery is situated some 40 miles nearer to the Kuwaiti border than Ras Tanura and although Ras Tanura has larger distillation capacity the destruction of Jubail would probably have a more profound effect on the world products market as Jubail has more sophisticated cracking capacity. In 1988 the Jubail refinery accounted for over 50 per cent of total Saudi naphtha production and 36 per cent of total Saudi Jet Fuel/Kerosene production (see Table 6). This shortfall would be significant for these two markets which are presently very tight. Two other refineries, UAE's Ruwais and Bahrain's Awali refinery, lie within theoretical range of Iraqi missiles but the risk to them is negligible.

3.4 The "Short-Term" Future

Whatever the political developments in the Gulf, Kuwaiti product exports will not resume until after this winter and any new refinery investment plans will take much longer to bring fresh product supplies to the market. The situation today is that although world cracking and octane-enhancing capacity is operating at full utilization levels, inefficient distillation capacity, previously mothballed or unused, in Italy and Japan is still needed to balance light product demand. The result of this situation is that many refiners who have deferred maintenance programmes to keep their refineries at full utilization run a higher risk of accidents or bottlenecks. A cold winter coupled with a demand surge in these circumstances would send supplies off the edge of a precipice and product prices into an upward spiral.

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[6] Mina Saud stopped operation following the invasion.

4. THE WORLD REFINING SYSTEM: THE DISTRIBUTION OF PLANNED CAPACITY

The structural change of the world refining system during the 1980s has lifted the industry out of its gloom about profit margins, which have improved since 1988. However, imbalances still exist between refinery yields and products demand and the high crude oil and product prices of today have put a question mark over the future path of products demand. This section considers whether capacity expansion planned today will be sufficient to meet future demand for the various products and how the regional balance of planned capacity may affect the oil products trade.

4.1 The Planned Expansion of Distillation Capacity

Currently OECD countries hold around two-thirds of the world's atmospheric distillation capacity. However, the balance has been changing and will continue to change over the next decade towards the Middle East and non-OECD countries in the Far East. Distillation capacity expansion in the Middle East (excluding Kuwait and Iraq) will exceed 1 million b/d between 1990 and 1992 almost double that of its nearest rivals in the Far East (see Table 7). The distillation capacity of the Middle East already exceeds its own consumption and with such significant expansion it can only be presumed that the planned increase in output is destined for export. The question is whether this increased Middle East production will be needed.

The aftermath of the 1979-80 price shock showed that product demand is price elastic, especially at the bottom of the barrel. The prospects for world product demand if the current high oil prices persist do not look good. Fuel-switching is already taking its toll on the fuel oil market and it is unlikely that the 3 per cent per annum growth in OECD and developing countries fuel oil demand between 1987 and 1989 (see Table 1) will now be maintained. However, distillation capacity in those same countries is planned to rise by 2 per cent this year and by 1 per cent in the two following years. In addition, Japan is set to remove the restriction on product exports by the mid-1990s, bringing over 1 million b/cd of idle distillation capacity into play on world product markets. Unless product demand is bolstered by an unpredictable factor (for instance the collapse of the Eastern European refining system), this new distillation capacity will merely increase the current surplus in the Far East, Europe and the Middle East.

4.2 The Planned Expansion of Cracking Capacity

The increasing light to heavy product price differentials during the current Gulf crisis has emphasized the need for greater cracking capacity. On the basis of current plans, world cracking capacity in FCC equivalent should grow by some 1 per cent in 1990 and by 2 per cent in 1991 and 1992, just over the distillation capacity growth rates mentioned in the previous section. Most of this expansion is planned for FCC units but 37 per cent of planned cracking capacity will be in hydrocracking, which currently accounts for only 16 per cent of world cracking capacity. Unfortunately, if the Kuwaiti refineries are destroyed these plans will result in no net gain for world hydrocracking capacity as it will take until 1993 to replace those units. From whichever perspective, the plans to expand world cracking capacity are insufficient to meet relative product demand. The result will be (a) surplus heavy fuel oil which will depress refiner margins, and (b) an increase in price differentials between light and heavy products to compensate for inefficient distillation capacity, given expected increases in the demand for light products.

Some 31 per cent of total planned cracking capacity is in the USA with the Far East and Oceania and South America and the Caribbean accounting for 25 per cent each (see Table 8). The oddity here is that Western Europe is planning comparatively little expansion despite having a surplus of distillation capacity, net imports of gasoil and tightening supplies of gasoline. This may mean an increase in future gasoil imports and a tightening of naphtha supplies as more is used to maintain gasoline octane quality.[7] New hydrocracking capacity planned in the USA and Far East will help meet their large respective demand for jet fuel and kerosene.

4.3 Future Octane Concerns

World gasoline supplies are tight because octane-enhancing processes are running at full utilization to compensate for environmental restrictions and increasing demand for octane at the pumps. Pressure on gasoline octane quality will be maintained by lead phase-out in Western Europe and more stringent volatility restrictions in the USA. Moreover, increased gasoline demand is expected from Eastern Europe. Poland has started importing gasoline as its refining operations have almost ceased and East German consumption is expected to double by 2000 as a result of German unification.

On the other hand, considerable new octane-enhancing capacity is planned and Saudi Arabia will have a significant surplus of MTBE (MTBE is blended into gasoline to enhance octane and for environmental reasons, see Section 2.3) for export in 1991. World octane-enhancing capacity is set to increase by 2.5 per cent this year, 3.5 per cent in 1991 and 3 per cent in 1992 ahead of the growth rates for both distillation and cracking capacity. Also, the Saudi Arabian MTBE plant scheduled for completion in 1991 should ease the huge premium that Western European and US gasoline producers are currently paying for supplies.

The planned distribution of capacity expansion also holds some interest for the future pattern of gasoline trade. Saudi Arabian MTBE supplies - some 1.7 million tons per annum of capacity is due to come on stream in 1991 - will certainly find their way onto the tight European market. However, the forthcoming reformulation of US gasoline (see Section 2.3) will ensure fierce competition despite the extra transportation costs.

The remarkable expansion plans in the Far East for alkylation and isomerization octane-enhancing processes account for 29 per cent of total world planned capacity and can only mean that the increased gasoline output is planned for export. The domestic gasoline market in the Far East does not require such expansion and, even if it did, CRUs would be a more logical investment to enhance octane quality. Unlike CRUs, however, alkylation and isomerization units minimize the production of high-octane

[7]The availability of naphtha supplies will also depend on demand from petrochemical plants. For instance many new plants are using North Sea gas, thereby alleviating naphtha demand.

aromatics, such as benzene, over which there is increasing environmental concern in the USA and Western Europe. With this expansion the Far East will be well placed to challenge traditional sources of US gasoline imports, especially South America and the Caribbean, if and when the US Congress reformulates US gasoline specifications (see Section 2.3).

4.4 The Medium-Term Future

From our compilation of planned capacity expansions and anticipated demand it seems that investment in cracking capacity is certainly deficient, that gasoline quality concerns will probably be alleviated by new octane-enhancing capacity and that distillation capacity will tend towards excess. This scenario does not bode well for refiners or the price prospects for middle distillates. Refiners' profit margins will be pulled down by a continuing surplus of heavy fuel oil and that situation may be worsened by a less competitive gasoline market - although many variables may come into play here. The middle distillate markets, for products such as jet fuel/kerosene and gasoil, will continue to be tight unless investors take current market signals to heart.

5. CONCLUSION

Constraints have emerged in the world refining system that were not present in the last oil price shock of 1979-80. Although spare distillation capacity exists now as it did then (but not to the same extent), the fundamental change between the two shocks has been caused by a shift in the composition of demand towards the lighter end of the product barrel. The 1980s were, on the whole, lean years for refiners and as a result the investment in cracking facilities necessary to redress the balance between yields and product demand has not been forthcoming. This lack of flexibility in the world refining system has developed over the past four years with increasing demand for the lighter products and this has certainly contributed to the succession of price spikes in the last two years.

For the future, planned investment in capacity still seems unbalanced. The current small excess of distillation capacity will tend to increase and the implied surplus of heavy fuel oil will put downward pressure on refiner profit margins. Planned cracking capacity expansion is certainly insufficient and if sophisticated refinery capacity in the Gulf is lost this will worsen the long-term situation. Prospects for gasoline supplies are however improving. A great deal of octane-enhancing capacity is due to come on stream in the next two years and a large Saudi Arabian MTBE plant is due for completion in 1991. The distribution in planned capacity also indicates that the Far East is poised to increase gasoline exports to the USA and that Western Europe will increase imports from the Middle East. To sum up: the level of flexibility in the world refining system will not improve unless plans to increase cracking capacity are expanded.

In the short term there seems no immediate panacea to the products shortage caused by the Gulf crisis. The invasion of Kuwait has removed over 7 per cent of world hydrocracking capacity and the middle distillate yield that it supplied can only be replaced by utilizing inefficient distillation capacity. Added to this, Saudi light and middle distillate exports will not be fully resumed for the duration of the US military presence. Meanwhile the world refining system is operating at very high utilization rates and cannot defer maintenance programmes indefinitely without running an increased risk of accidents or bottlenecks. Let us hope this winter is not as cold as it will be long.

Table 1: OECD and LDC Oil Product Consumption (million tons)

		1979	1981	1983	1985	1987	1989
OECD	Gasoline	560.9	513.2	513.5	523.7	555.1	577.3
	Middle Distillates	582.7	515.3	492.9	524.9	558.3	583
	Fuel Oil	517.8	397.9	301.7	256.1	247.5	254.1
	Others	312.1	276.8	275	287.2	304.3	315.1
	Total	1973.5	1703.2	1583.1	1591.9	1665.2	1729.5
LDCs	Gasoline	91.8	99.8	104.5	111.4	115.3	127.5
	Middle Distillates	174.6	191.8	214.4	225.8	240.7	266.4
	Fuel Oil	179.7	184.6	167.7	164.4	170.3	189.2
	Others	69.8	76.1	81.4	86.7	99.4	108.1
	Total	515.9	552.3	568	588.3	625.7	691.2
OECD and LDC	Gasoline	652.7	613	618	635.1	670.4	704.8
	Middle Distillates	757.3	707.1	707.3	750.7	799	849.4
	Fuel Oil	697.5	582.5	469.4	420.5	417.8	443.3
	Others	381.9	352.9	356.4	373.9	403.7	423.2
	Total	2489.4	2255.5	2151.1	2180.2	2290.9	2420.7

Source: BP Statistical Review of World Energy 1990

Table 1(a): Percentage Share of Oil Products in OECD and LDC Total Product Consumption

		1979	1981	1983	1985	1987	1989
OECD and LDC	Gasoline	0.26	0.27	0.29	0.29	0.29	0.29
	Middle Distillates	0.30	0.31	0.33	0.34	0.35	0.35
	Fuel Oil	0.28	0.26	0.22	0.19	0.18	0.18
	Others	0.15	0.16	0.17	0.17	0.18	0.17
	Total	1.00	1.00	1.00	1.00	1.00	1.00

Source: BP Statistical Review of World Energy 1990

Table 2: World Crude Oil Distillation Capacities
(000s barrels per calendar day)

Region	1979	1981	1983	1985	1987	1989
Australasia	800	815	815	705	730	745
Japan	5285	5675	4975	4975	4565	4200
N.America	20235	20445	17890	17535	17615	17580
W.Europe	20100	19655	16635	14665	14185	13715
Total OECD	46420	46590	40315	37880	37095	36240
Africa	2000	2035	2340	2555	2630	2835
Asia (*)	6150	6210	6830	7145	7310	7700
L.America	8745	9065	8465	7425	7575	7900
Middle East	3540	3250	3560	3810	4165	4005
USSR and E.Europe	13160	14525	14970	14970	15355	15720
Total Other	33595	35085	36165	35905	37035	38160
Total World	80015	81675	76480	73785	74130	74400

(*)- Excludes Japan
Source: BP Statistical Review of World Energy

Table 3: 1990 Refinery Capacity (thousand b/cd) by Region and Process

Country	Atmos. Distil.	--- Cracking --- Thermal	Catalytic	Hydro	Octane (*) Processes	No. of Refineries
W.Europe	14198	1628	1735	333	2520	141
Middle East	5005	378	276	378	536	44
Africa	1792	19	132	35	258	35
Far East(**) and Oceania	10749	310	959	266	1272	113
S.America and the Caribbean	5603	453	797	188	394	72
N.America	18257	1099	6065	1361	4979	248
Grand Total	55604	3887	9964	2561	9959	653

(*)- Octane processes include Catalytic Cracking, Alkylation and Isomerization. All capacities represented on an equal basis.
(**)- Does not include China
Source: Petroleum Times, World Refinery Survey 1990

Table 4: 1990 Complex Refinery Capacity as a Percentage of Total Distillation Capacity

Region	Cracking Capacity(*)	Octane Capacity(**)
W.Europe	0.26	0.18
Middle East	0.21	0.11
Africa	0.10	0.14
Far East(***) and Oceania	0.14	0.12
S.America and the Caribbean	0.26	0.07
N.America	0.47	0.27
Average	0.30	0.18

(*)- Cracking capacity represented in FCC equivalent.
(**)- Octane capacity includes Catalytic Reforming, Alkylation and Isomerization. Capacities of each process represented on an equal basis.
(***)- Does not include China.
Source: Petroleum Times, World Refinery Survey 1990.

Table 5: 1988 Product Exports (000 metric tons) of OAPEC Gulf Countries

		Gasoline	Naptha	Kero./ Jet Fuel	Gas Oil	Fuel Oil	Total
Bahrain	Imports						
	Exports	436	1571	1572	3583	3743	10905
	Consumption	192	-	415	86	-	693
	Stock Changes & Stat. Error	(2)	(176)	36	43	(331)	(430)
Iraq	Imports	-	-	-	-	-	-
	Exports		1170	815	1123	1388	4496
	Consumption	2650	-	1890	4350	5350	14240
	Stock Changes & Stat. Error	30	(30)	-	-	-	-
Kuwait	Imports						
	Exports	800	5000	4000	6000	11600	27400
	Consumption	1233	-	339	711	574	2857
	Stock Changes & Stat. Error	616	(52)	(66)	(42)	2	458
Oman	Imports	12	-	-	-	-	12
	Exports	-	503	9	62	965	1539
	Consumption	415	-	104	425	18	962
	Stock Changes & Stat. Error	3	-	5	(8)	210	210
Qatar	Imports						
	Exports	103	160	144	503	570	1480
	Consumption	271	-	85	169	-	525
	Stock Changes & Stat. Error	(46)	(3)	(6)	(7)	(19)	(81)
Saudi Arabia	Imports						
	Exports	3100	9667	4550	8900	10200	36417
	Consumption	6700	-	1255	12500	14000	34455
	Stock Changes & Stat. Error	97	(64)	21	94	(3)	145
UAE	Imports	-	-	350	-	500	850
	Exports	333	1900	1289	1750	743	6015
	Consumption	920	-	1135	950	1800	4805
	Stock Changes & Stat. Error	(44)	(3)	(19)	4	(216)	(278)

Source: OAPEC, Prospects of Arab Petroleum Refining Industry, 1990.

Table 6: 1988 Refinery Capacities (b/d) and Product Yields of Gulf States.

Country (1st year of operation)	Atm. Distil.(*)	Vacuum Distil.	Cracking Capacity(**)	Catalytic Reforming	-1988 Product Yield (thousand metric tons a year)-					
					Gasoline	Naptha	Jet Fuel	Kerosene	Gas Oil	Fuel Oil
Bahrain										
Awali('36)	280000	65000	46480	18000	626	1395	1683	340	3712	3412
Iran(***)										
Abadan('89)	130000	25000	-	20000	-	-	-	-	-	-
Bakhtaran	18000	-	-	3100	-	-	-	-	-	-
Esfahan	200000	135000	51540	30000	-	-	-	-	-	-
Lavan	20000	-	-	-	-	-	-	-	-	-
Shiraz	40000	16000	14670	8000	-	-	-	-	-	-
Tabriz	80000	40000	28845	12000	-	-	-	-	-	-
Tehran	225000	100000	48940	28000	-	-	-	-	-	-
Iraq										
Baiji('78) (N)	20000	-	-	-	-	-	-	-	-	-
Basrah('74) (N)	155000	18000	-	17000	-	-	-	-	-	-
Dorah('55)	94500	8200	-	13800	560	50	220	289	890	1140
Haditha('49)	12000	-	-	-	-	90	-	108	128	216
Kirkuk('73)	30000	-	-	-	-	210	-	228	205	652
Nassiriyah('81)	30000	-	-	-	-	210	-	150	270	500
Qayyarah('56)	13300	-	-	-	-	50	-	-	-	140
Salah-el-Din('83)	300000	65000	49400	46000	2120		450	1100	3720	3590
Samawa('78)	30000	10000	-	-	-	210	-	160	260	500
Kuwait										
Ahmadi('49)	417000	77000	120150	36000	2087	2277	808	900	3985	7211
Mina Abdulla('58)	200000	127000	192000	-	-	674	-	899	256	2242
Shuaiba('68)	209200	130000	139000	15800	562	1323	716	950	2428	2723
Oman										
Fahhal('82)	62000	-	-	10000	406	503	118	-	479	1193
Qatar										
Umm Said ('74)	62000	-	-	12000	328	-	223	-	665	551
Saudi Arabia										
Jeddah('68)	100000	18000	13200	3000	350	679	-	-	1067	1603
Jubail('85)	302000	90000	84150	20000	178	2599	2120	-	3580	3970
Khafji('66)	33000	-	-	-	-	290	-	-	20	1050
Mina Saud('58)	55000	-	-	-	-	284	-	-	-	2120
Rabigh('90)	325000	108500	87750	50000	-	-	-	-	-	-
Ras Tanura('45)	530000	107000	28620	60000	2233	1295	127	1000	7825	8585
Riyadh('72)	153000	64400	31100	36100	1693	-	545	-	2403	-
Yanbu 1('83)	203000	-	-	35000	1650	-	-	130	2850	4145
Yanbu 2('85)	283000	107000	86598	42500	3793	-	1903	-	3749	2724
UAE										
Ruwais('81)	126900	46000	38760	19100	668	420	1316	-	1884	962
Umm al-Nar('76)	75000	-	-	13700	542	65	739	-	819	865
Grand Total	4813900	1357100	1061203	549100	17796	12624	10968	6254	41195	50094

(N)- Not in operation in 1988.

(*)- All capacities in barrels per stream day or 1988 crude throughput, whichever the greater.

(**)- All cracking processes represented in FCC equivalent.

(***)- Figures for Iranian refineries from Petroleum Times 1990 "World Refinery Survey" except for the Levan refinery which came from MEES Mar. 6 1989.

Source: OAPEC, Prospects of Arab Petroleum Refining Industry, 1990

Table 7: Distribution of Planned Capacity (b/d) by Region, Year and Refinery Process

		Atmosph. Distill.	Cracking (*)	Catalytic Reforming	Alky./ Isom.	MTBE (000 tons/yr
N.America	1990	4500	42500	72000	61050	-
	1991	203500	161300	177500	13700	272
	1992	7000	125700	27000	-	500
	Other	278000	-	85000	-	50
W.Europe	1990	40000	59882	10800	24820	-
	1991	41933	45932	58100	15500	-
	1992	-	26850	-	-	-
	1993	-	27720	-	-	-
	Other	18000	-	74850	11000	2812
Middle East(**)	1990	725000	-	-	-	-
	1991	160000	21981	-	-	1700
	1992	150000	-	-	5500	-
	Other	324700	-	-	-	370
Africa	1990	190000	-	-	-	-
	1992		-	30000	-	-
	Other	20000	-	-	-	-
Far East and Oceania(***)	1990	-	58334	49800	18300	-
	1991	188400	5001	79035	-	50
	1992	420493	112273	93500	6000	300
	1993	195000	-	100000	19000	-
	Other	347000	87667	46110	12000	-
S.America and the Caribbean (****)	1990	182000	-	4120	-	-
	1991	138700	145689	500	900	500
	1992	13000	58880	-	-	-
	1993	120000	37050	-	-	-
	Other		21300	-	-	560
USSR and E.Europe	1990	-	22048	-	-	-
	1992	-	-	18264	-	175
	Other	20151	-	1406	-	1175
Total World		3787377	1060107	927985	187770	8464

Other- Date of project completion post-1993 or not given
(*)- Cracking processes represented in FCC equivalent.
(**)- All projects attributed to Kuwait and Iraq have not been included
(***)- 720,000 b/d distillation capacity is under consideration in Indi
A 60,000 b/d distillation unit is undergoing a feasibility study in Vie
(****)- Brazil planning to add 253,200 b/d distillation and 119,940 b/d cracking capacity.
Source:Oil and Gas Journal "Worldwide Construction Report" April 16 199
except figures for MTBE projects from Petroleum Argus Mar.5 1990

Table 8: Percentage Share of Planned Capacity (b/d) by Region and Refinery Process

	Atmosph. Distill.	Cracking (*)	Catalytic Reforming	Alky./ Isom.	MTBE (000 tons/yr)
N.America	0.13	0.31	0.39	0.40	0.15
W.Europe	0.03	0.15	0.15	0.27	0.00
Middle East(**)	0.36	0.02	0.00	0.03	0.37
Africa	0.06	0.00	0.03	0.00	0.00
Far East and Oceania(***)	0.30	0.25	0.40	0.29	0.06
S.America and the Caribbean(****)	0.12	0.25	0.00	0.00	0.19
USSR and E.Europe	0.01	0.02	0.02	0.00	0.24
Grand Total	1.00	1.00	1.00	1.00	1.00

(*)- Cracking processes represented in FCC equivalent.
(**)- All projects attributed to Kuwait and Iraq have not been included.
(***)- 720,000 b/d distillation capacity is under consideration in India.
A 60,000 b/d distillation unit is undergoing a feasibility study in Vietnam
(****)- Brazil planning to add 253,200 b/d distillation and 119,940 b/d cracking capacity.
Source:Oil and Gas Journal "Worldwide Construction Report" April 16 1990 except figures for MTBE projects from Petroleum Argus Mar.5 1990 p.3

Figure 1 : Spot Price of Jet
(Amsterdam – Rotterdam – Antwerp)

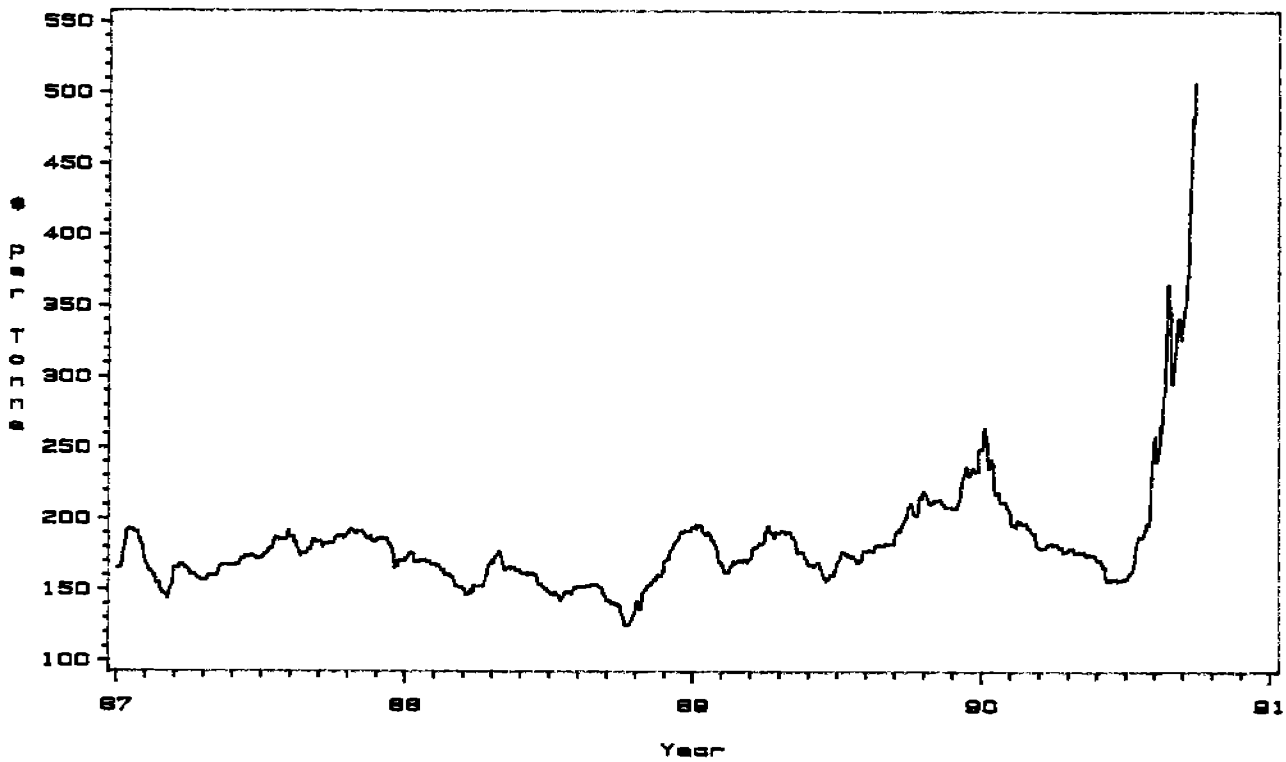


Figure 2 : Spot Price of Gasoil
(Amsterdam – Rotterdam – Antwerp)

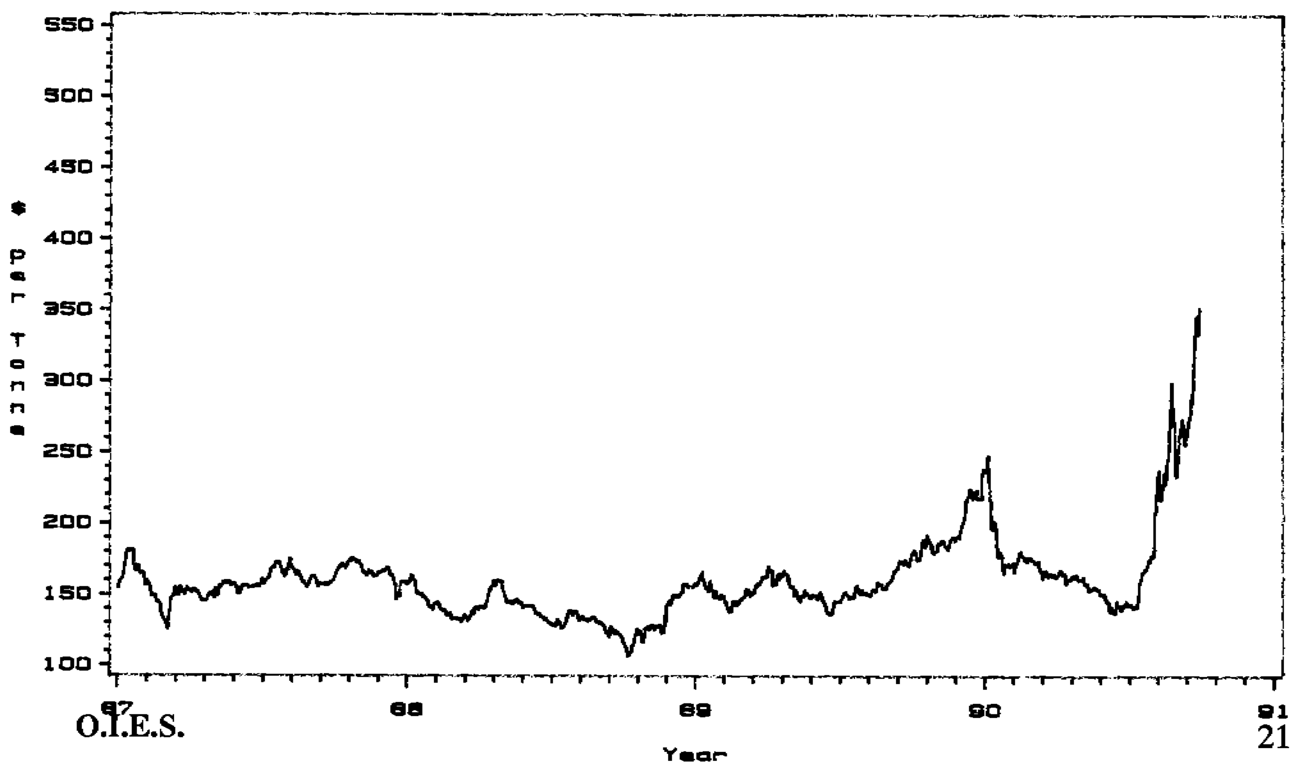


Figure 3 : Spot Price of Premium Gasoline
(Amsterdam – Rotterdam – Antwerp)

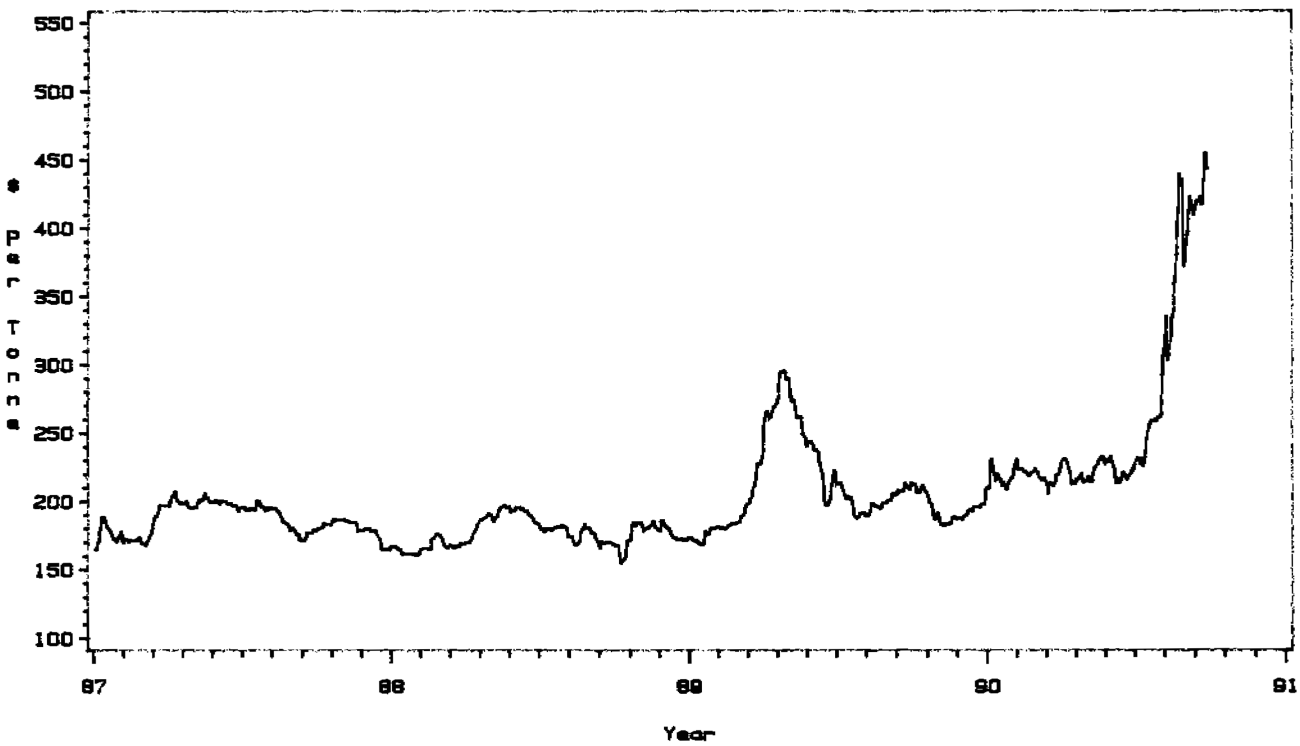
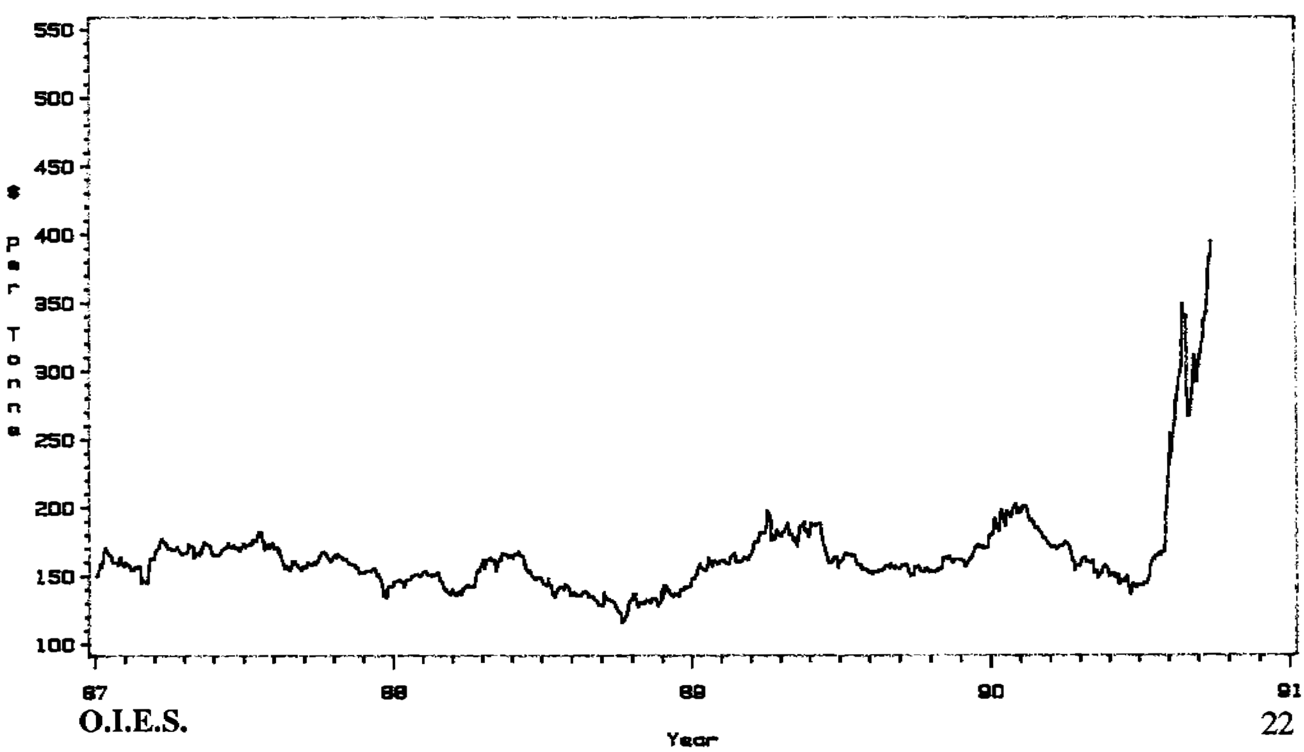


Figure 4 : Spot Price of Naphtha
(Amsterdam – Rotterdam – Antwerp)



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