IRANIAN ASSOCIATION FOR ENERGY ECONOMICS

Eghtessad-e-Energy

Energy Economics

In The Name of God

Apr-May.2007/No.90&91

Published by:

IRANIAN ASSOCIATION FOR ENERGY ECONOMICS (IRAEE)

issn 1563-1133

Director:
Seyed Gholamhossein Hassantash

Editor-in-Chief:
Ebrahim Ghazvini

Editorial Manager:
Homayoun Mobaraki

Editorial Board:
Majid Abbaspour, Reza Farmand, Ali Moshtaghian, Mohammad-reza Omidkhah, Ebrahim Bagherzadeh, Fereidoun Barkeshly, Hassan Khosravizadeh, Mohammad-ali Movahhed, Morteza Nassir, Morteza Mohammadi Ardehali, Ali Emami Meibodi, Seyed Mohammad-ali Khatibi Tabatabai, Afshin Javan, Hamid Abrishami, Mohammad-bagher Heshmatzadeh, Mehdi Nematollahi, Saeed Moshiri, Hamid Nazeman, Mohammad Mazreati

Layout:
Vahid Mohammadkhani

Advertisements:
Smael Shoja (9821) 22262061

Subscription:
Mahnaz Yousefi

Translators:
Mahyar Emami, Kambakhsh Khalaji

Coordinator:
Mahnaz Yousefi

Address:
IRANIAN ASSOCIATION FOR ENERGY ECONOMICS
Unit 13, Fourth flour, No. 203, Vahid Dastgerdi(Zafar) Ave., Tehran, Iran

Tel: (9821) 22262061-3

Fax: (9821) 22262064

Web: www.IRAEE.org

E-mail: publication@iraee.org

[Eghtessad-e-Energy]
Energy Economics

Articles on Oil & Gas in the English section, in cooperation with IranOilGas.com

Increasing Investment Cost in Oil Industry;
Reasons and Consequences

By: Behrouz Beikalizadeh
Oil Market Senior Analyst- Ministry of Petroleum
Email:balizadeh@nioc.org

Increasing investment costs in recent years has put pressure on the oil producers. In objection to this situation, Qatar oil minister "Alatieh", announced in April 2006 that the costs for implementation of oil exploration and production projects have increased and that the contractors have sharply raised their prices. He said the costs have almost been trebled. The Emirate oil minister also noted that oil projects have been faced with high risks and the cost of one-billion dollar projects has reached three billion dollars.

"Mohammad Barkindo", the then deputy for OPEC secretary general also said everyone claims OPEC is a cartel. However, now days the contractors have been converted into a cartel, he added.

In January 2007, Saudi Arabia announced that the design of a chemical plant that was to be built in a world scale has been postponed due to increasing costs adding that more financial studies should be performed for construction of the plant. This plant was due to be built in "Ras Altanureh" with the cost of 15 billion dollars.

In the same month, Kuwait was obliged to postpone constructing its fourth refinery with a capacity of 615000 barrels per day (bpd). The initial cost for building this refinery was estimated at the level of 10.4 billion dollars following several increasing reviews. However, the received bids from the conducted tender were about 14.9 billion dollars while some bids even stood at twice the initial estimates.

Algeria's energy minister Mr. Shakib khalil also declared on April 2007 that the construction of a GTL refinery with a capacity of 36000 bpd may be postponed due to higher costs.

But what is of particular importance for crude oil producers under prevailing condition is the increasing costs related to upstream activities. Prior to this development, the oil companies used to consider an oil price of $20 per barrel for their projects. Now they consider oil prices at $40 per barrel as a suitable figure in their projects. Increases of costs have been more for exploration and production projects in deep waters than for onshore projects. As a matter of fact, the index for investment costs has increased to 167 units in third quarter 2006 from 100 units in the year 2000 (base year), which is quite significant (see Figure-1).

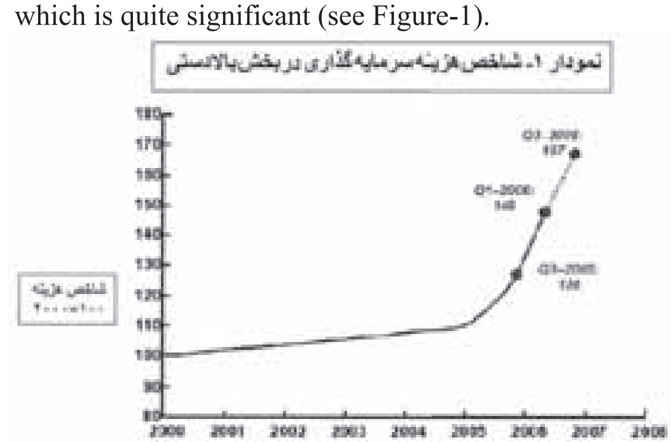


Table 1 shows the items constituting this index. Since drilling is responsible for 40-50 percent of the development cost, an increase of 25 percent in the rate of drilling would translate to a rise of 10 percent or more in the project's cost. In addition, less than two percent of total steel produced in the world is consumed by the oil industry. Since the steel used in drilling bits is of special type, the oil industry has been faced with high prices as well as capacity shortage for production of this particular type of steel.

Also, in view of long time required to manufacture equipment such as generator, compressor, boat and tow, the costs of supplying such items have been raised.

In addition, both equipment manufacturers as well as the contractors demand exorbitant prices and long delivery times when receiving orders and requests. This is due to saturation of their production and executive capacities.

Table 1 – Percent increase of items constituting investment cost for projects' development

	Percent
Steel	3.5
Offshore drilling	309.2
Equipment	16.5
Workshop-manufacture	21.7
Major materials	12.5
Ships for installing offshore facilities	41
Onshore drilling	18.2
Engineering and project management	23
Skilled manpower	13

- **Average of 12 months ending Oct. 2006**

The growth in the above-mentioned items involves points which should be taken into consideration:

1. Due to an increase in crude oil prices in recent years, the governments of oil-consuming countries and public opinion have put pressure on the oil producers. However, not much mention is made to significant rise in the downstream and upstream expenditures. It is incumbent on oil producing countries especially within OPEC to bring such an issue before the attention of public opinion.

2. The international economic officials should note that continuation of the current oil prices is a necessity for the continued existence of this industry. The endeavors directed at lowering crude oil prices would be considered as an action far from providence. A decrease in prices will cause postponement of many new projects. This is because older projects have been completed with lower costs. But the new projects are being implemented in regions and basins where capital costs in those areas are much higher than old oil regions.

3. Oil producing countries especially major countries influential in the international oil industry, such as Saudi Arabia, are bound to make efforts to maintain oil prices at higher levels. Because with increasing costs, the continuity of this industry entails higher prices. This phenomenon has caused, contrary to the past, the loss of power by these countries to launch price war for market share. Perhaps this hypothesis can justify to some extent the Saudi support for higher oil prices in recent years.

4. Postponement in implementing upstream projects will cause an increase of investment costs since it is not expected that the rising trend of the said costs to be halted in the short and medium terms. Countries possessing oil reserves should take into account the ascending trend of investment costs if expansion and development of their oil sector is a priority in their energy policies.

5. Increase in investment costs have caused the contractors to be called as cartels by some OPEC officials. Now the question is: Can the oil producers especially OPEC member countries cooperate to coordinate their upstream development plans in order to gain more bargaining power in their negotiation with the contractors? Although important obstacles exist, however, the current conditions are considered as the most suitable time to put forward such a question.

6. Under prevailing situation when investment costs have sharply increased in the upstream and downstream sectors and indications show continuation of this trend, the necessity of consolidation of domestic contractors in the producing countries is urgent more than ever.

Conclusion

In recent years, the investment cost for the oil industry's upstream and downstream sectors have sharply increased. It seems such a trend would continue in the short and medium terms. Under this situation, continuation of higher oil prices is a necessity for the industry's survival. For this reason, some producers support higher oil prices. This situation has denied the main producers the power of price war. Under prevailing conditions, consolidating the capability of domestic contractors and the necessity of cooperation between producers to attain more bargaining power in negotiation with international contractors has special importance. At present, delay in implementation of oil projects will cause increases in investment costs.

Sources:

1. REUTERS
2. MEES, 19 FEB 2007
3. MEES, 22 JAN 2007
4. JAIDEEP MISHRA, LET DOMESTIC OIL PRICES REFLECT GLOBAL SCARCITY, THE ECONOMIC TIMES, 21 JAN 2007

Iraq, Crescent oil companies sign agreements

An official at the UAE "s Crescent Petroleum Company announced that the company has finalized a 10-month study on oil exploration in Iraq jointly with Iraqi officials, Iraq Directory reported.

He said that the Iraqi area to be included in the study is between the southern city of Basrah and the borders of Kuwait. He added that the firm has also conducted studies on other Iraqi regions and has drawn up a development plan for the giant southern Ratawi field.

It is worth mentioning that the UAE Crescent Petroleum and the Iraqi Oil Exploration Company have signed several technical cooperation agreements since 2005 in order to encourage foreign companies to invest and develop Iraq's oil sector.

GECF to prepare the statue: Hamaneh

On his return to Tehran from the 6th Gas Exporting Countries Forum (GECF) held in Doha, Qatar, Kazem Vaziri Hamaneh, Iran's oil minister, said: "Gas producers have agreed to set up a committee led by Russia to prepare the statute of GECF and regulate its financial issues", adding: "The initiative is hoped to lead to the establishment of a strong gas exporting body".

He also revealed that the 7th GECF would be held in Russia.

On domestic issues, he said that a 53,000-bpd rise in the country's crude oil output was achieved last Iranian year, adding: "The crude production in the country reached a total of 4.3 Mln bpd last year, some 32,000 bpd over and above what Majlis had foreseen. This is while most of Iran's oil fields are old and are depleting at a rate of 250,000 barrels per year".

Dismissing the media speculations about his likely replacement with a new oil minister, Hamaneh said: "I represented Iran in GECF and such rumors have been going on ever since I was voted in as minister by Majlis".

Referring to talks with the Chinese officials on development of Yadavaran oil field, the minister stressed: "The talks are on the brink of completion and the only disagreement is over the ROR (Rate of Return) of the investment, which will hopefully be settled soon".

Elsewhere in his remarks, Hamaneh noted: "Some $ 14.3 Bln investment was made in the oil industry during last Iranian year, indicative of a rise of about $ 1 Bln compared to a year earlier", adding: "There was a 38% rise of investment in South Pars projects in the said time".

As for the delay in phase 6 of South Pars field, which was said to be due to the contractor's failure to live up to its commitments, he stated: "The phase will become operational in August this year".

Concerning the issue of export of Iran's Salman gas to U.A.E (also known as Crescent deal), Vaziri said: "The Emirate officials have made no new offer yet and we still believe that no gas can be exported unless its price is adjusted".

Asked about the investment of the Chinese Sinopec in Masjed Solaiman field, he replied: "Given the rise in the prices, a new MDP had to be defined for the field and we are now talking on how to incorporate those changes in the final deal".

Asked why the participation of 200 companies in the Vienna conference, held to present 17 exploratory blocks of Iran, had resulted in the willingness of only 6 companies to invest in these blocks, he replied: "Hopefully more companies will be announcing their willingness to contribute to the plan in the time left".

ROR not yet settled in Yadavaran development: PEDEC MD

Talking about the outcome of talks held with the Chinese Sinopec on the ROR (Rate Of Return) of investment on the development of Yadavaran oil field, Mehdi Baza'rgan, managing director of PEDEC told ISNA: "Contractual talks are underway between the Legal Affairs of NIOC and Sinopec and the next stage of negotiations will be starting soon. The ROR and other contractual conditions have not been finalized as yet".

In related news, reported by Reuters from Qatar, Iran's Oil Minister, Kazem Vaziri Hamaneh, was quoted as saying: "Iran is close to a deal with China's Sinopec on developing Iran's Yadavaran oilfield".

In the final months of last (Iranian) year, Gholam Hossein Nozari, managing director of NIOC had disclosed that some $ 100 Mln would be allocated to start the development of Yadavaran field, adding that the five existing wells in the field would be examined for a possible 'early production' stage.

OMV to prepare MDP of Iran's Mehr block

Erich Bauer, the new managing director of the Iranian branch of the Austrian oil company, OMV, said: "NIOC will be formally endorsing the commerciality report of Mehr block, presented by OMV, in the coming days", adding: "OMV will then set to prepare the Master Development Plan (MDP) of the block to pave the way for talks with NIOC on its development".

He explained: "In the preliminary contract for the exploration of Mehr block, the time set for finalizing those talks was foreseen to be 6 months from the date of the official endorsement of the commerciality report".

He further said: "In a conference held in Vienna last February, NIOC declared that Mehr block was a commercial find, but this has yet to be formally sanctioned to OMV".

OMV holds 34% of the shares of the development of Mehr block and leads the project's contracting consortium formed with the Spanish Repsol (33%) and Siptrol, an affiliate of the Chilean national oil company (33%).

Alborz semi-sub could be ready in July

Alborz semi-submersible drilling rig, being constructed by SADRA at its Neka yard of the Caspian Sea port, is now said to be ready for its commissioning stage.

According to sources close to the project, the commissioning stage is expected to be completed in 2 to 3 months and the rig will then be ready in July to be shipped to its Sea drilling site for test drilling.

There have been previous dates set for completion of Alborz which have never been met.

SADRA is in talks with the companies involved in producing different parts of the rig to take part in its commissioning.

SADRA is also using its Neka yard for building the three tug boats needed to take Alborz to its drilling site.

At present, one of the said tug boats has set afloat for commissioning. Another boat is still undergoing its construction and the third one has yet to start being built.

Given the currant sluggish trend of affairs at the Neka yard, the tug boats are not likely to be ready by that July date, announced by SADRA.

Once completed, the rig will be operated by NDC, which has signed a contract with the Chinese COSL in 2005 for the purpose.

On the other hand, Khazar Exploration & Production Co. (KEPCO), an affiliate of NIOC, is talking with the Brazilian Petrobras for joint exploratory activities in the Caspian Sea. Fruitful conclusion of these talks depends partly on successful completion of Alborz semi-submersible rig.

Alborz was originally foreseen to be ready for operation in the 2nd Q of 2005. Later, however, the date was pushed back to February 2006 and then to August 2006, to February 2007 and now the most optimistic views believe the rig will not be commissioned before the summer this year.

The semi-sub, has been under construction for about five years at SADRA's Neka yard on the Caspian Sea coast.

The 14,000-tonne Alborz, designed on the basis of the GVA 4000 model of the Swedish GVA Consultants, should be able to drill at depths of up to 1,000 metres.

Work-scope of phases 17&18 altered

The work-scope of the offshore section of the development of phases 17&18 of Iran's South Pars gas field has undergone basic alterations.

In the initial work-scope 2 offshore platforms were to be constructed along with two 32" pipelines for linking the platforms to the onshore refining facilities. In the revised work-scope, the number of platforms has increased to 4 and some changes have been made in the pipelines.

Apparently, the rise in the number of the platforms will not change the volume of gas production of these phases.

At present, client of the project (POGC) and contractor of the offshore section of the project (IOEC) are busy talking on fresh terms to take in the rise in the price of the contract and to work out new schedules for implementing the project.

The British ODE and the Iranian Namvaran, which have jointly undertaken the basic engineering design of the offshore section of the project, will have to effect the changes in the engineering of the plan.

The alterations will also lead to a rise in the number of wells to be drilled in these phases. Normally, 11 production wells are drilled in each phase of South Pars field.

In the refinery sector, the contractor of which is the JV of IDRO and OIEC, the Australian Worley Parsons has started the relevant basic engineering design and is to complete the job by the end of 2007. EIED, a subsidiary of OIEC, is cooperating with Worley in the project.

Pakistan to start building IPI pipeline in mid 2008

Pakistan will award contracts worth up to $3 billion to construct its portion of a pipeline to transport Iranian gas to India, a petroleum ministry official said.

The total cost of Iran-Pakistan-India project has been estimated at $7 billion and the pipeline will link the world's second largest gas reserves in Iran with India through Pakistani territory.

Petroleum Secretary Ahmed Waqar said the Economic

Co-ordination Committee (ECC), the country's highest economic decision-making body, had approved the construction of project on a 'segmented basis'.

'Under this approach Pakistan and Iran will construct their portion of the project,' said Waqar after the ECC meeting, who headed Pakistani negotiations with Iran and India.

The pipeline's route through the Pakistani territory has still to be decided, but Waqar said would be in the range of 750-1050 km long.

The contract to build the pipeline will be open to foreign as well as Pakistani companies.

Prime Minister Shaukat Aziz and his Indian counterpart renewed their commitment to the project during a regional summit in New Delhi.

Waqar said the construction of the pipeline would likely start in mid-2008 and expected the gas to start flowing by 2012.

Latest with production/desalting projects of ICOFC

The tender for construction of a production/desalting unit in Dehloran oil field with 55,000 bpd capacity was held and the project was assigned to a consortium of local companies; Iran Itok Co., Technicon Co. and Tarh-e Sanat Consulting Engineers.

The project became effective on the 7th of this April and is foreseen to take 21 months to complete.

The tender for construction of a production unit in Sarkan and Maleh Kouh oil fields with 22,000 bpd capacity, which got underway in May 2006, has yet to be finalized. The tender deadline was extended several times and the latest deadline remains unclear.

The project to construct a production unit in Sarvestan and Sa'adat Abad oil fields with 25,000 bpd capacity was assigned to ODCC, a subsidiary of NIOEC. The executive works of this project, which is to take 30 months to complete, started on the 8th of last March.

The project to construct a production unit in Khesht oil field with 30,000 bpd capacity was assigned to SADRA. The executive works of this project, which is to take 26 months to complete, started mid last March.

The project to construct a production unit in Cheshmeh Khosh oil field with 135,000 bpd capacity, which was assigned to the JV of Bina and Kherad Sanat (Kherad Industry Technical & Engineering Co.) in the spring of 2006, is underway.

Iranian Central Oil Fields Company (ICOFC) is also holding a tender for the basic engineering design and preparation of the EPC tender documents for the expansion of that production unit. The plan will boost the unit's capacity up to 170,000 bpd. The outcome of this tender is likely to be announced in coming May. The expansion initiative is aimed at treating the crude oil produced in Paydar and West Paydar fields.

Doha to host 3rd Annual Middle East LNG Shipping Forum

Over the past five years, the rapid growth of the LNG business has started to create linkages between what were previously isolated regional gas markets. LNG shipping has therefore become one of the most critical factors in the expansion of global LNG industry and key to the development of new LNG supplies with the growth of the spot and short term LNG market.

Throughout 2006, Asian demand for LNG imports has been very strong from source countries in the Middle East, which has become one of the world's most important exporters of LNG. It is predicted that global trade in LNG will reach 261 million tones per annum by 2010 as LNG producers are boosting their export capacities. As liquefaction capacity expands and LNG production increases globally, world supplies will grow, and competition among LNG consuming markets should soften.

The 3rd Annual Middle East LNG Shipping Forum, which is due to be held during 8-9 May 2007 in Doha will identify and analyze the most important challenges impacting the Middle East LNG Shipping industry which will also include developments in Qatar, Iran and Egypt. This annual Forum aims to provide a high profile forum, presenting the international and regional shipping sector with an insight to the main strategic issues impacting this dynamic and important component of the energy supply chain.

Latest with desalting capacity boosting of NISOC

With the aim of boosting the capacity of its desalting units, the National Iranian South Oil Company (NISOC) has embarked on a plan to both renovate its existing desalting units and construct new ones.

To that end, a three-stage plan is underway by the NISOC.

The first stage of the plan entails construction of 3 new desalting units and boosting of the capacity in another 3 of the existing ones, as per the following:

1- Construction of Gachsaran-2 unit with 110,000 bpd capacity, underway by OEID (a subsidiary of OIEC), is due to be commissioned late May 2007.

2- Construction of Binak unit with 50,000 bpd capacity is underway by IRITEC. The unit has made around 43% headway so far and is due to be commissioned in the 2nd

Q of 2008.

3- Construction of Keranj unit with 100,000 bpd capacity is underway by the JV of ODCC & PetroTech Sun. The unit has made around 33% headway so far and is due to be commissioned in the 3rd Q of 2008.

4- Boosting the capacity of Maroun-2 unit from 55,000 bpd to 110,000 bpd is underway by the JV of Kherad Industry Technical & Eng. Co. and Kaj Co. The project has made around 33% headway so far and is due to be commissioned in the 2nd Q of 2008.

5- Boosting the capacity of Ahwaz-1 unit from 55,000 to 110,000 bpd is underway by Hirbodan Company. The project has made around 28% headway so far, which is 10% behind the initial schedule, and is due to be commissioned in the 1st or 2nd Q of 2008.

6- Boosting the capacity of Ahwaz-Ab Taymour-3 unit from 55,000 to 110,000 bpd is underway by the JV of Bina and Metal Mechanic Companies. The project has made around 45% headway so far, which is about 10% behind the initial schedule, and is due to be commissioned in the 1st Q of 2008.

The second stage of the plan entails construction of Gachsaran-3 unit with 110,000 bpd capacity, Lab-e-Sefid unit with 30,000 bpd capacity and Bibi-Hakimeh unit with 55,000 bpd capacity. The plan also includes boosting of the capacity of Maroun-3 desalting unit from 55,000 to 110,000 bpd.

Bina Company has prepared the tender documents for the projects of the second stage. The pre-qualification phase of the plan has been completed and the tender documents are due to be made available to the qualified companies.

The third stage of the plan focuses at constructing a centralized desalting unit at Haftkel with a capacity to treat 45,000 bpd of crude and another one of 220,000 bpd capacity for 'Ahwaz Asmari 1,2 and 4' .

The local engineering company 'Enerchimi' is busy carrying out the basic engineering design of the third stage as well as preparing its tender documents. The initiative has so far made 55% headway.

POGC issues prequal for Mercaptan unit

Pars Oil & Gas Company (POGC) has invited local/foreign firms to take part in a pre-qualifying tender for construction of a Mercaptan Removal Unit in Assalouyeh.

The workscope of this EPC project entails the detailed engineering design of an industrial Mercaptan Removal Unit (DMC-3) of 80,000 bpd capacity, its procurement, construction, installation and commissioning.

The unit will be used for treating the condensate produced in phases 4-5 of South Pars gas field. The project is foreseen to take 2 years to complete.

Interested companies have been given until late this April to submit their qualifying documents.

Pre-commissioning of refineries of phases 6-8 to start in May

The pre-commissioning of the gas refineries of Phases 6,7&8 of Iran's South Pars gas field will begin next month and the whole project will come on full stream by March 2008, says Gholamreza Manouchehri, managing director of PetroPars, the project's operator.

Manouchehri also reiterated that since the offshore platforms of Phases 6-8 have not yet been installed, there would be no gas from these Phases for the pre-commissioning of their onshore refineries and hence gas produced by Phases 1-3 would be used for the purpose.

Putting the overall progress in the development of Phases 6-8 at over 95%, the PetroPars MD said the gas refineries had made more than 97% physical progress.

Touching on the works underway to install the three platforms of the project, Manouchehri said: "SADRA has promised to install the first platform by the end of this (Iranian) month (20th of April) and do the same for the second one a month later. Commissioning of each platform would take two months".

Referring to the financial constraints SADRA is faced with, the PetroPars boss said certain measures had been taken to ease pressure on SADRA so that it could live up to its promised dates.

Qatar, Marubeni sign HoA for LNG deal

Qatar Petroleum (QP) and Marubeni Corporation signed a Heads of Agreement ("HoA") for the sale of approximately one million tonnes per annum of liquefied natural gas (LNG) from the Qatargas 4 Project. The LNG will be shipped to Japan in one of the new Q-Flex vessels.

In addition, the HoA provides for an equity stake to Marubeni in Qatargas 4 company, once established, and it will be one of the owners of the seventh LNG processing train under Qatargas' operation.

The Qatargas 4 Project is currently sponsored by QP and Shell Gas and Power Developments B V Construction work at the Ras Laffan Industrial City is proceeding well on train 7 and production is expected to start in 2010, a news release said.

Marubeni is a shareholder in Qatargas 1 which has been operating since 1996. To date Qatargas 1 has delivered over 900 cargoes to Japan since it started operations in late 1996.

Can Iran boost oil production capacity as planned?

Iran's 4th Economic, Cultural and Social Development Plan (Apr 2005-Apr 2010) was approved late 2004 and then formally sanctioned to the government for implementation

The Plan specified certain objectives for Iran's oil/gas upstream and downstream sectors in the 5-year period.

The foreseen goal for the oil upstream part is the boosting of Iran's crude oil production capacity by 1 Mln bpd by April 2010.

Based on available statistics, Iran's crude oil production stood at a mean of 3.92 Mln bpd at the beginning of the 4th Plan, but the country's production capacity was 4.2 Mln bpd, which is to be boosted to 5.2 Mln bpd by the end of the Plan.

To examine the chances of attaining the foreseen goal in the upstream sector, we need to go back to some earlier time.

In the late 90s and early this decade, NIOC raised some projects to boost the crude oil production capacity of the country by 2.1 Mln bpd by 2007. A capacity rise of about 500,000 bpd was attained by 2005, but since then no project has been completed to help boost the capacity any further.

That planned 2.1 Mln bpd rise in the production capacity was supposed to come from fields other than Azadegan, North Azadegan and Yadavaran oil fields, which are separately foreseen to add another 400,000 bpd to the production capacity of Iran by 2010.

Ever since the beginning of the 4th Plan, no fresh project has been commissioned to enhance the country's production capacity.

While some of the projects defined in the late 90s and early this decade have not yet been completed, some others have yet to start.

These include the ones to boost the capacity of Bangestan layer of Ahwaz field, tap the oil layer of South Pars gas field, the '8 fields project', the '16 fields project' as well as Aghajari, Cheshmeh Khosh, Darkhoain (phase 2), Jufeyr, Masjed Solaiman, Forouzan, Esfandyar, Resalat, Reshadat and Doroud fields.

Once these projects are done with, some 1.2 Mln bpd will be added to the entire crude oil production capacity of the country. However, given the sluggish trend of progress in the ones being executed, it is quite unlikely that they could go on stream in the remaining three years of the Plan.

Besides, the executive works of some of those planned projects have not even started as yet, like the development of Masjed Solaiman, Jufeyr, Resalat, Bangestan layer of Ahwaz, Aghajari POSFR and 6 of the '8 fields project'.

The only projects that could possibly come on stream by the end of the 4th Plan are; Darkhoain (phase 2), Doroud, oil layer of South Pars gas field, Reshadat, Cheshmeh Khosh, few of '16 fields project' (such as Sarvestan and Sa'adat Abad), Mansouri and one of the '8 fields project'. These will at most add some 450,000 bpd to the overall production capacity of the country.

And if by then Azadegan, North Azadegan and Yadavaran oil fields are ready to produce another 100,000 bpd, then the total production capacity will be boosted by a rough total of 550,000 bpd and no more.

That means, in reality nothing more than 55% of the 'Planned' boost in Iran's crude oil production capacity can be expected.

Europe's nightmare: A world natural gas cartel

World's natural gas exporting countries will gather in Doha on April 9 for a forum that may set the grounds for a new natural gas cartel built on the rules of OPEC. The cartel, which for a start would bring together Russia, Iran, Algeria, Qatar and Venezuela, aims at becoming the most important energy player worldwide. Not a new idea, but rather one that was extensively discussed lately.

The most important supporter for such a cartel is Iran, the world's second largest natural gas producer, which is forced especially by political reasons to create a mechanism of control over the international resources market.

Iran and Russia can form an OPEC-like organization because these countries hold some half of the gas reserves in the world; Ayatollah Ali Khamenei was recently quoted as saying.

And he did not consider in his statement that currently Iran exports just a little share of its energy production and that it would become a significant player on the European market once the Nabucco project is completed - in the second half of the next decade the earliest.

A grand supporter of a natural gas OPEC is Venezuela, which again exports very little of its gas production as it lacks the necessary infrastructure. Its leader Hugo Chavez thus finds another opportunity to militate politically against the United States.

Paradoxically - apparently - it was Russia, which first launched the idea through the voice of President Putin - had a cautious attitude towards the project.

But while Russian official statements avoided to straightforward support the gas move, key players in Moscow did not hesitate to push for the establishment of the cartel.

Gazprom and Algerian state company Sonatrach have recently signed an accord allowing the former to join eight natural gas exploitation projects in Russia. Meanwhile, Gazprom is to expand it activities in the field of liquefied natural gas, targeting new markets in Europe and North America.

In fact, a majority of analysts consider a "natural gas OPEC" would serve the interests of Moscow only in the sense of a growing dependency of Europe on Russian supply of resources.

Moscow is interested in pressing Europe because last year's hitches in oil and gas deliveries from Russia showed the West is starting to look for alternatives, a recent report of the Economist Intelligence Unit shows.

It argues that Gazprom has little alternatives for selling its gas besides Europe and Turkey, to which it sells about a third of its production, but from where it gets 70% of its income while planned exports to Chine would be extremely costly, the EIU analysis says.

Europe's energy security is a subject that has drawn the interest of NATO itself, according to statements made by the organization's secretary general Jaap de Hoop Scheffer, who visited Bucharest late last year.

And in November 2006, a confidential NATO report warned about Russia's plans to build a natural gas cartel involving Algeria and other major producers.

The initiative was seen as extremely dangerous for EU's energy independence as the Union imports 25% of its natural gases from Russia and 10% from Algeria. That adds to the geopolitical balance in Eastern Europe, where Russia has been accused of imposing its points of view through economic blackmail.

Europe has already started to consider opportunities to reduce its dependence on Russian gas. But for energy analysts, the Union should first consider alternative measures to natural gas and only then fear a future "natural gas OPEC".

"For the European Union, the issue with this hypothetical cartel is mainly about the measure in which such an organization would strengthen the negotiation stands of two major exporters - Russia and Algeria. Actions by countries such as Iran or Venezuela are of less relevance for the Union.

"But there are at least two aspects capable of alleviating the risks of using such a cartel in political purposes by the said countries.

"I said it before. Importers and exporters depend on one another. Additionally, when compared to oil, the natural gas resources are less globalized, are a goods that sells locally or regionally and that is more difficult to store", says Romanian analyst Catalin Dimofte.

He believes natural gas exporters now depend more on the financial flows of the importers while the latter have increased their capacity to save and resist without gas supplies for short terms, while alternatives are considered for the medium and long terms.

Dimofte believes it is unlikely that the oil shock determined by OPEC repeats. "A repetition of that extreme situation, this time in the field of natural gas, would not have the same impact. Exporters know that for sure, too, so it is improbable that they would risk an open conflict with importers".

When it comes to Romania, the risks of establishing a "natural gas OPEC" are not predictable. Dimofte believes Romania's problem is that the country imports gas exclusively from Russia and "besides statements as warlike as pompous, and all of them futile, we did nothing to reduce our dependence".

Caspian oil & gas production in 2006

Crude oil production in the Caspian littoral states of Azerbaijan, Kazakhstan and Turkmenistan averaged 2.114mn b/d during 2006, an increase of more than 186,000 b/d over the 2005 average of 1.928mn b/d, according to information supplied to MEES by Moscow-based RPI Inc.

Oil output in Azerbaijan rose by an average of more than 130,000 b/d, most of which can be attributed to the East Azeri and West Azeri oilfields coming on-stream during 2006 and the opening of the 1mn b/d capacity Baku-Tbilisi-Ceyhan (BTC) pipeline. Both projects are operated by BP.

Kazakhstan's crude oil production rose on average by 68,500 b/d during 2006, while Turkmen output for the year declined on average to 170,700 b/d.

Azerbaijan also registered an increase in gas production to 6.755 bcm for 2006 compared to 5.814 bcm in 2005. A considerable portion of the increase can be credited to associated gas production from BP's offshore Azeri-Chirag-Guneshli (ACG) oilfields. Although the first well in the Shah Deniz project – also operated by BP – came on-stream in December, output was halted after one week due to technical problems and the second pre-drilled well did not become operational until February of this year. Kazakh gas output rose by nearly 2 bcm to 25.6 bcm from 23.8 bcm in 2005. Turkmen gas production was put at 65.0 bcm for 2006 with exports for the year amounting to 47.5 bcm.

Caspian Crude/Condensate Production

	Average (2006)	Average (2005)
Azerbaijan		
Production	649,140	518,710
Exports	525,320	400,390
Kazakhstan		
Production	1,294,060	1,225,560
Exports	1,103,240	1,000,570
Turkmenistan		
Production	170,770	183,310
Exports	N/A	29,000
Total Production	2,113,970	1,927,580
Total Exports	1,628,560	1,429,960

Caspian Natural Gas Production (Mn Cu Ms)

	2006	2005
Azerbaijan	6,755.5	5,814.4
Kazakhstan	25,649.5	23,818.7
Turkmenistan	65,030.0	62,980.0
Turkmenistan Exports	47,500.0	45,180.0

Key Role of the Private Sector in the Development of the Regional Gas Business

By Hamid D. Jafar, Executive Chairman, Dana Gas
(MEGAS, Doha, 5/02/07)

Executive Chairman of Dana Gas, Hamid D. Jafar delivered the following speech at the 12th Annual Middle East Gas Summit in Doha, Qatar, entitled "Gas in a Changing world" on the role that the private sector can play in the gas business of the region:

There is universal agreement that natural gas will be the defining energy source of the 21st Century, not only as the natural progression of fossil fuels, after coal and then oil, but also most likely as the key to many of the renewable technologies that we will need in the future. We have heard interesting introductions to the growth of the international gas market, and in particular the role of Qatar. I would now like to talk about the trends and patterns affecting the gas industry in the Middle East Region, viewed especially from the perspective of the indigenous private sector, and citing the real-case example of Dana Gas. This I will do by examining interactions with relevant global industry and local socio-political trends, as these lead to the increasingly important role being played by the indigenous private sector of the Region.

I shall start by describing the enormous changes I have noticed during my 38 years in the oil and gas business in the Gulf, particularly within the context of the emerging natural gas sector. I shall also touch upon some of the broader economic and political developments we have been witnessing recently, and their relevance. Finally, I will tie all this together with a brief exposé of the role and relevance of the indigenous private sector in the development of the Region's gas business.

Undoubtedly, it is incumbent on the Middle East, and particularly the Gulf Region, to play a major role in the global gas business, which is why we have such a gathering here today at this distinguished event. The GCC States, plus Iraq and Iran, together hold over 40% of the world's proven gas reserves, and yet today they still account for less than 10% of global gas production, with an even smaller percentage of exports. And practically all of these enormous gas reserves have in reality been discovered by chance! It will be no surprise, therefore, that the real potential reserves of the Region's gas are likely to be much, much greater, as we have only just started exploring for gas per se, with obvious supply-demand implications in the medium to long-term. The general saying in the old days of the oil industry, after drilling an unsuccessful well, used to be "the bad news is we didn't discover oil, but the good news is we didn't discover gas either!" And this was largely true in our Region until relatively recently, because the bulk of hydrocarbon exploration in places such as Saudi Arabia, Iraq, Iran, the UAE and Kuwait targeted oil only, with gas often seen as a nuisance by-product.

But how times have changed virtually overnight with the recent paradigm shift in global oil prices! Here in Qatar, for example, the development of the North Field has led to a meteoric growth in GDP and living standards, now among the highest in the world. The country will soon be exporting 5 million barrels of oil equivalent per day, with over 80% of this as natural gas. All the countries of the Region are now consciously looking to find new gas reserves: Last year Kuwait announced, with excitement, a natural gas find in the tens of Tcf; Saudi Arabia is finally making big strides in gas exploration with a planned new gas upstream drive to follow its First Gas Initiative; and Egypt is already producing more gas than oil, with 70 Tcf proven to date and the number progressively increasing. Iran, with the second-highest gas reserves in the world after Russia, is close to 30 phases of planned development for its South Pars gas field. Not to mention increased gas exploration and development activity in the UAE with the Abu Dhabi sour gas development plan, and also in Oman and Bahrain.

The latest report issued last summer by APICORP forecasts required energy investments in the MENA Region of $345 billion in the next five years alone, with 45% of this targeting the natural gas chain. A truly staggering figure!

Algeria, Libya, Egypt, Iran, Qatar, Oman and the UAE are all currently gas exporters from the Middle East, through LNG or by pipeline. Other countries will surely augment this list, including significant expansion from Iran and Yemen - even Iraq I dare say. With its key geographic location between East and West, and huge potential for expansion in this sector, the Gulf Region will no doubt increasingly act as swing gas producer and price-setter between the Atlantic Basin and the Asia Pacific gas markets. Indeed, Qatar's planned 77 million tonnes per annum of LNG exports have been judiciously divided between Eastern and Western markets.

Beyond the growth of gas exports from the Region, there is the very important development of the Region itself becoming a significant gas market in its own right, with natural gas rapidly becoming the fuel of choice and feedstock in many vital and important applications such as power generation, water desalination, petrochemicals and fertilisers, as well as for secondary recovery of oil production.

In the Gulf countries alone, natural gas demand has doubled over the past decade, driven by growing economies and populations, rapid urbanisation, and surging industrial development. Natural gas is being substituted for oil and petroleum products in domestic energy consumption. Aside from growing concern about environmental issues, the economic advantage of using gas instead of liquid petroleum products is compelling at today's oil prices, particularly in the Middle East, made more so by a relatively low transportation factor.

It is clear that the potential for future expansion in local gas demand in the Gulf is considerable.

Gas use by the power generation and water desalination sector is expected to keep growing at more or less 10% p.a. for at least the next 5 years. These sectors will continue to absorb about half of the Region's total gas demand, with the industrial sector accounting for nearly 35%. The balance (15%) being used for petroleum operations and pressure maintenance of mature oilfields, many of which have been in production for 50 years or more. The use of gas for secondary recovery has, in fact, been a growing and urgent imperative with every passing year.

In addition to historical trends, it is also necessary to take into consideration new structural changes that will surely affect future patterns of energy consumption as the Region continues to witness high population growth rates. One obvious example of an increasing trend towards liberalisation of the energy sector is the privatization of power and water generation, which are currently consuming the bulk of the Region's domestic gas demand.

According to the Gulf Organisation for Industrial Consulting (GOIC), annual requirement for gas in our Gulf Region is projected to reach an aggregate of nearly 300 bcm in 2010, and 440 bcm by 2015. Astonishing growth!

Who is going to supply all this gas? Despite a net surplus when the Region is taken as a whole, the reality is that several Gulf countries today have a significant and growing gas deficit, including the UAE, Kuwait, Saudi Arabia, Oman and Bahrain, as well as the Levant countries of Lebanon and Jordan. The only currently-existing regional export supply options are Qatar and Iran, to some extent Egypt, and of course Algeria. Looking ahead, Saudi Arabia and eventually Iraq are expected to be added to this list, but all of these countries will face competing demands for their now-precious resource, between domestic consumption and export options, whether through pipeline, LNG or alternatives such as gas-to-liquids. The debates on the options are already raging amongst technocrats and policy-makers in Oman, Egypt, Iran, the UAE, and Saudi Arabia.

Having outlined the Region's gas potential, I would now like to briefly describe some of the important challenges that the Middle East faces, as these will have a significant impact on the direction and development of our industry:

There is evidently an enormous focus on many aspects of the Gulf Region at present, and a great deal being written by political analysts and sociologists on such issues as terrorism, democracy, Islamic extremism, and so on. At the risk of massive over-simplification from a businessman's perspective, I am going to say that from a socio-economic perspective, the Region is undergoing one major positive phenomenon while facing a quite separate serious challenge, and that these two factors considered together are leading to the greatest change to the Region that I believe we will see in our life-time.

The major positive phenomenon we are experiencing is the new, and many would say permanent, paradigm shift in global energy prices. Debate over how sustainable this is requires a summit in itself. Many of us have seen several oil price cycles in our careers, but the main difference this time is the absence of any negative impact on world economic growth by this demand-driven energy price rise, and its evident acceptance world-wide. This is amply illustrated by recent falls in the oil price below $60/ bbl, which triggered an uneventful OPEC supply cut, with a declared target price band of $50 – 60 per barrel that would have been unthinkable a few years ago!

This new oil boom has led to massive oil revenue increases for many regional governments amounting to hundreds of billions of dollars. The difference this time, though, is a more prudent management and investment of these revenues, with more of an emphasis on capital formation and capacity-building at home, and significantly more intra-regional trade and investment than was seen in the past, not to mention a huge growth in the size and depth of the Region's capital markets driven by the private sector.

However, the one serious and major challenge that I referred to earlier facing the Region is job creation. Unlike Europe or Japan, who contend with shrinking and ageing populations, the Middle East faces quite the opposite problem: growing and ever-younger populations, necessitating the creation of hundreds of millions of jobs in the coming few decades, or else risking serious social instability and a massive strain on government budgets. In Saudi Arabia alone, for example, over 160,000 new jobs need to be created annually, and the State Sector, until now the main employer, has been struggling to maintain its historic absorption of new jobs. Nor would that be efficient economically, if it did. In total, the Arab world will have to create

100 million new jobs in the next 20 years – more than we have achieved during the whole of the last century! It is simply not sustainable, nor indeed desirable, for this increase in the labour force to be absorbed by the State Sector. Encouragement of a robust and growing private sector is therefore critical to the Region's socio-economic well-being, not to mention for the sake of its global competitiveness.

It is this policy driver more than any other, that has led to the growing support across the Region for an increased role of the local private sector in practically all aspects of the economy, including (dare I say) the energy sector. Economic reform, privatisation, and market liberalisation are the watch-words of the day all across the Region, from Algeria and Egypt to Jordan, Lebanon and Syria, and across into Saudi Arabia, the Gulf States, and even Iran. And of course, most significantly Iraq, which has just finalized a commendable modern and ground-breaking oil and gas law that emphasizes the need for private sector involvement in the country's upstream development, including (significantly) encouraging the participation of the Iraqi private sector. Unlike political debates over democracy and the role of religion in politics, these economic initiatives have already met with significant acceptance and success in many parts of the Region. Indeed now the debate is more over "how far and how fast", rather than "whether or not".

The natural gas business in particular is very conducive to, and indeed in my view is complemented by, the active participation of the local private sector. The gas business is in many ways less politically sensitive than oil, and is not bogged down in such issues as OPEC quotas and the international politics of oil supply policy. In fact, gas often requires a long-term cross-border market, whether local or international, and this naturally lends itself to private sector participation, where a politically neutral commercial approach can facilitate cross-border projects that (experience has clearly demonstrated) do not otherwise happen easily between two governments, where political considerations or bureaucratic inertia and pride usually stifle progress. The natural gas business has close linkages to gas-utilisation industries such as power generation and petrochemicals, which have already experienced a major trend of private sector involvement throughout the Region. Finally, whereas the oil business has become mainly a matter of operational ability, the gas business also requires marketing skills, local relationships, and business development creativity, all of which call for the active participation of the local private sector.

Historically, the main constraints on such participation were access to technology and capital, but the years when these were held only by IOC's are long gone, and it's time that we all realize this. The days of the "Khawajah" are over! With very few exceptions, technology in our industry is readily available and more often provided by service companies accessible to everyone, and raising capital for energy projects is not an issue, particularly in this Region. For instance, our company Dana Gas's regional IPO just over a year ago was oversubscribed by 144 times, raising US$78 billion in barely ten days, and this example is by no means unique.

Within the context that I have described, the new company that I have just mentioned, Dana Gas, was launched as the first truly regional private sector natural gas enterprise in the Gulf. With an initial Core Founder group of 12 companies from across the Region, the Founders list of the Company was expanded to include over 300 highly reputable founder shareholders from all across the GCC, made up of major governmental and financial institutions, members of ruling families, and highly respected individuals and business groups. The structure was purposely designed to give confidence, and emphasize the readiness of the private sector to cooperate seamlessly across state boundaries.

A regional IPO for Dana Gas followed, and this attracted over 400,000 investors from across the Region (and even beyond), achieving both the depth and breadth of shareholding that assures for the Company both its political neutrality as well as the wide shareholder base that brings with it inherent support from the Region's policy-makers, as the structure of the Company ensures direct participation and benefit of the citizens across the Region.

The reception of Dana Gas has been breath-taking, and captured the imagination of all. But Dana Gas had to deliver results as well. That said, we are already well on our way towards our objective of playing a major role in the rapidly-growing natural gas business of the Gulf and the wider Middle East. Dana Gas's momentum has already begun in developing and investing in all aspects of the Region's gas industry: from upstream; through the midstream transmission and distribution of gas and LNG; and downstream into gas-related industries.

The two defining characteristics of Dana Gas are that it is private sector, and that the Company is truly regional:

Unlike other successful companies that were created from state company privatisations or as government initiatives, Dana Gas was born from a purely private sector collaboration across the Gulf Region. It is also regional in every sense – from its shareholder base; to its Board of Directors, who are from Saudi Arabia, Kuwait, Bahrain, Qatar, the UAE, Oman, Lebanon and Egypt; through to its management, made up of an experienced regional multinational team of gas sector professionals.

As a publicly-listed company launched from the Region, by the Region, and for the Region, Dana Gas has a long-term commitment to our Region's economies and the growth of this sector, and is not affected by external factors such as conflicting priorities of a foreign management, fears of security or political risk, nor (for example) the burden of having to book elusive reserves.

With our core presence and identity here in the Gulf, we view our geographical area of activities as spanning from Morocco in the west, to South Asia in the east.

Our objective is to grow rapidly through the acquisition of synergistic assets and companies, as well as simultaneously developing new "green-field" projects, either alone or with partners - - partnering being a core part of our strategy. Dana Gas can thus be seen as a strategic partner of choice – both to local state-owned companies who are seeking a credible private sector partner with technical and financial capability but without having to look abroad; and also to international energy companies who seek a local regionally-focussed partner that operates to international standards and has a strong regional network, which is also politically neutral. Our goal is to build bridges in this manner and achieve innovative solutions to the Region's energy challenges, which provide enormous opportunities.

The point on standards is very important to us – besides the transparency required of a public company, Dana Gas has pioneered policies of corporate governance, HSE, and corporate social responsibility in the Region, with the World Bank Group's IFC acting as our advisor. In addition, the Board of Directors is complemented by an illustrious International Advisory Board, made up of international energy personalities well-known to most of you (including our distinguished Conference Chair), who act as a strategic sounding board and help provide the management and the Board with an international perspective and network of global relationships.

It has been an active first year for Dana Gas. The Company has truly established itself as a regional company, with offices in six locations and an expanding cross-border network. It has developed a solid and experienced management team, served by the talents of 300 full-time industry professionals, and already with business activities across the Region in all sectors of the rapidly growing natural gas industry.

In addition to working on implementation of existing projects in the UAE, 2006 saw Dana Gas acquire Centurion Energy for a billion dollars in January 2007, marking its strategic entry into exploration and production. This places Dana Gas among the top six gas producers in Egypt, providing it with proven reserves approaching 100 million barrels of oil equivalent (boe), as well as significant exploration potential in the Nile Delta and elsewhere. We aim to expand our upstream activities across the whole of the Middle East.

In other segments of the gas chain, Dana Gas has proven its ability to partner with state companies and others to achieve rapid solutions to local energy needs, such as a joint venture with Emarat of the UAE to build, own and operate the first common-user gas line in the Region: a 48" diameter pipeline with a capacity of 1 billion cubic feet per day, to serve local customers. Another example is leading a consortium with partners from Bahrain to develop a gas liquids plant in the Gulf of Suez to produce 120,000 metric tonnes per year of propane and butane, in partnership with the state-owned Egyptian Natural Gas Holding Company, EGAS, and the Pan-Arab investment company APICORP based in Saudi Arabia.

I hope I have given you some interesting points to ponder over, relating to our conference title: "Gas in a Changing World". It has been a real pleasure to review with you the enormous challenges of the global natural gas industry, and what these mean to our Region.

I wish you all a productive and enjoyable Conference, and look forward to catching up with as many friends as possible over the coming couple of days.

Adding Value to our Customers Businesses via the Provision of Expert Services

J. K. Dunleavy

Introduction

The oil refining and petrochemical markets have to operate in a challenging business environment with rapid technological innovation. These markets are more competitive than ever and it is vital that process plants operate at maximum efficiency to minimize operation costs and therefore remain cost competitive. The trends towards increasing use of high activity catalysts, the requirements (global and local) of stricter environmental and emission standards and the continuous drive to reduce operational costs with improved performance are becoming increasingly imperative. This dictates even closer co-operation between catalyst suppliers and operators to deliver improved plant performance and ensure that customer expectations are achieved without compromising environmental, health or safety standards.

Johnson Matthey has adopted a two-strand approach to support our markets. Firstly, Johnson Matthey has committed to provide leading-edge research and development that underpins the delivery of new catalysts and technologies for our customers. Secondly, Johnson Matthey recognises the need to better support the operation of the catalysts in the various applications. Catalyst abuses , misuse or simple mal-operation are major problems for catalyst suppliers to contend with. Catalyst incidents on refinery hydrogen plants (but also other process units) have been increasing as a direct result of the increased severity of the process conditions and the reduced number of personnel on hand to monitor unit operations. Catalyst suppliers must therefore provide professional and timely after sales service and advice which includes training of operators, troubleshooting and impartial advice with the aim of preventing unplanned shutdowns, premature catalyst change-outs and the economic penalties associated with these activities. We aim to establish a close working relationship with our customers so that we truly understand their operations, identify opportunities, and concentrate our efforts on issues that need to be addressed.

The provision of expert technical service is therefore a vital aspect of a catalyst suppliers remit. Johnson Matthey is the industry leader in the field of technical service and has an international reputation for quality, reliability and expertise. The provision of technical service is delivered on a global basis through regional centres of excellence. Our service capability is focussed on addressing technical issues and is available to all our customers to ensure selection of the most appropriate product quality for a particular application and to provide the best after sales service and objective advice.

Johnson Matthey has committed the necessary time and resources to establish a comprehensive range of value-adding services to assist its refinery and petrochemical clients that differentiates us from all our competitors. With the integrated efforts of catalyst, applications know-how and services in a single business unit, we demonstrate our commitment to delivering best plant performance on behalf of our customers. Technical service is by its nature dynamic, so we are committed to adapting the range of services on offer and to maintaining our focus on delivering real value, customer satisfaction and a competitive edge through the use of the latest technologies and ideas.

With the increasing cost of feedstock such as natural gas prices for hydrogen plants, all plant operators are under increasing pressure to maximise the efficiency and output of their hydrogen plants as hydrogen is now recognised as a valuable commodity to a refinery. It has been estimated that hydrogen cost is $2/barrel of oil for hydrotreating and up to $6/barrel for hydrocracking which has a significant impact on the process economics. The improvements in performance can generally be achieved in one or two ways.

- Improvements in plant efficiency whilst maintaining production rate
- Increased plant production rate whilst maintaining or improving plant efficiency.

Johnson Matthey offers a comprehensive range of in house services through KATALCOJMTM PERFORIVIANCE that focuses on improving areas that have the greatest effect on profitability and safety. This service covers catalyst selection, installation, start-up assistance through to detailed plant modelling and optimisation advice. Johnson Matthey, through its Tracerco-Trutec subsidiary , also offers a suite of specialist measurement and diagnostic services. These are predominately based on radioisotope technology which naturally lends itself to non-intrusive on-line diagnosis with no interference to normal plant operations, and no, or very little, pre-preparation of the worksite. However, our capabilities extend far beyond these services. By working in close co-operation with a number of carefully selected external partners, we can also deliver a wide number of complementary studies and services covering the key performance areas of concern to plant operators. The result is a single convenient source for integrated solutions.

Optimisation of operating conditions allows for small incremental improvements in plant production or efficiency but may require units to be operated closer to critical equipment limitations. Correct catalyst selection also offers the opportunity for small incremental improvements and essentially represents a free up-rate provided that the catalyst is changed when the previous charge is spent. Operational excellence can also offer small improvements by ensuring that attention is paid to small details of plant operation. If a significant increase in plant capacity is required then a number of revamp options could be explored to meet the needs whilst minimising capital Whilst proven catalysts are crucially important to our customers, there are other activities outside the catalyst envelope that can have a profound effect on the overall plant performance. To meet these challenges, Johnson Matthey has developed a portfolio of industry leading consultancy and service products to help our customers achieve the best possible performance from their manufacturing assets. Our aim is to partner with our customers to establish their priorities and identify any performance gaps or opportunities for improvement. This paper details a number of the services that Johnson Matthey is able to offer which whether taken individually or as a group will allow one or more of the objectives to be met.

Johnson Matthey has incorporated a range of service options under the KATALCO PERFORMANCEJM badge. These are services specifically designed to concentrate on issues that are important to the customer with the aim of delivering measurable improvement in plant performance, profitability and reliability. Our proven methodology focuses our experience and knowledge in five important areas:

- Efficiency
- Throughput

- Reliability
- Environment
- Safety

The extensive range of services and applications know-how will enable customers to make more product, at higher rates, to tighter specifications, at reduced cost, whilst improving safety and reducing environmental impact.

The KATALCO PERFORMANCEJM package provides advice and options for optimisation, specialist diagnostic measurements, asset improvement and catalyst handling/recycling with a dedicated multi-disciplinary team. Johnson Matthey believes that we are uniquely qualified to provide value-adding services to our catalyst customers with our history and extensive experience in plant operation, design, catalyst technology and catalyst manufacture. However, our alliance partners bring additional specialist, practical knowledge and expertise, which enable us to offer cost-effective, tailored solutions to address key issues.

Process Diagnostics TRACERCO

Exchanger leakage tests Detector

KATALCO PERFORMANCEJM services cover all stages of the improvement process:

- Strategic review to identify business improvement process
- Assessment with a specific focus to identify the improvement scope
- Development of improvement options and selection of the optimal solution
- Implementation that delivers the improvement

The scope of each of these steps is obviously project dependent and all information is kept entirely confidential.

I want to briefly highlight some examples of the services available through Johnson Matthey to achieve required outcomes for plants. The deliverables and content of a project or consultancy support are individually tailored to meet customers' specific needs. The following examples are by no means exhaustive and are designed to provide an appreciation of the breadth of knowledge and support available to our customers.

a. Improve Energy Efficiency

Unfortunately, significant amounts of energy are still wasted in many refinery applications and in today's competitive landscape, companies operating inefficient plants are at a distinct disadvantage when compared to those with lower energy costs. Energy still represents one of the largest components of the overall operating costs for a refiner and must be actively and systematically managed to run efficiently. Legislation is becoming more stringent as the link between energy consumption, carbon dioxide emissions and global warming become clearer, leading to the introduction of laws such as the Climate Change Levy and regulations incorporating energy efficiency such as Integrated Prevention of Pollution Control (IPCC). The financial imperatives to improve the competitive situation by increased energy efficiency and minimized operational costs, therefore go far beyond the simple energy costs, putting pressure on companies to reduce feedstock costs, energy consumption and resultant emissions. Reducing energy consumption will reduce greenhouse gas emissions as well as operating, manufacturing, and consumption costs.

Johnson Matthey offers a range of services to improve energy efficiency from energy audits to plant modifications. Energy efficiency improvements need to be sustainable to be really beneficial so process optimisation and plant surveys are essential tools. A base-line energy audit is recommended to collate relevant information as an objective parameter so that any opportunities for reductions in fuel or feedstock usage, energy savings and continuous improvements in energy efficiency and plant performance can be compared.

• Implementation of Johnson Matthey's novel 'StreamlineTM' technology on a US plant yielded $50,000/yr additional profit due to saved pressure drop.

• Steam control on a US plant saved between 7,000 and 16,000 Kg/Hr of steam.

b. Increased Capacity

Hydrogen supply is becoming a growing issue for many refiners with the increased demand to meet tighter specifications for low sulphur gasoline and ultra low sulphur diesel. Refiners may be faced with the question of building a new on-purpose hydrogen plant or looking for incremental production capacity from existing assets. Whether you are looking for a quick win such as optimising the current operation or considering a full plant revamp to generate the additional hydrogen, Johnson Matthey can help you achieve your goals by providing an in-depth analysis of the process and identifying possible opportunities to be exploited.

Full plant simulation models are created using Aspen Technology's HYSYS modeling tool. Johnson Matthey has developed additional extensions for all syngas catalytic unit operations allowing rigorous models to be developed. These allow a wide range of options to be reviewed in a short timeframe. PERFORMANCEJM can assist in every stage of project delivery from conceptual ideas through to detailed engineering and implementation.

• One reformer re-tube for a plant produced $2.1 millionl yr in additional profit due to extra production.

• Revamp study on a hydrogen plant highlighted a potential 60% increase in throughput.

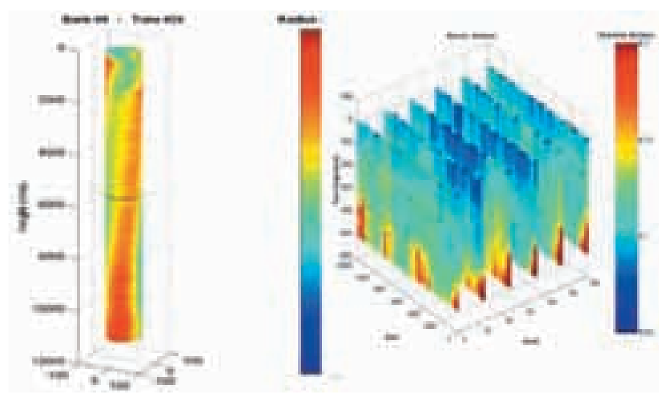
c. Increased Reliability

Maximising the return on investments by squeezing existing assets are normal modes of operation for many refiners. This means that it is important that operators implement a well-thought out and effective strategy for plant optimisation through proper plant maintenance and scheduling. Process reliability of individual unit operations is absolutely essential to a refiner if they are to be able to predict and plan timely shutdowns to meet maintenance schedules. This reliability issue is an important factor in determining the overall economics for a refinery. The interdependency of many units on a refinery means that the knock-on consequences of emergency shutdowns and catalyst change-outs can seriously impact the productivity of other process units. The business interruption costs associated with unplanned downtime can be prohibitive and significantly outweigh the costs of the catalyst change-out itself Johnson Matthey can assist in areas such as maintenance and turnaround services:

- Improved maintenance practices
- Management of major turnarounds
- Training for turnaround managers
- Worklist preparation
- Job specification techniques
- Material procurement
- Contractor management
- Inspection schedule planning
- Shut-down and start-up scheduling

The focus here is achieving high plant availability, rate and quality from routine operations/maintenance activities and targeted application of plant ageing.

Benchmarking studies permit a direct comparison of an individual plant's performance in relation to a number of key performance indicators against competitor's performance. Such studies, conducted by our alliance partner, ABB Engineering Services, have shown that world-class petrochemical plants typically achieve 98% occupacity but many plants fall significantly short of this level at only 75- 80% occupacity. Plant reliability is not just equipment related but assets, people and practices, processes and systems might also contribute. KATALCO PERFORMANCEJM offers a suite of products that can help monetize this opportunity by increasing the reliability and availability of your plant.



Examples of Lotis scanning showing creep in a reformer

• Reformer tube inspections using the proprietary Lotis laser scanning technology avoided premature tube failure/shutdown saving $200,000.

• Single item identified close to failure by Asset Life study saved shutdown losses of $1.3 Million.

d. Environment

Modem plants are designed to the highest international standards and plants have to be operated and maintained to ensure compliance with local regulations regarding emissions and waste minimization. Failure to meet acceptable environmental performance can increase local opposition and attract the attention of local regulatory authorities. The bad publicity could then affect licence to operate (consent decrees) by denial of requisite permits, stricter regulation and oversight, possibly harsher financial penalties and also tarnish the credibility of the organisation within the community. Refining and petrochemical operations are under much more public scrutiny and a company's corporate responsibility image is important, and like quality, is an integral aspect of modem business. Companies are judged on their environmental record as much as any other aspect of their overall performance. It is generally accepted that plant operators must be proactive, and not inactive, in looking to continuously improve their environmental performance. This generates the need for process plant operators to demonstrate their commitment to the environment and use best available technology and practices to minimise harmful impacts on the environment. In practice, this means that operators must adhere to the highest professional standards during operation: avoidance of major incidents, noise abatement, minimization of potential liquid effluents and gaseous emissions that may endanger human health or the environment and responsible recycling of spent catalysts. Extra precautions must be taken during plant start-up/shutdown periods and particular vigilance during any plant upsets/emergency shutdowns as errors are much more likely to occur under stress conditions that could impact adversely on the environment.

• Installing low-methanol LTS catalyst reduces methanol production by more than 80%.

• Installation of John Zink low NOx burners can reduce the NOx emissions from approximately 60-90 ppm to 20 ppm.v

e. Improve Safety

Safety on any plant is of paramount importance to protect the local community, on- site manpower, equipment and the environment from any harm or avoidable damage. We start with the premise that all accidents are avoidable and that safety is the responsibility of everyone within the organisation. A 'safety-first' environment within a business requires clear, unequivocal policies, goals, procedures, defined minimum standards, management commitment to hazard identification, accident prevention, risk analysis, effective reporting and monitoring, and active involvement from all levels in the organisation. Johnson Matthey (and our alliance partners) are able to offer customers consultancy in world-leading safety practices to achieve the highest possible safety performance. Johnson Matthey can offer advice on policies and procedures for maintaining standards and fulfilling the challenge of continual improvement in safety performances. Such advice could cover diverse topics such as:

- Designing for safety
- Process hazard reviews
- Quantitative risk assessments
- Fire and explosion studies
- Pollution abatement techniques
- Trip and alarm studies on existing and new assets
- Toxic emergency procedures
- Major incident planning and control
- Thorough incident/accident investigations with learning obtained to improve/share understanding of underlying causes.

We are able to offer our proven methodology and guidance in running hazard and operability studies to systematically review potential hazards if the plant operation deviates from the normal operation. This service is available throughout the design, construction and commissioning stages to ensure a safe, operable and maintainable plant. Ultimately, the best outcome is for us to train the plant personnel to become competent in such studies, as this would help promote an on-going commitment to continuous improvement and a safety culture.

• A producer with several sites requested Johnson Matthey to conduct a process hazard review on each site to provide an impartial comparison of safety standards within the same organisation.

Conclusion

Johnson Matthey takes great care during the manufacture of its catalysts to ensure a consistent high quality of its products and believes that we are at the forefront of catalyst technology. However, we fully recognise that truly world-class performance can only be achieved when a number of parameters come together: the most suitable catalysts must be selected, installed correctly, commissioned properly, operated according to the suppliers guidelines and the process optimised. To enable all our clients to profit from the accumulated corporate expertise of 70 years experience of catalysts and chemical plant operation Johnson Matthey has introduced KATALCOJMTM PERFORIVIANCE services package. Johnson Matthey has the experience and the resources to deliver an effective suite of services and our reputation is such that you can work with us in complete trust and confidence.

References:

1. John Brightling & M. Roberts, Catalyst Catastrophes II, AICHE Ammonia Safety Symposium, 2005

2. Lee Robins, ERTC, 2006

3. R. McConnell, Risk Management, IMTOF, 2001

How to meet shortage of motor gasoline in Iran

For Presentation to 1st Iran Oil Refinery Forum, 17-18 Feb, 2007
By H.A. Hajarizadeh and A. Mahboub.

Abstract

The paper titled "How to Meet Shortage of Motor Gasoline in Iran" describes the type of fuels commonly used in road vehicles worldwide. These fuels include: liquefied petroleum gas (LPG), motor gasoline (MG), gas oil/diesel (GO) and also compressed natural gas (CNG).

Part of this paper covers history and background of the refining schemes and need of petroleum products in Iran. Another section of the paper will discuss the current consumption and projection of growth for demand of the vehicle fuels in Iran consistent with vehicle population, varieties and fuel efficiency and energy management.

The paper also deals with potential supply of the different types of vehicle fuels namely: LPG, MG, GO and CNG in Iran. Costs of production of these fuels, compliant with the international specifications and standards, and also the related costs to transport them to the filling stations are estimated.

Based on the above findings, costs to utilize the four vehicle fuels (LPG, MG, GO and CNG) in Iran vis-à-vis benefits to be generated by exporting them will be compared and thus the priorities will be determined.

In conclusion the paper renders a rough illustration of the projects to be planned and implemented to meet the demand of vehicle fuels in Iran in the foreseeable future.

1. Introduction

Motor gasoline, once an extra and inferior commodity in the spectrum of the refined petroleum products in Iran, nowadays plays a key role in consumption of the motor vehicles.

Unprecedented growth and limited supply of motor gasoline in Iran has resulted in import in excess of 30 million liters of this petroleum refined product per day.

Four hydrocarbon derived products in oil and gas refineries are being utilized extensively as vehicle fuels world-wide. These vehicle fuels are: motor gasoline (MG), diesel or gas oil (GO), liquefied petroleum gas (LPG) and compressed natural gas (CNG). All these four basic hydrocarbon products utilized as vehicle fuels are abundantly available in Iran and at the same time, they are replaceable by each other. Moreover, the fact is that the production costs of MG, GO, L.P.G. and CNG are not the same and more importantly the national income generated wherefrom, if exported, are significantly different.

The ensuing studies cover the subjects related to: potential resources, production costs and projected consumption of vehicle fuels in Iran, and based on a preliminary techno/economic evaluation, recommendations are made for an optimized alternative to ameliorate the prevailing shortage of motor gasoline and meet, as a whole, the foreseeable demand of the vehicle fuels in Iran.

2. Type of vehicle fuels

Fuels commonly used in the varieties of vehicles for land transport differ widely in different countries. For example, in the United States of America the predominant fuel used in transport is motor gasoline whereas in Europe gas oil consumption exceeds motor gasoline. In general, vehicle fuels in order of consumption are: motor gasoline (MG), diesel fuel (or in many countries referred to as gas oil and abbreviated GO in this paper), liquefied petroleum gas (LPG) and compressed natural gas (CNG). Other types of vehicle fuels such as ethanol and biodiesel are gaining momentum.

Number of different types of vehicles running in the year 2005 in USA and their average daily consumption of four types of the vehicle fuels and their expected growth rates are given in Table 2.1.[1]

As seen in Table 2.1, the sum of the three liquid fuels consumed in transport vehicles in USA in 2005 amount to an average of 2117×10^3 cmd of which 68.95% is MG, 30.93 % GO and only 0.12% LPG with corresponding growth rate of, 7.4%, 1.1% and 5 % respectively. CNG represents less than 0.1% of transportation fuel on equivalent heat basis.

Out of about 200×10^6 transport vehicles only 0.19×10^6 and 0.13×10^6 of them use LPG & CNG respectively.

Gas oil, in addition of being used in vehicles, has other applications such as in diesel engines for generating electricity, turbines and also for heating purposes. Among the numerous utilizations of LPG are for: heating (especially in cold seasons), manufacturing of olefins and for making chemicals.

Total USA current consumption of natural gas (NG) is about 1500×10^6 cmd[2] of which only 1.7×10^6 cfd (less than 0.11%) is compressed and used as CNG in motor cars & trucks.

MG, unlike other three vehicle fuels, is almost exclusively utilized as fuel in motor cars.

3. Sources of vehicle fuels

The main sources of the four vehicle fuels are briefly described in the following sections:

3.1 Motor gasoline (MG)

The main source of MG is derived from the cut of naphtha in oil refineries. Naphtha, as such, does not meet the specifications of MG, therefore it normally undergoes catalytic reforming process. Quantity of naphtha varies in different types of crude oil, and on average it represents roughly about 15%. Yield of catalytic reforming of naphtha is about 80%, therefore MG derived from virgin naphtha in 81.4×10^6 BPD crude oil[4] run to refineries worldwide would be about 10.1×10^6 BPD (1.6×10^6 cmd). This amount of MG is far less than 3.25×10^6 cmd consumed currently[3]. The balance of the MG demand of about 1.65×10^6 cmd is met from other sources including by blending light components of refinery by-products and also by cracking of heavy cuts, mainly waxy distillates from the atmospheric residue distilled in the vacuum distillation towers. Also, a small amount of MG's demand is met by other sources including renewables such as ethanol. Worldwide production of ethanol in 2006 was 780,000 B/D of which 350,000 B/D was made in US[5]. It should be noted that energy of ethanol is about two third of gasoline.

It is also important to note that a good portion of naphtha (about 10×10^6 BPD or 1.6×10^6 cmd) is being consumed as petrochemical feedstocks. Of course condensates, extracted from rich and associated gases, constitute major portion of naphtha consumed for petrochemicals. Motor gasoline is almost exclusively used as vehicle fuels in motor cars equipped with sparking plug and internal combustion engines. It should be noted that energy of ethanol is about two third of gasoline.

3.2 Gas oil/ distillate (GO)

Gas oil (or distillate) is a major and valuable products of the oil refineries representing on average about 25.5 percent of the refineries throughput and based on 81.4×10^6 BPD oil refinery throughput, production of world GO is about 20.8×10^6 BPD. In most cases GO derived from crude oil meet the diesel fuel specifications except sulphur for which undergoes hydrodesulfurization.

Gas oil of high quality is also made via gas to liquid (GTL) process and biodiesel, but the quantity so far made this way is minimal. GO, in addition to being used extensively as vehicle fuel in diesel engines, it has many other applications which include residential heating, and also in off-road appliances such as diesels for generating electricity and turbines for variety of purposes.

3.3 Liquefied petroleum gas (LPG)

Sources of supply of LPG in Iran, in declining order are: derivatives of rich natural gases, associated gases, crude oil refineries, and also it is made as by- product in catalytic reforming of naphtha and cracking of heavy cuts of crude oil.

LPG, apart from being a good quality fuel for internal combustion engines equipped with sparking plugs (high octane & almost sulphur free), it has numerous other applications, including for heating and petrochemicals.

3.4 Compressed natural gas (CNG)

CNG is normally referred to natural gas (NG) when compressed to about 200-250 bar pressure.

Natural gas is predominantly methane, which possesses octane number of over 100, and therefore quite suitable to replace MG. CNG is also used in heavy transport vehicles such as buses, trucks, etc, and to a lesser extent in motor cars.

Application of CNG as vehicle fuel has some drawbacks such as: relatively high cost incurred for compression of NG, high cost of fueling station (US$ 750,000-1.5 million)[3] and also changes to be made in devices related to the fuel system of motor cars and trucks apt for CNG use. These disadvantages cause limited use of CNG as vehicle fuel.

Foremost application of NG is for use in turbines,

Table 2.1: Number of transport vehicles, fuel consumption and growth rate in USA in 2005

Number Million	MG		GO		LPG		Total		CNG	
	10^3 cmd	Growth %	10^3 cmd	Growth %	10^3 cmd	Growth %	10^3 cmd	Growth %	10^6 cmd	Growth %
200	2330	1.5*	655	1.1*	2.5	5*	2117	5.4*	1.70	10*

* Average

boilers, home heating appliances, etc. NG is also an attractive feedstock for making chemicals such as ammonia, methanol and synthetic gas.

4. Consumption of vehicle fuels in Iran

The four types of vehicle fuels described in section 3 are all currently used in Iran.

Table 4.1 demonstrates number of transport vehicles and also current demand and expected growth rate of MG, GO, LPG and CNG used in transport vehicles in Iran.

Total current use of three types of liquid fuel in motor vehicles in Iran amounts to 113 million litters daily with expected average annual growth rate of about 9%. Consumption of CNG is estimated at 0.71×10^6 scmd and taking each standard cubic meter of NG roughly equivalent to one lire (equivalent BTU wise) of liquids, fuel consumption of four vehicle fuels amounts to 114×10^6 cmd of which MG,GO, LPG & CNG represents, 58.77, 39.47, 0.88 and 0.88% respectively.

Based on growth rate indicated in Table 4.1, total liquid fuel consumption of transport vehicles is expected to reach 268×10^6 lit per day in Iran within 10 years of which 171×10^6 lit is MG and 93 lit is GO.

5. Production costs of vehicle fuels in Iran

As said earlier, all four types of vehicle fuels are abundantly available in Iran or could be made available if so desired. But, however their costs of production and more importantly national incomes, if they are exported, are not the same and differ widely.

MG and GO are exclusively final products of the crude oil refineries, but LPG is a by-product of the refineries as well as products of gas refineries processing associated gas and/or natural gas from gas fields.

5.1 Production costs of petroleum products

Design and operation of oil refineries in any location are dependent on the quality of crude oil being processed and also quantity and specifications of the products.

For objective of this paper a typical and relatively simple refinery of 150,000 BPD capacity shown in Figure 5.1 and final products given in Table 5.1 has been considered.

Based on available information & experience, total capital cost of a grass root refinery with 150,000 BPD capacity and product slates, as demonstrated in Figure 5.1 and Table 5.1, is estimated to be 1650-1950 million US$ (11,000 to 13,000 US$ for each BPD).

Production cost of each barrel of products has been computed on the basis of the following assumptions:

Capital cost of the refinery = US$ 1,810,000,000

Depreciation of the refinery = 15 years

Salvage value of the refinery = 20% of CAPEX

Execution of the refinery in 3 years & capital investment during 1st, 2nd & 3rd year of 25,50 and 25% respectively

Stream factor = 345 days/year

Operating costs (except fuel) = 4% of CAPEX

Internal annual rate of return (IRR) = 15%

Based on the above assumptions operating costs for processing each barrel of the product slate shown in Table 5.1 has been found to be 8.39 US$.

This cost can not be allocated equally to the 7 refinery products since some of the products such as fuel oil and LPG are sold at less than crude oil price fed to the refinery and others well above the oil price. At the same time price of petroleum products not only varies almost directly with crude oil price but also seasonally and with supply & demand.

Estimate of approximate price of refined products at US$ 35/ barrel of crude oil in Persian Gulf are given in Table 5.2.

5.2 Production costs of gas products from associated gas

Hydrocarbon gases are being produced in Iran from two sources: associated and natural gas fields. It is to be noted that one fourth of about 27 tcm gas reserves in Iran

Table 4.1: No. of vehicles, fuel consumption and growth rate in Iran in 1385 (2006)

Type of Vehicles	Number 1000	MG		GO		LPG		Total		CNG	
		10^6 Litre/d	Growth %	10^6 Litre/d	Growth %	10^6 litre/d	Growth %	10^6 Litre/d	Growth %	10^6 cmd	Growth %
Motor cars (3/1)	6,100	65.5	9.8							0.71	NA
Motor cycles	5,500			-	-	-	-	-	-	-	-
Busses	64	NA	NA	NA	NA	-	-	NA	NA	0.39	NA
Medium/ heavy Trucks	1572	1.5	2.0	NA	NA	-	-	NA	NA	-	-
Off roads	95*	NA	NA	NA	NA	-	-	NA	NA	-	-
Others	95	NA	NA	NA	NA	-	-	NA	NA	-	-
Total	13426	67	7.0*	45	5.6*	1*	-	113	9*	1*	NA

* Estimate

is "dome gas" which is not normally produced unless the related oil field is depleted.

Gas, dissolved in crude oil is produced in stabilization process at the crude oil production units. The associated gas, thus released from stabilized crude oil, is transferred to a gas refinery for treatment (removal of sulphur compounds) and processing.

Raw gas produced from natural gas fields is also processed at a gas refinery. The dominating product of the refinery is natural gas (predominantly methane). Other products, depending on quality of the feed gas are: ethane, propane, butane and pentane and heavier. Quantity of ethane and heavier hydrocarbon products depend on richness of the gas fed to the refinery.

Production costs of the above gas products from the associated gas, have been calculated on the basis of the following assumptions:

Quantity of associated gas =400×10^6 scfd

Heat value of associated gas =1180 BTU/scf

Total capital costs for gas refinery and related facilities }= US$ 251×10^6

Depreciation period of the facilities = 15 year

Salvage value of the gas refinery = 10% of CAPEX

Execution of the refining in 3 years and capital expended during 1st, 2nd & 3rd year equal to 25, 50 and 25% respectively

Stream factor = 345 days/year

Annual operating cost (except fuel) = 3.5% of CAPEX

Internal rate of return (IRR) = 15%

Fuel requirement (on BTU basis) = 2% of feed

Based on the above assumptions, production cost for each MM BTU of the five products has been found to be US$0.36. This cost is equivalent to US¢ 1.20/ cubic meter for NG and about US$ 16/tonne for other four products i.e. C_2,C_3,C_4 and C_5+.

5.3 Production costs of gas products from natural gas fields

Processing of raw gas produced from natural gas fields is fundamentally similar to that of dissolved gases produced in association with crude oil.

Products derived from a typical rich raw gas are: NG (predominantly methane), ethane, propane, butane and C_5+ so called natural gasoline or more commonly referred to as condensate. Sulphur, which is produced in treating of most sour raw gases has not been considered in this study since no credit has been assigned to it.

Schematic block flow diagram of the gas refinery is drawn in Figure 5.2.

Production costs of the gas products from natural gas fields have been computed based on the following assumptions.

- Quantity of raw gas = 1000×10^6 scfd
- Heat value of raw gas = 1073 BTU/scf
- Total capital cost for gas refinery and related facilities }= US$ 460×106
- Expenditure of capex in 3 year 25, 50 & 25% in 1st, 2nd & 3rd year respectively
- Salvage value of the refinery = 10% of CAPEX
- Stream factor = 345 days/year
- Annual operating cost (except fuel) = 3.5% of CAPEX
- Fuel requirement (on BTU basis) = 2% of feed

Calculations based on the assumptions made above, results in equally distributed production cost of the five gas products at US$ 0.30/MM BTU or equivalent to US¢ 1.05/cubic meter for natural gas and US$ 13.2/per tonne for other four products i.e C_2, C_3, C_4 and C_5+.

Production cost of the associated gases is contingent upon the methodology for allocation of expenses to

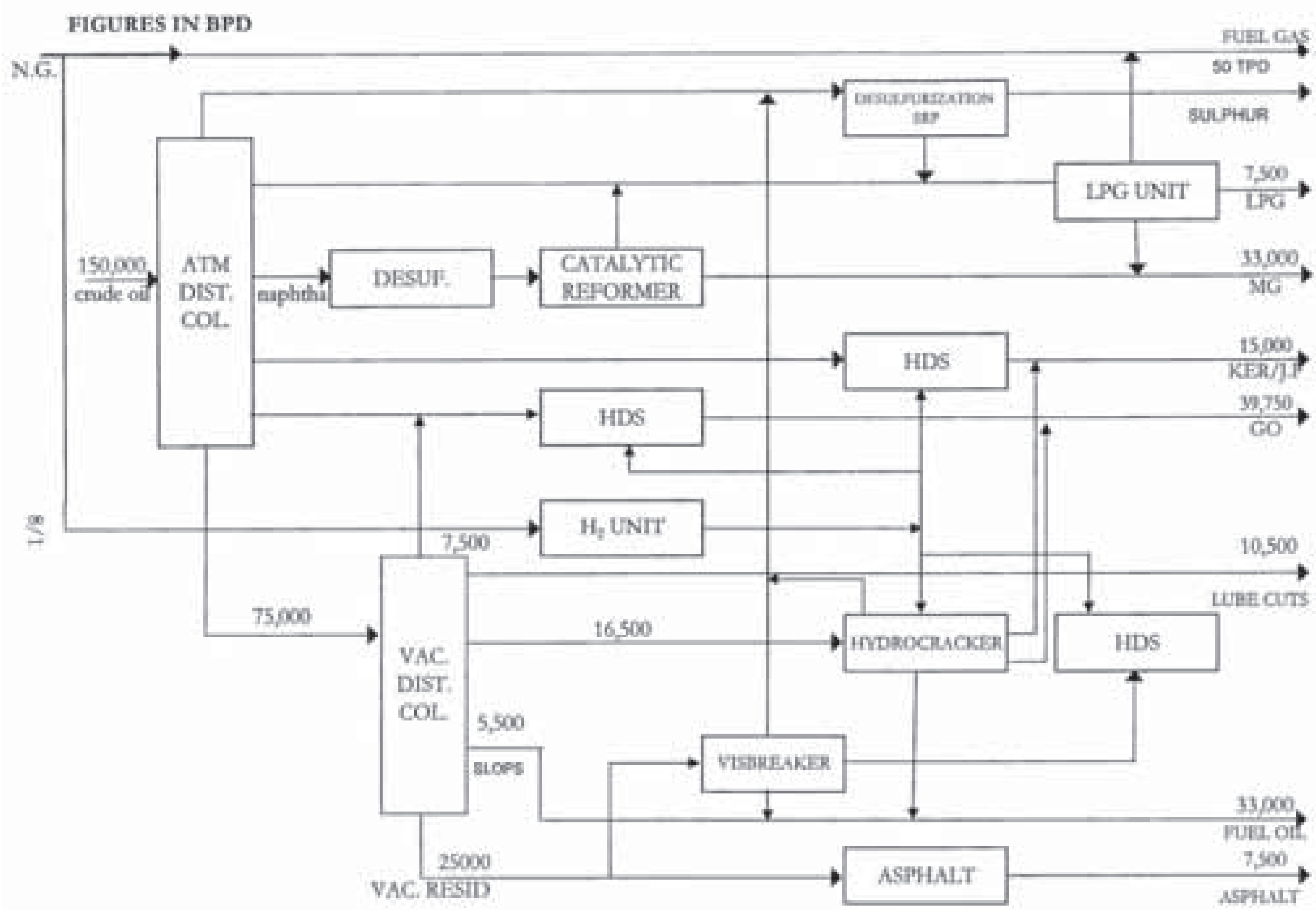
Table 5.1: Pattern of products in a typical refinery of 150,000 BPD

Products	Vol. %		Quantity BPD	Sp. Gr.	10^3 lbs/D	Heat Value 10^{6}BTU/Bbl
	On feed	On product				
Gas & loss	2.5*	-	3,750	-	1,550	-
LPG	5	5.13	7,500	0.55	1,440	3.79
MG	22	22.56	33,000	0.74	8,550	4.88
Kerosene	10	10.26	15,000	0.80	4,200	5.32
GO	26.5	27.18	39,750	0.85	11,830	5.45
Fuel Oil	22	22.56	33,000	0.97	11,200	6.51
Lube Cuts	7	7.18	10,500	0.89	3,270	5.92
Asphalts	5	5.13	7,500	1.02	2,680	6.74
Total	100	100	150,000	0.85**	44,720	5.50**

* Includes process gain, used as refinery fuel

** Spec. gravity and heat value of the crude oil

Figure 5.1 : SIMPLIFIED BLOCK FLOW DIAGRAM OF A TYPICAL REFINERY



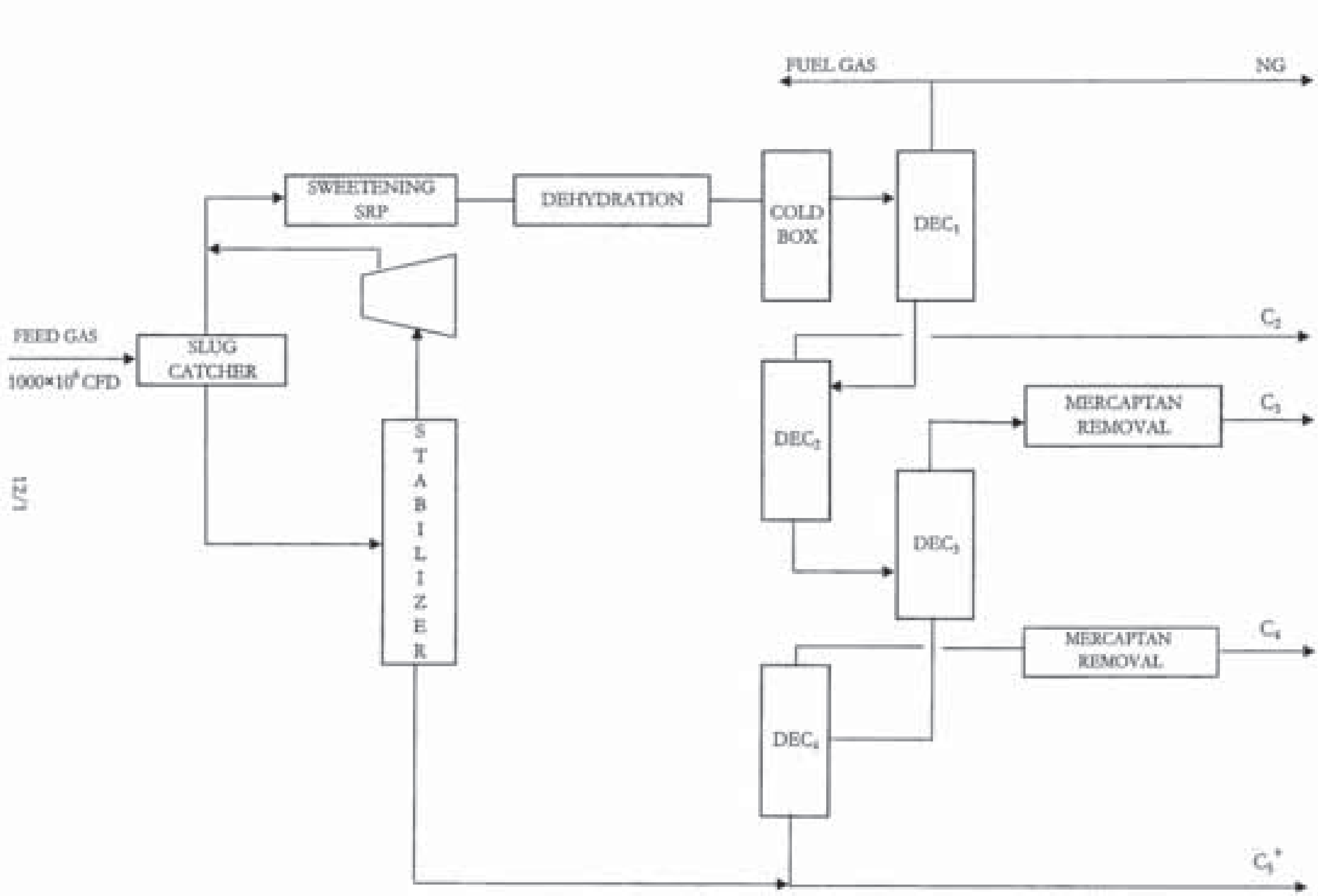
stabilized crude oil on which basis, it could vary between zero up to crude oil production cost of about US$ 2.5/bbl which is equivalent to US$ 0.45/MM BTU. Therefore production cost of the gas products is the sum of the costs allocated to associated gas (between zero and US$0.45/MM BTU) and processing which was found to be about US$0.36/MMBTU.

Production costs of raw gas from gas fields, covering: exploration, drilling, transportation, etc, vary significantly depending on gas field location (onshore

Table 5.2: Approximate price of refinery products at crude oil price of US$ 35/bbl

Refinery Product	Processing Cost US$/bbl.	Product Price		
		US$/bbl.	US¢/lit	US$/tonne
LPG	-15.8	19.2	12.1	220
MG	15.3	50.3	31.6	434
Ker.	9.4	44.4	27.9	350
G.O.	16.5	51.5	32.4	391
F.O	-6.9	28.1	17.7	182
L.C.	20.0	55.0	34.6	385
Asph.	8.2	43.2	27.2	267
Crude oil	-	35	22.0	259

Figure 5.2 : Schematic Block Flow Diagram of A Typical Gas Refinery



or offshore), quality, quantity, etc. A rough estimate of average production costs for the Iranian natural gas fields renders an approximate figure of US$ 0.3/MM BTU.

Bearing in mind that, bulk of the NG in Iran is supplied from natural gas fields, production & processing costs for NG has been taken at US$ 0.61/MM BTU in this paper.

Table 6.1 : National revenue to export vehicle fuels at crude oil price of US$ 35/bbl.

Figures in US$

Cost Item	MG		GO		LPG		NG (as LNG)
	bbl	MM BTU	bbl	MM BTU	bbl	MM BTU	MM BTU
Sale price (FOB)	50.3	10.31	51.3	9.45	19.2	5.07	5.0
Production	3.0*	0.61	3.0*	0.55	1.1	0.30	0.3
Refining/Processing	15.3	3.13	16.5	3.03	1.1	0.30	0.3
Refrigeration/ liquefaction	-	-	-	-	2.3	0.60	3.2**
National revenue	32.0	6.57	32.0	5.87	14.7	3.87	1.2

* Crude oil delivered to refinery
** Includes shipping (ca. 2000 miles and

Table 7.1 : Oil refineries operating in Iran

Figures in 1000 BPD

No.	Oil Refinery	Nominal Crude Capacity	Average Daily Products						
			LPG	Naphtha	MG	KER	GO	F.O.	Total
1	Tabriz	118.0	4.0	8.2	14.4	21.5	34.5	25.7	**108.3**
2	Kermanshah	25.0	0.7		4.7	2.9	4.5	8.3	**21.1**
3	Arak	180.0	6.3	12.3	30.4	27.2	47.1	46.0	**169.3**
4	Abadan	370.0	7.9	25.0	26.8	47.3	75.3	136.3	**318.6**
5	Tehran	250.0	10.9	1.6	47.2	30.0	87.5	45.0	**222.2**
6	Esfahan	370.0	13.2	14.3*	48.4	46.5	103.8	94.5	**320.7**
7	Shiraz	52.0	1.9		10.4	14.00	10.4	9.1	**45.8**
8	Bandar Abbass	272.0	7.8		53.0	22.8	80.7	99.9	**264.2**
9	Lavan	30.0	0.2		5.6		11.4	10.3	**27.5**
Total		**1667.0**	**52.9**	**61.4**	**240.9**	**212.2**	**455.2**	**475.1**	**1497.7**
% of Products			**3.53**	**4.1**	**16.09**	**14.17**	**30.39**	**31.72**	**100**

* Includes refomate to Esfahan Petrochemical Complex

6. Net income to export motor vehicle fuels

The net income or national revenue to the Iranian governments by exporting four types of fuels used in motor vehicles are calculated from the previous works in section 5 of this paper and are tabulated in Table 6.1. Price of crude oil in this exercise is taken at US$ 35/bbl level.

It is to be noted that LPG can not be exported as such and the two components in LPG namely propane and butane should be chilled to -41°C and -5°C respectively, stored in storage tanks and then shipped. The additional costs of such refrigeration and loading facilities is estimated at about US$ 0.6/MM BTU (US$ 2.3/bbl).

Price of natural gas, like any other commodity, is very much linked to supply and demand and also to its main substitute i.e. fuel oil which itself is related to price of crude oil. Historically, NG is slightly higher than fuel oil price on equivalent BTU basis and the latter is about 75 to 80% of crude oil on volume basis. In this study price of NG for major consumer has been taken equal to 80% of crude oil price on equivalent heat value basis. Now based on crude oil of US$ 35/ barrel corresponding price of NG will be US$ 5.00/MM BTU.

Unlike LNG which is sold at the unloading point, other three vehicle fuels are sold in Persian Gulf. This price, on long term basis is the sum of crude oil price and processing cost.

7. Potential supply of vehicle fuels in Iran

As said earlier all four types of the fuels commonly used in motor vehicles namely MG, GO, LPG and CNG are, or could be made, available in Iran in appreciable quantities.

GO and NG are exclusively made at the oil and gas refineries respectively. At present, the only source of MG supply is oil refineries, but condensates (or C_5+),

a by-product of most gas refineries is a suitable feedstock for MG. LPG is available at oil refineries, but bulk of it is made at the gas refineries.

7.1 Production of vehicle fuels in oil refineries in Iran

There are at present 9 oil refineries operating in Iran. Capacity and production at these refineries are given in table 7.1.

As seen in this table total capacity of 9 refineries

Table 7.2 : Gas refineries operating on raw feed gas from independent gas fields

No.	Gas Refinery	Capacity 10^6 cmd	Potential of C_2^+ Products 1000 tonnes/year				
			ethane	propane	butane	C_5^+	Total
1	Hasheminejad (Khangiran)	41.5	92.44	23.24	17.38	87.43	**220.49**
		4.5	29.29	10.90	19.06	41.81	**101.06**
2	Bid Boland I	34.0	891.78	454.04	161.29	191.77	**1698.88**
3	Ilam*	6.8	152.77	69.90	70.09	153.02	**445.78**
4	Fajr Jam	118.0	1722.57	870.14	632.39	1728.83	**4953.93**
5	Parsian*	80.0	1147.96	531.43	395.24	735.43	**2810.06**
6	Sarkhoun	14.4	207.92	127.69	100.08	362.66	**798.35**
7	Qeshm	1.8	11.89	10.53	12.06	63.43	**97.91**
8	South Gasho	14.0	65.15	34.85	31.65	58.99	**190.64**
9	Masjed-I-Soleiman	1.0	47.06	32.11	15.74	16.85	**111.76**
10	South Pars (Phases 1 to 8) **	226.6	4764.43	2834.80	2059.14	8637.72	**18296.09**
11	Bid Boland II *,++	56.7	2083.94	1058.51	373.50	532.09	**4048.04**
12	Farashband	36.8	171.26	240.45	81.66	130.39	**623.76**
Total		**636.1**	**11388.46**	**6298.59**	**3969.28**	**12740.42**	**34396.75**

* Facilities for C_2^+ recovery considered
\+ Phases 6,7 & 8 under construction and will be operational by 2009
++ Under construction and will be operational by 2009

is 1,667,000 BPD and production of LPG, MG and GO amounts to 52.9, 240.9 & 455.2 thousand barrel per day corresponding to 3.53, 16.09 and 30.39% of total products respectively.

7.2 Production of vehicle fuels from natural gas fields in Iran

Gas refineries operating in Iran and those under construction, expected to be in operation by 2009 processing raw gas from natural gas fields, are listed in table 7.2. As seen in the table production of NG is expected

Table 8.1: Vehicle fuels which could be made potentially available in Iran

Source of Supply	Motor Gasoline		Gas Oil		LPG	
	10^3 bbls/c day	10^6 Lit/c day	10^3 bbls/c day	10^6 Lit/c day	10^3 bbls/c day	10^6 Lit/c day
Oil refineries ($1667 \cdot 10^6$ BPD)	346.6	55.1	417.5	66.4	78.8	12.5
Gas refineries ($2.8 \cdot 10^9$ cfd ass.g.)	-	-	-	-	140	22.3
Gas refineries ($636 \cdot 10^6$ cmd gas field)	-	-	-	-	280	44.5
Total	**346.6**	**55.1**	**417.5**	**66.4**	**498.8**	**79.3**
Condensates	260	41.3	-	-	24	3.8
Grand Total	**606.6**	**96.4**	**417.5**	**66.4**	**522.8**	**83.1**

Table 9.1: Realistic price of vehicle fuels at crude price of US$ 35/bbls

Cost Item	Motor Gasoline		Gas Oil		LPG		CNG
	US$/bbl	US$/ MMBTU	US$/bbl	US$/ MMBTU	US$/bbl	US$/ MMBTU	US$/ MMBTU
Production	3.0	0.61	3.0	0.55	1.1	0.3	0.3
Processing	15.3	3.13	16.5	3.03	1.1	0.3	0.3
Transfer *	0.39	0.08	0.44	0.08	0.76	0.20	0.5
Fuel station	0.39	0.08	0.44	0.08	0.76	0.2	0.25
Compression	-	-	-	-	-	-	0.22**
Net income if exported (Table 6.1)	32.0	6.57	32	5.9	14.7	3.87	1.20
Total price to consumer	51.08	10.47	52.38	9.65	18.42	4.87	2.77

* For average distance of 1000 km via pipeline

** Compressed to 250 bar from 17 bar and price of power at US$ 0.07/KWH(6)

to exceed 560×10^6 cmd (20×10^9 cfd). Quantities of LPG (propane + butanes) which could be made potentially available will be about 9×10^6 tonnes annually or about 280,000 BPD (44.5×10^6 lit/d).

There are plans for installation of plants to convert NG to liquid or so called GTL. Should implementation of GTL plants be realized it is expected that about 37,000 BPD (5.9×10^6 lit/day) of GO of high quality & free of sulphure to be made from feeding 750 million scfd NG which is equivalent to production of one phase of South Pars Gas Field.

However, economically implementation of a GTL project in Iran may not be feasible. The same conclusion could be reached for dimethyl ether (DME) project in Iran.

7.3 Production of vehicle fuels from associated gases

Production of crude oil from all oil fields in Iran is associated with production of gas released in stabilizing crude oil, normally processed in four stages of declining pressure. Quantity of dissolved gas in crude oil and thus produced varies widely from 350 to over 2500 scf per barrel of oil which is referred to as gas oil ratio (GOR). The associated gas, on average, contains about 76.4% methane, 5.7% propane and 2.3% butane. Based on 4×10^6 BPD crude oil production (onshore & offshore) and an average GOR=700, quantity of NG (or methane) and LPG (C_3 & C_4) amount to about 2.5×10^9 scfd and 140,000 BPD (4.5×10^6 tonne per year) respectively. Potential quantity of condensate (C_5+ or NGL) which could be made available from the associated gas amounts to about 2.8×10^6 tonnes/year (about71×10^3 bbl./day)

8. Potential availability of vehicle fuels in Iran

Sources for producing four types of vehicle fuels are: crude oil refineries and gas refineries, the latter being fed from associated gas and natural gas fields. One additional source of feedstock for making motor gasoline is condensate produced as by-product of the gas refineries. Heart cut of the said condensate extracted from associated gas and raw gas produced from natural gas fields (amounting to about 60% of total condensate) can be reformed to good quality motor gasoline. Potential quantity of MG which could be made from the said condensates would amount to about 220×10^3 bbl/day (35×10^6 lit/day).

In reforming process of the above condensate inevitably LPG is made which could amount to about 18×10^3 bbls/day.

Table 8.1 shows quantities of four types of vehicle fuels which could be made potentially available from hydrocarbon resources produced and processed in Iran.

CNG is not included in Table 8.1, since supply of NG is so large that there will be practically no limitation for making CNG.

As seen in Table 8.1, quantity of LPG which potentially could be made available is 79.3×10^6 Lit/day. It must be pointed out that relevant facilities have not been included in the design of the refineries for recovering of LPG and, in addition, good portion of LPG is currently exported and partly used for heating and making chemicals. At the same time it is to be mentioned that gas production from natural gas fields will expand and will be doubled within five years, and if proper measures are taken in design and recovering of potential LPG in the gas refineries it is expected that over 100×10^6 lit/day LPG could be made available and used as vehicle fuel if such plan proves technically and economically feasible.

Table 8.1 also shows that if condensates produced at gas refineries are reformed locally (instead of being exported as practiced at present) over 96×10^{6} lit/day motor gasoline could be made available.

9. Realistic price of vehicle fuels in Iran

The fact is that over 97% of the total 3.0×10^{6} barrel oil equivalent (BOE) consumed daily in Iran is of hydrocarbon origin, and other fossil fuels and renewable shares in meeting energy demand in Iran is less than 3%.

It is also true that the above situation will remain in Iran for the foreseeable future. It is a fact that price of energy in Iran is unbelievably low and the subsidy for energy consumption based on prevailing international prices exceeds

US$ 45×10^{9} annually. This state of affairs is chronic and it is doubtful if it could be rectified for time being.

Notwithstanding the above, it is logical that demand of energy in Iran to be supplied from sources that creates low net income or national revenue for Iran.

Realistic price of the four vehicle fuels to the consumers in Iran is the sum of all costs plus national revenue accrued if exported. Based on analyses made in the previous sections, the said price is calculated in table 9.1. In these analyses it has been assumed that vehicle fuels are transported to the fuel stations via pipelines over an average distance of 1000 km.

As seen in Table 9.1, lowest price of vehicle fuels in Iran on BTU basis is CNG and highest is MG. But this is not the only criterion to be considered. Other factors such as efficiency and price of the vehicle for similar functions are important as discussed in the following section.

10. Efficiency of fuel in motor vehicles

Internal combustion engines can be classified broadly according to characteristics as whether they work on four-stroke or two-stroke cycle; have electric-ignition or compression-ignition; use gaseous or liquid fuel and/or combinations of these sets of alternatives.

10.1 Carnot Cycle

The thermodynamics of the cycles on which these engines work have limitations which prevent the maximum possible efficiency from being attained.

Nicolas Leonard Sadi Carnot (1796-1832), French Physicist gave the answer to this question in 1824 by showing that maximum work would be obtained from a given amount of heat if it could be made to pass from source to sink (receiver) through an engine working in a strictly reversible manner.(see figure 10.1)

Although the maximum possible efficiency of the Carnot Cycle in any working engine can only be conceived theoretically, it is, however, one of the aims of designers to get nearer and nearer to the maximum efficiency of conversion of heat into work, it is necessary to study the ideal, reversible cycle of Carnot as that of perfect engine.

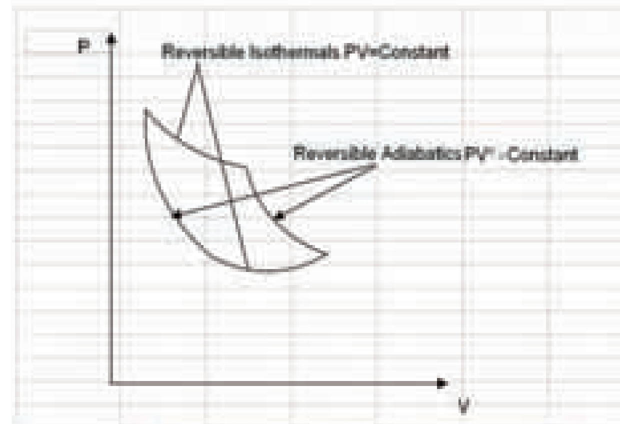


Figure 10.1: Carnot cycle

The efficiency of Carnot Cycle =

$$\frac{\text{work done}}{\text{heat supplied}} = \frac{Rm(T_1 - T_2)\log_e r}{Rm(T_1)\log_e r} = \frac{T_1 - T_2}{T_1}$$

Where

R= universal gas constant

m= mass of the gas

T1= absolute temperature of the hot source

T2=absolute temperature of the receiver or sink (cold body)

r= ratio of isothermal expansion and isothermal compression

Nevertheless, in practice cost of manufacturing the engine and other ancillaries for achieving the high efficiency of converting heat into mechanical energy together with cost of fuel as well as other limiting factors such as emission standards have to be considered.

Unlike steam engines and turbines, the efficiency of reciprocating internal-combustion engines is almost independent of size, and a compression-ignition engine can be made to approach a thermal efficiency of 40 percent as against an efficiency of 30 percent in spark-ignition gasoline engines.

It should be mentioned here that economic efficiency based on overall running costs may be equally or even more important than thermal efficiency and that is why the compression-ignition engine with thermal efficiency approaching 40 percent has not displaced steam turbines in power stations whose overall efficiency is only about 30 percent.

No real engine can work in a strictly reversible manner of Carnot cycle due to eddying motions in gases and heat transfer between working substances and bodies. Thermal efficiency of, other hypothetical cycles such as Otto, Atkinson, and Diesel cycles for internal combustion engine and Rankine cycle for steam engines and turbines, necessarily less efficient than Carnot Cycle, have been projected as practical ideals or standards of comparison for actual engines.

10.2 Otto cycle

In the Otto cycle shown in figure 10.2, heat is added at constant volume with previous compression and heat is rejected also at constant volume, the efficiency η is calculated by the formula:

$$\eta = 1 - \left(\frac{1}{r}\right)^{\gamma - 1}$$

where

$$\gamma = \frac{C_p}{C_v} = \frac{\text{specific heat of gas at constant pressure}}{\text{specific heat of gas at constant volume}}$$

r = compression ratio

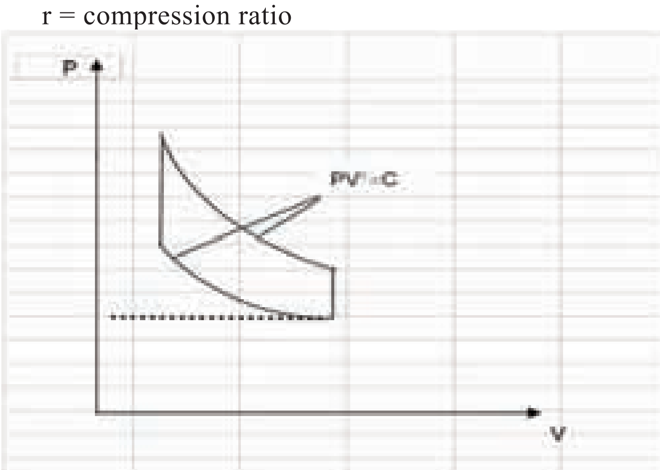


Figure 10.2 : Otto cycle

10.3 Atkinson cycle

The Atkinson cycle shown in figure 10.3, in which heat is added at constant volume with previous compression and heat is rejected at constant pressure, gives a greater efficiency than one working on the constant volume during heat rejection but its use in practice in ordinary engines has not been successful due to difficulties expressed in the mechanism for making the expansion stroke longer than the compression stroke.

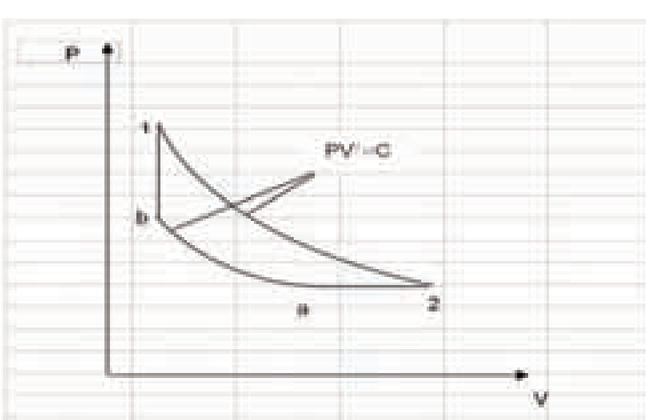


Figure 10.3 : Atkinson Cycle

$$\text{Efficiency of cycle} = 1 - \frac{\text{heat rejected}}{\text{heat supplied}}$$

$$= 1 - \frac{mc_p(T_2 - T_a)}{mc_v(T_1 - T_b)}$$

$$= 1 - \gamma\frac{T_2 - T_a}{T_1 - T_b}$$

In actual spark-ignition engines, working on constant volume cycle, explosion will only occur if the mixture of fuel and air is correct. In a gasoline engine the ratio of air to gasoline by weight must be within the region of between 10 and 20 (representing very rich and very weak mixture respectively) in order for ignition to take place by means of a spark. If the mixture is either too rich or too weak it will not burn.

It can be seen from the efficiency formula $\eta = 1 - \left(\frac{1}{r}\right)^{\gamma-1}$ that the higher the compression ratio, r, the higher will be the efficiency (see fig. 10.4).

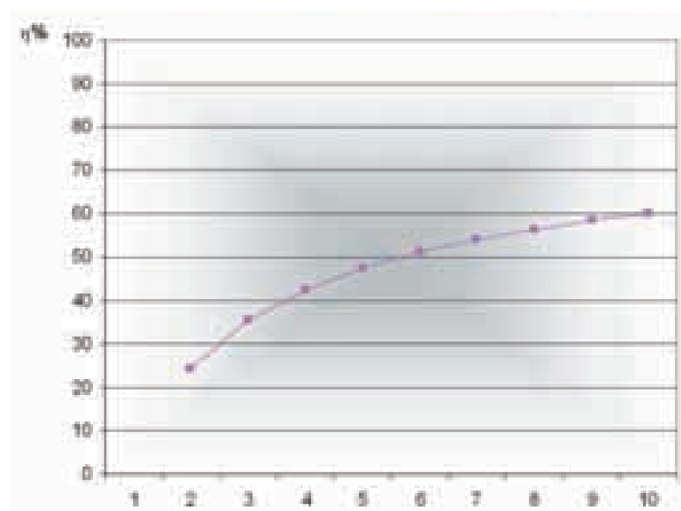


Figure 10.4 : Effect of compression ratio on efficiency

The ratio of compression, however, is limited by the ignition temperature of the mixture. If r were too great, the temperature due to compression may be higher before the end of compression than the ignition temperature of the mixture, and pre-ignition would occur which must be avoided. Therefore, compression ratio must be limited in these types of engines. In ordinary gasoline engines using low octane gasoline a compression ratio of 6 is the limit. However, for gasoline engines with higher compression ratios (up to 10 or 11), higher octane gasoline with higher ignition temperature must be used.

10.4 .Diesel cycle

In hypothetical cycle proposed by Diesel shown in figure 10.5, in which heat is added at constant pressure with previous compression while heat is rejected at constant volume, the efficiency

$$\eta = 1 - \frac{1}{\gamma}\left(\frac{\rho^{\gamma}-1}{\rho-1}\right)\left(\frac{1}{r}\right)^{\gamma-1}$$

Where $\rho = \frac{T_1}{T_b} = \frac{V_1}{V_b}$

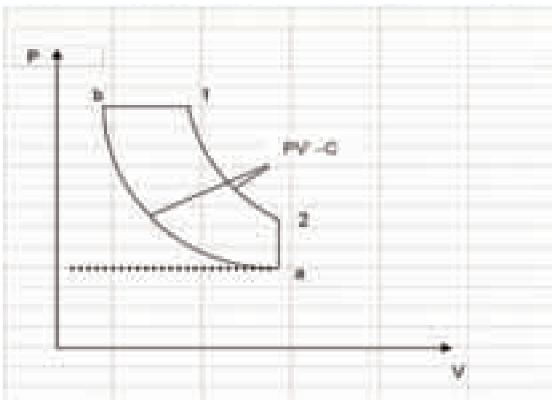


Figure 10.5: Diesel cycle

In the cycle where heat added and rejected in constant pressure (known as Brayton cycle) the theoretical efficiency is the same as the Otto cycle i.e. $\eta = 1 - \left(\frac{1}{r}\right)^{\gamma-1}$.

In an engine working on the Diesel cycle there is no combustible gas in the cylinder during compression and therefore the compression ratio, r, is made much higher than in an engine working on the Otto cycle, since there is no danger of pre-ignition, and therefore by increasing r to say 16 or 18, a higher efficiency is obtainable in the diesel than is possible in the Otto cycle which has a limiting r of about 6 to 10. The temperature due to compression in a compression-ignition engine is sufficient to ignite the fuel-oil which is injected into the cylinder near the end of compression at some pressure of 26,000 psi.

10.5. Mixed or dual cycle

There are also mixed or dual cycles in which heat is added partly at constant volume and partly at constant pressure with previous compression as shown in Fig. 10.6.

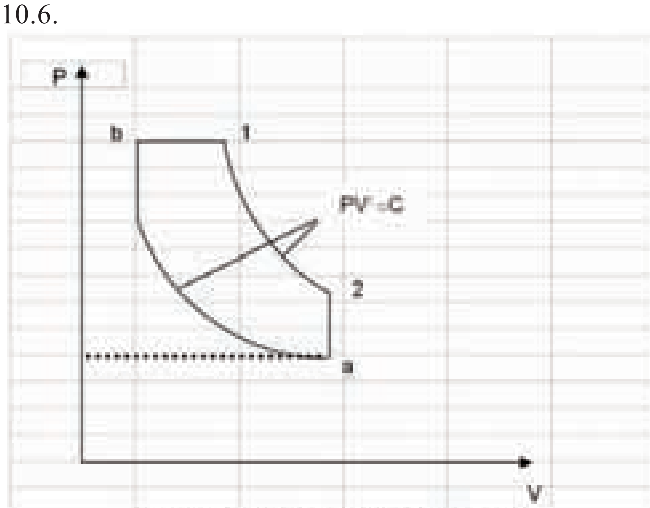


Figure 10.6: Mixed or dual cycle

10.6. Actual efficiency in internal combustion engines

It should be emphasized that no real engine can follow exactly any of the above mentioned cycles, because heat, being supplied by the process of combustion, can not be added strictly at constant volume or at constant pressure, nor can any actual expansion or compression be carried out in a strictly reversible adiabatic manner or without friction. Furthermore, the working agent was assumed to be air or gas which never left the cylinder, and to have constant values for specific heats, which is not the case in practice.

Also, in actual reciprocating-piston internal-combustion engines, although the mechanism undergoes a cycle of operation, the working agent does not undergo a cyclic process, for it is not brought back to its original condition but is replaced by a new charge of mixture or air.

10.7. Air standard efficiency

The expression $\eta = 1 - \left(\frac{1}{r}\right)^{\gamma-1}$ has become known as the "air standard efficiency" because it is usually taken as a standard of comparison for the performance of actual internal-combustion engines. What is true of imaginary engines as regards thermal efficiency increasing with r is true of actual engines. This expression which was proved as the efficiency of the Otto or constant-volume cycle was on the assumption that the specific heat C_v remained constant over the range of temperature involved. In actual engines the working agent, after combustion, is neither a perfect gas, nor even air, but a mixture containing nitrogen, oxygen, water vapour, carbon dioxide , carbon monoxide, etc, and thus specific heats of these gases vary with temperature. At high temperatures the specific heats increase considerably, hence, during combustion, a lower maximum temperature is produced in the cylinder of an engine (due to an increase in specific heat) than would be produced if the specific heat remained constant. Thus the formula for air standard efficiency always gives a higher value than can be attained in an actual engine.

In high-speed compression-ignition engines the rate of rise of pressure is so high (e.g. at 2400 rpm each stroke is completed in $\frac{1}{80}$ second) that the assumption made in the Diesel cycle, namely, that heat is added at constant pressure, is far from what happens in reality. It is therefore thought that the formula $\eta = 1 - \left(\frac{1}{r}\right)^{\gamma-1}$ may quite reasonably be taken as the standard of comparison for compression-ignition engines as well as for engines working with electric ignition.

There are many other factors which can either improve the efficiency or adversely affect the performance of the internal-combustion engines. Here, we can only mention some of these factors and briefly explain how they enhance or deteriorate the performance of an engine.

10.8 Scavenge efficiency

Combustion of all the fuel is not as a rule completed in high-speed compression-ignition engines despite the fact that there is usually an excess of oxygen available. It is found that in order to maintain a clear exhaust; only about 3/4 of the air in the cylinders of compression-ignition engines can be consumed. At high speeds the volumetric efficiency decreases, as does the ratio of the available oxygen to the quantity of fuel injected, thus increasing the tendency to incomplete combustion.

The scavenge efficiency of an engine is a measure of the degree to which the products of combustion of the previous cycle have been cleared from the cylinder and is equal to: mass of products expelled from the cylinder divided by mass of products in cylinder before exhaust valves open.

10.9 Supercharging

The power output of any internal-combustion engine depends on the mass of oxygen which can be burnt per unit of time in the cylinders. This can be increased in an engine drawing air from the atmosphere, by increasing the speed of the engine or by supercharging or both.

Supercharging is the name given to the process of increasing the pressure of the fuel-air mixture entering an engine to a pressure greater than that of atmospheric air, and is usually achieved by means of a small compressor or blower called a supercharger which also whirl the mixture into a more homogeneous state. Supercharging is also known as pressure-charging or boosting.

It should be noted that the higher the initial temperature of the mixture or air in the cylinder the higher will be the temperature after compression, i.e. before any heat is released by the fuel. Raising the inlet temperature is to the detriment of thermal efficiency and mechanical endurance due to greater losses because of heat transfer, higher specific heats and dissociation.

10.10 Turbulence and angle of fuel jets

Turbulence may be said to be violent eddying motion and swirling of fluid in the cylinder. The object of turbulence in internal-combustion engines is to achieve a rapid relative motion between the air and fuel particles. If the gases in the cylinder of an engine have eddying and swirling motion at the point of ignition, it is found that this produces fast propagation of flame and its rapid spread throughout a fuel-air charge in the cylinder. In an experiment on an air-gasoline mixture in a stagnant condition it was found that the time from ignition to the point of maximum pressure was 0.03 second, while in a cylinder of engine this time was reduced to less than 0.003 second as a result of turbulence.

Special designs of cylinder and piston heads, shapes and positions of inlet ports can produce the turbulence which improves the propagation of flames. Also, in order to maintain the relative velocity between fuel and air which is so necessary for rapid combustion, the fuel in compression-ignition engines must be injected across and never in the same direction as the air stream, hence bringing the fresh oxygen into contact with the fuel particles for rapid combustion. It is also known, that an angle of inclination of nozzles (the angle between the axis of the cylinder and axis of jet) practically for diesels with volumetric mixture formation, should have optimum value at which best parameters of the engine operation are reached. At large value of jet angle (85o), about 20% or more of fuel gets on the surface of the cylinder where fuel evaporates very badly. At small value of jet angle the fuel quickly reaches a hot surface of the piston and evaporates in an initial stage of injection (up to TDC).

Turbulence in an engine is also increased with increasing speed of the engine. However, it should be noted that high air-swirl entails high heat losses by convection.

10.11. Dissociation

The amount of heat required to dissociate or split a compound, say H_2O or CO_2, into its elements again is numerically equal to the heat evolved when the compound was formed by combustion of its elements. At high temperatures H_2, O_2, CO_2, N_2 can, due to dissociation, exist in the mixture. The dissociation of CO_2 is more serious than that of H_2O in the internal-combustion engines.

The heat absorbed by dissociation is released again when the gases recombine at a lower temperature.

However, since dissociation occurs at higher temperature the maximum temperature reached is less than that calculated from calorific value of the fuel.

10.12 Detonation and knock

Detonation will occur when certain types of fuels are used in internal-combustion engines. Knock is usually thought to be caused by a blow delivered against the cylinder or piston by a high-pressure wave traveling at high speed through the gas in the cylinder. In spark-ignition engines the explosion wave set up by an extremely rapid rise of pressure, passes through the gas much faster than the speed of flame propagation and strikes the cylinder with a hammer-like blow known as pinking. Detonation is not pre-ignition. It is something that occurs after the spark has initiated ignition in electric-ignition engines.

All fuel-air mixtures will start pinking if compressed beyond a certain point. Many engines begin pinking after run for a long time because carbon, mainly from burnt lubricating oil, collects on top of the piston and gradually increase the compression ratio.

10.13 NOx and soot emissions

While diesel engines offer a superior economy in comparison with spark-ignition gasoline engines, they, however, have a relatively high level of NOx and soot emissions. With the increasingly stringent emission standards, most of the engine research is focused in simultaneously reducing the fuel consumption and emission. The reduction of NOx and soot from a diesel engine has been traditionally challenging since most strategies which reduce one, result in an increase of the other. The problem becomes further complicated by the fact that often a reduction in NOx is at the expense of the fuel consumption.

Some manufacturers have succeeded in making diesel engines which, in terms of fuel consumption, emission and refinement, prove to be far better than other current engines of similar output. Their fuel consumption is down by some 10% while emission is cut by 30 to 40 percent, outperforming the Euro 4 limits. They use the latest multi-jet direct injection system with fuel supply by "common rail" at a pressure of 1600 bar to five hole nozzles controlled by an ultramodern solenoid valve. The fuel injection system's response time is less than 20 millionths of a second which keeps fuel consumption and exhaust emission low and also ensures smooth, low-noise operation. The diesel engine knock in the warm-up phase is reduced to a hardly identifiable level by the pilot injection.

Also, Spin-Spray combustion has shown to reduce soot by enhanced mixing (improved soot oxidation).

NOx reduction occurs through rapid convection of burnt gas into evaporation region.

10.14 Speed of vehicle and fuel economy

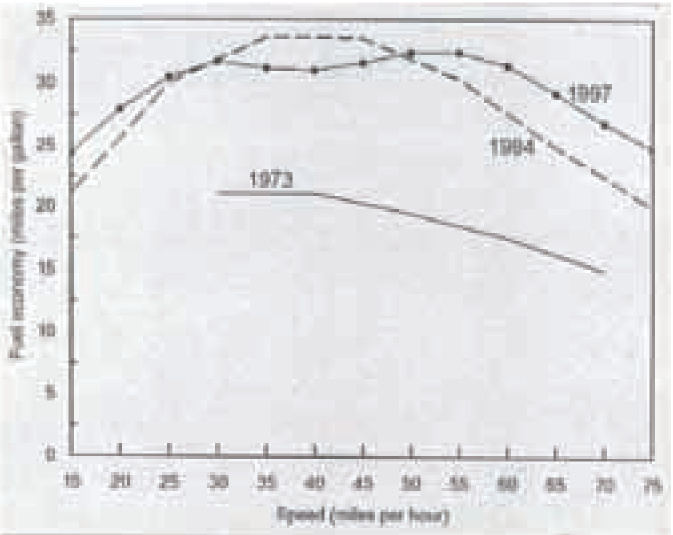
The fuel consumption of engines is usually expressed in weight of fuel per brake horse power (bhp)- hour, which gives the amount of fuel required by an engine to do the definite amount of work equal to 1 horse power-hour (or 1,980,000 ft-lb or 270,000 kgr-m).

A curve plotted over the range of power output (no load to overload) for an engine will reveal the particular break power at which the engine can run with least consumption of fuel per b.h.p-hour and therefore with maximum thermal efficiency.

The expression for brake thermal efficiency shows that the power at which there is minimum consumption per b.h.p-hour is also the power at which the brake thermal efficiency is a maximum.

For engines used in road vehicles the fuel economy (say miles per gallon or km per litre) is plotted against speed (miles per hour or km/hr) and the best speed is where the distance traveled per gallon or litre of fuel is a maximum.

The fuel economy by speed for light vehicles used in USA were studied in 1973, 1984 and 1997 and the outcome is shown the following figure:



11. Pros and cons of fuels in motor vehicles

11.1 Motor gasoline

With limitation of benzene to maximum 0.5%(7) and gradual elimination of MTBE, an oxygenate with high octane and relatively low vapour pressure in MG, it is costly to boost octane for use in internal combustion engines with compression ratio (CR) higher than 8. Thus, achieving higher than 30% efficiency in motor cars consuming MG would not be economically feasible.

At the same time making MG in oil refineries is more cumbersome than other types of vehicle fuels such as LPG and GO.

Reforming process of straight run naphtha incurs relatively high capital investment, compared with other types of vehicle fuels and, in addition, about 20% of naphtha is converted to lighter hydrocarbon compounds which has much less value than naphtha. Also, extracting benzene from reformate, to meet maximum 0.5% MG specification, is costly.

11.2 Gas Oil / distillate

Combustion of gas oil takes place at relatively high compression ratio (CR) of 18-20. Fuel efficiency at such level of CR is above 40% resulting in mileage per unit fuel of about twice of that of MG.

Specification for sulphur content of GO is very tight at less than 50 ppm. This level of sulphur could be achieved by hydrodesulphurization process with cost of less than US$ 1/barrel. As said earlier in this paper straight cut of GO derived from most of crude oils, including Iranians, meet all other specifications notably cetane number. As seen in table 9.1 realistic price of MG and GO are very close at US$ 10.47 and 9.65 per MM BTU respectively, with crude oil at US$ 35/bbl.

However, as said under section 10.14, NOX and soot emissions of diesel engines are higher than spark ignition gasoline engines. But it is also ture that noticeable improvement has been achieved in diesel engines which in addition of better mileage, emission is cut by 30 to 40 percent.

Therefore it could be concluded that gas oil is a preferred vehicle fuel compared with MG.

11.3 Liquefied petroleum gas (LPG)

Table 8.1 depicts that quantity of LPG which could be made potentially available in Iran is in excess of 490,000 bbls/day (79. $\times 10^6$ lit/day). Most part of this LPG is either not recovered, or used for heating or exported, whereas the preliminary results indicate that its realistic price to consumers in Iran is US$ 4.87/MM BTU or less than half of either MG or GO.

A. Battell Institute study has shown that propane is the most economic alternative fuel for fleet vehicles on a per-mile basis. The National Propane Gas Association claims the higher octane rating (104-112) and low carbon and oil-contamination characteristics help engines last three times longer than those fueled by gasoline. Vehicle conversion costs are relatively cheap at $ 1500-3000 and can be partially offsets through tax deduction or other incentives.

Based on above discussion and subject to detail scrutiny of the matter, it appears that LPG is a superior transportation fuel compared with MGand GO in Iran.

11.4 Compressed natural gas (CNG)

As said earlier, CNG applies to NG when compressed to 200-250 bars pressure. It is obvious that there will be no shortage of NG to supply motor vehicles in Iran in the form of CNG. The stumbling blocks for development of CNG use as transportation fuels are: very high cost of fuel station estimated to be between US$ 750,000-1,500,000 high cost of conversion and to certain extent safety consideration of motor vehicles loaded with CNG trafficking in residential areas.

Based on data obtained in table 9.1 realistic price of CNG to consumer at US$ 35/bbl is about US$ 2.77/MMBTU which is less than one third of MG and GO. It should be noted that no tangible data were available on the costs for compression and distribution at fuel stations, and also the additional capital cost for conversion of engines using MG to CNG.

Should detail studies result in different costs on the above items, the conclusion could be different.

12. Summary and conclusion

12.1 All four types of fuels commonly used in motor vehicles namely motor gasoline (MG), diesel, liquefied petroleum gas (LPG) and compressed natural gas (CNG) are potentially available in Iran. These fuels are adequate to meet the demand of transportation fuels in Iran for foreseeable future.

12.2 Based on preliminary studies and limited available data, use of LPG as transportation fuel in Iran is economically and technically feasible. It is strongly recommended that a detailed study to be carried out on the subject for implementation of the project.

12.3 Preliminary studies indicate that use of CNG as transportation fuel in Iran could be attractive, but for development of system, especially use of CNG in motor cars, requires further investigations and detail studies.

12.4 Use of gas oil and promotion of diesel motor cars in Iran should be encouraged. Analyses in this paper clearly show that, both economically and technically, the use of gas oil in motor vehicles is superior to MG.

12.5 It should be emphasized that an appropriate feasibility study is needed for optimization of transportation fuels in Iran. This study should be based on reliable data and statistics for growth rate of vehicles and consumption of fuels during the next 20 years, as well as the actual costs of each type of fuel.

References & Sources

(1) Transportation Energy Data Book U.S.A. Edition 25-2006.
(2) Oil & Gas Journal, Nov. 27, 2006 page 64
Global oil, gas outlook bright; US gas production nears plateau
(3) Oil & Gas Journal, Jan.15, 2007 page 56
US gasoline markets to rebalance by 2010
(3/1) Eghtesad-e-Energy, July-Aug. 2006
How to resolve Iran's gasoline issue
(4) Oil & Gas Journal, Nov. 27, 2006 page 20
Global oil, gas outlook bright; US gas production nears plateau and O3GJ. Jan. 15, 2007 page 30. Growth expected for global oil demand, production.
(5) Oil & Gas Journal, Dec. 4, 2006 pages 18 & 22
Alternative fuels gaining transport market share and Hydrocarbon Processing. Jan.2007, page 21
(5/1) Hydrocarbon Processing Nov. 2006 page 27
(5/2) Hydrocarbon processing Jan. 2007 page 59
Compressed natural gas – Another solution to monetize stranded gas.
(6) Engineering Data Book Natural Gas Processors Suppliers Association, page 35
(7) Oil & Gas Journal, Sept. 11, 2006 page….
Study outlines US refiners options to reduce gasoline benzene levels.

Criteria Concerning the Registration Of Companies, and Industrial-Intellectual Ownership in Free Trade-Industrial Zone of I.R. Iran

Chapter one: Definitions

Article 1

In this decree the following terms are utilized against their pertinent detail expressions:

Country: Islamic Republic of Iran

Zone: Each one of the Free trade-Industrial Zones

Organization: Each Organization of Free Trade-Industrial Zones established in accordance with law.

Law: Law on Administration of Free Trade-Industrial Zones of I.R. Iran

Registry Office: Authority in charge of registration of companies/industrial and intellectual ownerships in each organization of Free Trade-industrial Zones.

Branch of company or institute: Branch of a company or institute, is the legal person which is set up in the Zone by the principal company or institute located outside of the Zone. The majority of its shares belong to that of principal company or institute and this legal newly established person in the Zone is the subsidiary company or institute of that principal one.

Representative of company or institute: Representative of a company or institute to whom necessary authorization is vested and its liabilities in the position of representative of company or institute shall be deemed as the liabilities of the authorizing company or institute.

Chapter Two: Establishment And Functions Of Registry Office

Article 2

In order to perform the functions pertaining to registration of companies and industrial and intellectual ownerships, the organization of each zone shall set up a unit named as" Companies, and Industrial and Intellectual Ownership Registry Office" in that zone.

Article 3

The functions of the Registry Office are as follows:

3-1: Registration of Iranian and Foreign companies and institutes.

3-2: Registration of trade marks and trade and industrial names.

3-3: Registration of inventions, patents monograms and industrial drawings.

3-4: Registration of traders' commercial books.

3-5: Plumbing of commercial and non-commercial books in the territory of each Zone.

3-6: Registration of banks and credit institutes with regards to the Regulations on Monetary and Banking Operations in the Free Zones.

3-7: Registration of insurance companies in accordance with the governing regulations in the Free Zones.

Chapter 3: Legal Formalities for Registration of Companies and Industrial Intellectual Ownerships

Article 4

Each company or institution registered in the Zone, whose principal center is in the same Zone, shall be deemed as Iranian and registered in the Zone.

Note 1

From the date of enforcement of this decree, any foreign company or institution willing to carry out economic activities through its branch or representative in the Zone, must have been registered in accordance with the current laws and regulations of its own sovereign state, attested by the legation of Islamic Republic of Iran and registered also in the Zone's Registry Office.

Note 2

Any foreign company or institution which, from the date of enforcement of this decree, is engaged in economic activity through its branch or representative in the Zone, has to be registered within three months from the enforcing date of this decree otherwise such a company has no legal status and its founders are jointly responsible for probable indemnities.

Article 5

All kinds of companies and non-commercial institution mentioned in the Commercial Code and other Iranian laws may be registered in the Zone's Registry Office, provided that the subject of their activity is legal. Establishment and activity of companies in accordance with enacted laws, in any case, is possible.

Article 6

All legal persons having economic activities in the Zone are to adjust their status with the provisions of this decree and its pertinent executive instructions thereto, within three months of proclamation made by the Registry Office.

The executive instruction of this Article shall be written and implemented by of each Zone authority.

Note

The State Title Deeds and Real Estate Registration Organization shall, upon the request of the Zone's Registry Office, send to the said Office, all the documents and files pertaining to the legal persons who have been, prior to the establishment of the Zone's Registry Office, registered in other places of the country and whose principal center (domicile), according to their charter is in the Zone and have obtained license for their activities in the Zone.

The State Title Deeds and Real Estates Registration Organization shall also cooperate with the Zone's Registry Office to prevent and avoid determining similar names for the companies who are in the process of the registration.

Article 7

Registration of company or institution in the Zone shall be made upon submission of the following documents:

1- Letter of declaration applying for registration

2- Company's article of association

3- Minutes of the founders' general assembly

4- Minutes of the first cession of the board of directors

5- Certificate issued from one of the banks located in the Zone attesting that a minimum of %35 of cash capital has been paid.

6- License of the activity issued by the Organization.

Note 1

In case of the foreign legal persons, it is necessary to provide and submit the original letter of authorization indicating representation and the license of the establishment of those legal persons.

Issuance of such documents must be in accordance with those laws and regulations of legal persons' sovereign state (and attested by representative of Islamic Republic of Iran in that country).

In order to register a branch or a representation in Iran, the foreign legal persons, are to attach the Farsi translation of the company's registry declaration forms, and attested copy of the documents indicating the registration of company in their own sovereign country.

Note 2

All documents subject of the article 8 of this decree are also to be submitted, by foreign legal persons, in officially translated Farsi version.

Note 3

In all cases, steps shall be taken for registration, once the pertinent fees are received.

Article 8

Letter of declaration pertaining to registry of branches or representations of foreign legal persons in addition to the date and signature, contain the following points:

1- Full name of company or institution in Farsi language with its probable acronyms, and specifications.

2-Type of company or institution and its activities.

3-The main office and domicile of company or institution abroad.

4-Nationality of the company or institution.

5-The amount of capital of the company or institution.

6-The last balance sheet of the company or institution.

7- Registering authority, postal code (country and city) and registering date of company or institution abroad.

8-The envisaged activity of company or institution to be performed in the Zone.

9-The other branches or representatives of company or institution in Iran and names of their directors (if any).

10-The domicile of company or institution in the mainland of Iran and the Zone and introduction of competent authorities who are responsible to receive the summons and communiqués.

11 -Affidavit signed by director or directors of branches or representations, on permits or authorization letters subject to Note (1) Article (7) of present decree, indicating they have accepted the assigned position.

12-Names, surnames and domicile of the directors or administers of company or institution.

Note

Name, surname, domicile and nationality of the proxy and also the original and a copy of attested letter of proxy, in case, the letter of declaration and application for registry is to be submitted by the proxy.

Article 9

The legal persons shall have legal personality once they are registered and may have activity in the Zone in accordance with the governing laws and regulations. The Registry Office of the Zone Organizations is bound to submit to applicants a certificate, sealed by Registry Office, indicating the registration of the legal persons or their branch or a representative.

Article 10

Legal persons are required to declare in writing to the Registry Office any changes in their charter, composition of the board of directors, inspectors, authorized signatories, and increase or decrease in capital and liquidation, within one week.

Lack of timely declaration shall not obviate the responsibilities of the director of the legal persons.

Article 11

Any party having interest may get information from the contents of the Registry office files, and obtain attested copies upon request.

Article 12

The Registry Office is required to declare the establishment of a company or institution and the alterations on its status within 10 days following the date of registration in order to be publicized in the Official Gazette of the Islamic Republic of Iran and local newspaper. Such proclamation shall be financed by the applicants.

Article 13

Application for registering of trade marks and trade-industrial names and registering of inventions, designs, and industrial drawings in the Zone shall be made upon submission of a letter of declaration. The requisties for registration at the Registry Office shall be in compliance with the executive directions adopted by each Zone authority.

Article 14

All the Iranian natural who, under the Commercial Law do business in the Zone, are bound to register their names or their managers' names in the commercial register of the Registry Office within three months of proclamation made by the Registry Office.

Article 15

Registration of the Iranian and foreign nationals persons in the registers which shall be made upon submission of three copies of filled in declaration form, and within three months from proclamation of Registry Office, shall contain the following points:

1-Name and surname of trader.

2-Date and place of birth, identity certificate number and its place of issuance, and the photocopy of the pages of identity certificate in case of the Iranian nationals and photo-copy of the pages of passport in case of foreign nationals

3- Original and present nationality of the individuals, if any new nationality has been obtained besides the date and the manner of obtaining the new nationality.

4- Date of entry into the Zone, number and place of issuance of……. permit, and place of residence.

5- Legal residence of natural persons.

6- Registering and sealing (Plumb) number of commercial books provided in accordance with the provisions of paragraph (5) of the Article No.3 of the present decree.

7- Type of activity in Iran and abroad separately or in both cases.

8- Other trading specifications of traders inter alia the registry number, trade marks, commercial codification books, etc.

Article 16

The Registry Office is required, after registering within 10 days, the contents mentioned in the letter of declaration, to submit a signed and sealed copy of letter of declaration to the applicant and send another copy to the pertinent office in the Zone's organization.

Article 17

Applicants for registration are bound, when any new alteration occurs, to provide new letter of declaration in three copies and submit it to the Zone authority - s Registry Office.

Article 18

The natural and legal persons who, in accordance with the provisions of this decree, register their names, are bound to mention their registration number as well as their commercial title on the papers, invoices, order forms and any other kind of documents they utilize.

Chapter Four: Miscellaneous

Article 19

The commercial books of the natural and legal persons shall be sealed (plumbed) in accordance with the manner determined by the organization of each Zone and shall be stamped once the representative of the Registry Office has signed them.

Article 20

Expenses pertaining to the registration of company, institution and the alterations thereafter, and registration of trade marks, commercial and industrial titles and brands, inventions and designs and drawings, also registration of commercial books and sealing (plumbing) of commercial and non-commercial books shall be collected, with due regard to relevant laws, in accordance with the directions provided by each of the Zone authorities.

Article 21

Upon the request of the Zone authority the activities of those who violate the provisions of this decree shall be prevented by the disciplinary forces. Such deeds shall not eliminate the responsibilities of the directors of company or institution or natural persons against the third parties.

Article 22

Directions pertaining to this decree and related printed forms shall be provided and put to effect by the authority of each Zone within one month from the approval of the present decree.