ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

ERC Hydro-Cracking Complex Project at Mostorod

FINAL VERSION

Appendix 4.1 – Detailed Discussion of the Design Alternatives

51287-1

December 2008

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Hydrocracking

Hydrocracking unit plays the major role in meeting the need for cleaner-burning fuels and more effective lubricating oils. As stated before, through hydrocracking heavy fuel oil components are converted into transportation fuels and lubricating oils with a quality that meet the environmental and markets demands.

Hydrocrackers are classified as: single-stage, series flow units, and two-stage units.

In single-stage once through (SSOT) or series flow units, all catalysts (one or more) are contained in the same stage (one or more reactors).

The two-stage units are used to minimize the exposure of catalyst to the high levels of H2S and NH3 generated during the removal of organic sulfur and nitrogen respectively, although the presence of ammonia enhance the liquid yields.

The two-stage unit employs interstage product separation that removes H2S and NH3 to minimize their level in the second stage hydrocracking unit. This unit is used to maximize the transportation fuel and the light products yields.

The following is a brief discussion for the proposed alternatives for the hydrocracking unit.

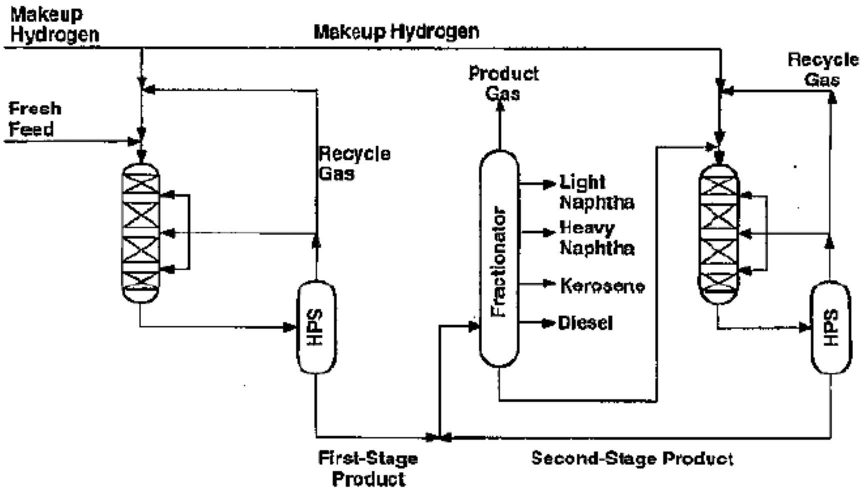
Chevron Isocracking-hydrocracking unit

The Chevron Isocracking process–licensed for over 30 years- has technological advantages for gasoline, middle-distillate and lubricating oil productions. The name "Isocracking" refers to the high ratio of isoparaffins to normal paraffins in the light products.

Process description

A two-stage isocracking unit as shown in the next figure will be used in order to maximize the yields of transportation fuel oil, middle distillates and naphtha.

The bottoms from the fractionator are again mixed with hydrogen and charged to the second stage. The operating conditions are more severe in the second stage since the feedstock contains a mixture of already treated hydrocarbons.



Two Stage Chevron Isocracking Unit

The catalyst used is developed by the Chevron R&D department. This catalyst has proven to be highly effective with the heaviest part of VGO feed where the nitrogen compounds are concentrated due to its high denitrification. Such activity plays a major role in minimizing the wastes produced from organic nitrogen components as previously stated.

Besides having high activity, this catalyst shows much greater stability, longer run cycle and lower fouling rates than the comparable catalysts. It's obvious that a catalyst with such long run cycle minimizes the solid waste and hence protects the environment.

Product yields and quality:

The yield quality greatly depends on the catalyst choice. The Isocracking amorphous catalysts give a 5 to 10 percent higher yield of quality middle distillate than other amorphous catalysts. They also prevent the formation of aromatics in the products; such aromatics decrease the burning quality of the middle distillates which can cause air pollution.

As for the undesired polynuclear aromatics (PNA), using Chevron amorphous cogel catalysts prevents their formation.

The Chevron's noble metal/ zeolite and base metal/ zeolite catalysts give high naphtha yields with long run lengths.

The following table shows a product yield structures and qualities using Chevron Isocracking process.

Isocracking - typical yields and product qualities

PRODUCT	PRODUCT YIELDS		PRODUCT QUALITY	
	Wt %	**LV %**	**Characteristic**	**Value**
C_5-180 ºC	4.8	5.9		
180-290 ºC	15.4	17.4	Smoke point, mm Cetane index	22 56
290-370 ºC	16.4	18.1	Flash point, ºC	145
370-425 ºC	13.7	15.0		
425-475 ºC	19.3	21.0	Solvent dewaxed 240N VI Pour point, ºC	 97 -12
475 ºC +	27.4	29.6	Solvent dewaxed 500N VI Pour point, ºC	 105 -12

Basis: feedstock, Russian VGO: Density, 18.5 ºAPI; Sulfur, 2.28 wt%.

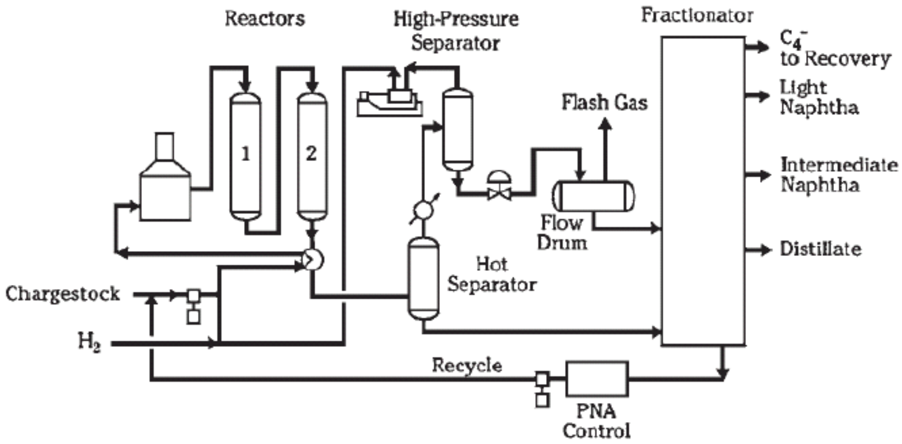
UOP Unicracking process:

The UOP has developed many flow configurations for hydrocracking, but the single-stage flow scheme is the most widely used. This design allows the complete conversion of feedstocks and improves the operating performance.

Process description:

The UOP unicracking process is carried out at moderate temperatures and pressures over a fixed catalyst bed in which the fresh feed is cracked in a hydrogen atmosphere.

The next figure shows the hydrocracking unit that will be used in the ERC plant. The use of hot separator improves the energy efficiency of the allowing hot liquid to go to the fractionator section and prevents the PNA fouling. Whereas the cold separator is used to separate the recycle gas from the product.



Typical flow diagram of a single stage UOP Unicracking unit

The UOP zeolitic catalyst used (HC type) has excellent selectivity and activity suitable for full conversion of the feedstock. The most important advantage for this catalyst is its regenerability. After typical operation cycle for the catalyst (about 2 years), after regeneration, it is fully regenerable and recover almost full activity.

Product yields and quality:

The proper catalyst choice will maximize the product yields and quality. This is illustrated –as an example- in the next table.

Typical UOP Hydrocracking yields

	Distillate	Naphtha
Yield:		
NH_3, wt%	0.1	0.1
H_2S, wt%	2.6	2.6
C_2-, wt%	0.8	0.8
C_3, wt%	1.0	3.3
C_4, vol%	2.9	21.4
Light naphtha, vol%	7.3	39.1
Heavy naphtha, vol%	7.7	68.9
Distillate, vol%	94.0	-
Product properties:		
Jet-fuel cut:		
Smoke point, mm	27	-
Freeze point, ^{o}C	-59	-
Aromatics, vol%	9	-
Diesel-fuel cut:		
Cetane no.	56	-
Naphtha:		
P/N/A, vol	-	33/55/12
Research octane no.	-	68

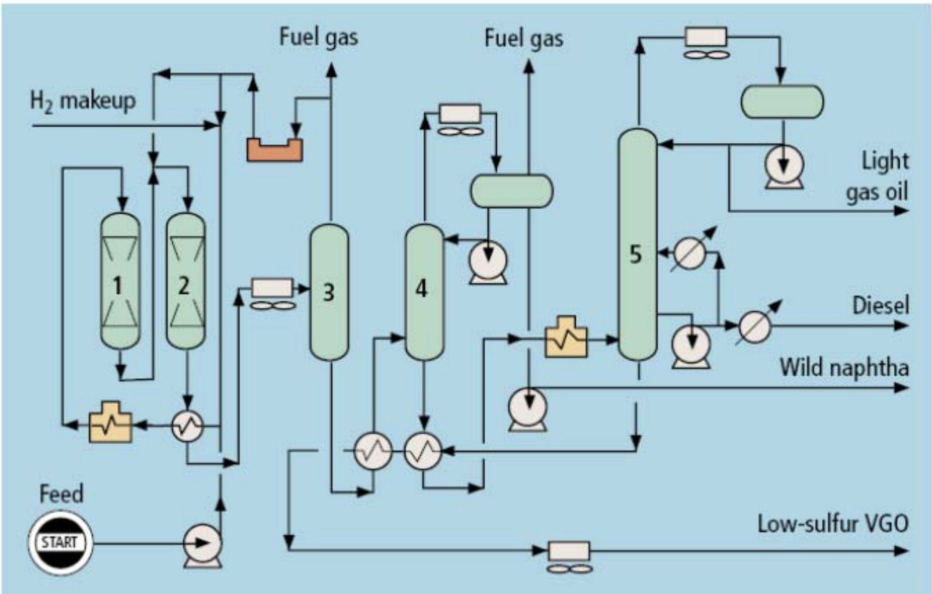
Basis: feedstock, Middle East VGO: Density, 22.2 API; Sulfur, 2.5 wt%.

Axens Hydrocracking process

The Axens hydrocracking unit is characterized by its ability to process not only VGO alone, but also if it's blended with various feedstock.

Process description

The Axens hydrocracking process will be a single-stage/ total conversion with liquid recycle as illustrated in the next figure. The Axens catalysts used have high tolerance to nitrogen in the feedstock and high selectivity to the middle distillate.



A simplified flow diagram of a single stage Axens Hydrocracking unit

In order to protect the environment, the Axens catalysts have long run cycle that can reach up to 4 years and hence, minimize the solid wastes from the reactors.

Product yields and quality:

From the wide range of catalysts produced by Axens, the choosed one gives a high quality yield as shown in the following table:

Typical Axens Hydrocracking Yields

	Jet Fuel	Diesel
Specific gravity	0.800	0.825
TBP cut point, ºC	140-225	225-360
Sulfur, ppm	<10	<10
Nitrogen, ppm	<5	<5
Metals, ppm	-	-
Cetane index	-	62
Flash point, ºC	≥40	125
Smoke point, mm, EOR	26-28	-
Aromatics, vol%, EOR	<12	<8
Viscosity at 38 ºC, cSt	-	5.3
PAH, wt%, EOR	-	<2

Basis: feedstock, HVGO: Specific gravity, 0.932; Sulfur, 31,700 ppm.

Hydrogen Plant

By-product from catalytic reforming

Hydrogen has been produced in catalytic reforming as a by-product of the production of the high-octane aromatic compounds used in gasoline. Where by product hydrogen production has not been adequate, hydrogen has been manufactured by steam reforming.

Partial oxidation (POX)

Hydrogen can also be produced by partial oxidation of hydrocarbons

$CH_4 + ½\ O_2 = CO + 2\ H_2 \quad \Delta H = -23.7$ kJ/gmol

The shift reaction also participates so the result is a mixture of CO and CO_2 in addition to H_2. Temperature in partial oxidation is not limited by catalyst tube materials, so higher temperature may be used which results in reduced methane slippage.

In some cases, partial oxidation has been used, particularly where heavy oil is available at low cost. However, oxygen is then required, and the capital cost for the oxygen plant makes partial oxidation high in capital cost. For light feed, it has been generally replaced by steam reforming.

Catalytic partial oxidation

Also known as autothermal reforming, catalytic partial oxidation reacts oxygen with a light feedstock, passing the resulting hot mixture over a reforming catalyst. Since a catalyst is used, temperatures can be lower than in non-catalytic partial oxidation, which reduces the oxygen demand.

Feedstock composition requirements are similar to those for steam reforming. Light hydrocarbons from refinery gas to naphtha may be used. The oxygen substitutes for much of the steam in preventing coking, so a lower steam/carbon ratio can be used. Since a large excess of steam is not required, catalytic POX produces more CO and less hydrogen than steam reforming. Because of this, it is suited to processes where CO is desired, for example as synthesis gas for chemical feedstocks. Partial oxidation requires an oxygen plant, which increases costs. In hydrogen plants, it is therefore used mainly in special cases such as debottlenecking steam reforming plants, or where oxygen is already available onsite.

Steam reforming / wet scrubbing

Natural gas mixed with steam in reformer over a nickel catalyst. The outlet gases from steam reformer are cooled to about 345°C and passed over an iron oxide catalyst in the first stage CO converter, these hot gases are cooled before entering the second stage CO converter.

The cooled gases from the second stage CO converter are scrubbed with potassium carbonate solution in the absorber to remove essentially all the CO_2. Following this, the gases are heated to about 315°C and passed to the methanator over a nickel catalyst to convert essentially all the carbon oxides to methane by reaction with H_2. Typical final hydrogen purity is 97 mol% with the remaining impurities consisting mainly of methane and nitrogen.

Analysis

The PSA unit is simpler to operate than a wet scrubbing system, since it has no rotating equipment or circulating solutions. In addition, the adsorbent will remove methane and nitrogen, which could not be removed by the wet scrubbing process. Typical hydrogen recoveries in a PSA unit are in the 80 to 90% range with product purity generally 99.9 vol %.

Because of the loss of hydrogen to the PSA tail gas, the reformer and front end of a PSA plant are larger than in a wet scrubbing plant. A PSA plant uses less process steam and does not require heat for the reboiler, this leaves additional steam available for export. Capital cost is generally lower for the design with PSA. The additional export steam can provide a strong utility cost advantage for the PSA plant in addition to its purity and operability advantages.

Hydrogen purity depends primarily on the purification method. In wet scrubbing, the major impurities are methane and nitrogen. Methane in the product is the residual left after reforming, or is formed in the methanator from residual CO or CO_2. Nitrogen in the feed is carried through the plant unchanged, although there is a dilution effect because of the larger volume of hydrogen compared to the feedstock.

In a PSA unit, most impurities can be removed to any desired level. Removal of a more difficult impurity will generally ensure virtually complete removal of easier impurities. Nitrogen is the most difficult to remove of the common impurities, and removing it completely requires additional adsorbent. The exception occurs where the hydrogen is to be used in a very high pressure system such as a hydrocracker. In that case, the extra cost for nitrogen removal is justified by the savings in hydrogen purge losses.

Composition of hydrogen product

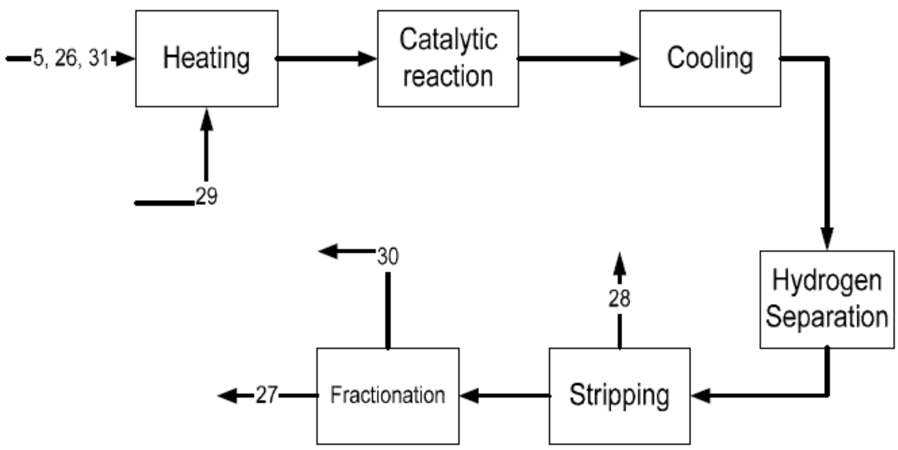
Process	Wet scrubbing	PSA
Hydrogen purity, vol %	95-97	99-99.99
Methane	2 – 4 mol %	100 vol ppm
$CO + CO_2$, vol ppm	10 – 50	10 – 50
Nitrogen, vol %	0 – 2	0.1 – 1

Impurities - Ease of removal by PSA

Easy	Moderate	Difficult	Not removed
C_3H_6	CO	O_2	H_2
C_4H_{10}	CH_4	N_2	He
C_{5+}	CO_2	Ar	
H_2S	C_2H_6		
NH_3	C_3H_8		
BTX	C_2H_4		
H_2O			

Kerosine and Diesel Hydrotreatment Units

All different licenses have nearly the same processing steps. These steps are illustrated in the following process flow diagram.



*Block flow diagram for the Diesel 1-**Error! No text of specified style in document.**Figure and Kerosine Hydrotreating unit*

There are some slight differences which are shown in the next table.

Differences between different licensors

		UOP	ABB Lummus	Axens
Catalyst used	-Highly-activity TK catalysts with optimized graded-bed loading and high-performance, patented reactor internals	- a high-surface-area base loaded with highly dispersed active metals	SynCat catalysts with two stage reactor system	HR 400 series catalysts
Main features	- High efficiency internals have a low sensitivity to unlevelness and are designed to ensure the most effective mixing of liquid and vapor streams and the maximum utilization of the catalyst volume. - Enabling high turn down ratios. -Minimum pressure drop	- Simple down flow reactors incorporating a graded bed catalyst system designed to accomplish the desired reactions while minimizing side reactions and pressure drop build up are used. - catalyst choice can be adjusted to achieve a desired improvement	-Maximum reactor performance by using advanced reactor internals	- HR 400 series catalysts cover wide range requirements with highly active and stable catalysts - Use of proven, efficient reactor internals. - Application of advanced process control for longer catalyst life

Naphtha Hydrotreatment Unit

Haldor Topsoe A/S

For more than 30 years, Haldor Topsoe A/S has been involved in the production of hydrotreating catalysts. The TK- series catalyst developed by the R&D department in Topose company are used for reduction of sulfur, nitrogen, metals in the feed with an outstanding performance. They also have proved efficiently in delaying pressure drop build-up and enable a high turn down ratios.

The high efficiency internals have a low sensitivity to unlevelness and are designed to ensure the most effective mixing of liquid and vapor streams and the maximum utilization of the catalyst volume.

Catalytic Reforming

There are many versions of the catalytic reforming process depending on the oil company that developed it. The next table shows the main advantages for two important processes:

CCR Platforming: A Platforming version, designed for continuous catalyst regeneration (CCR), developed by UOP.

Octanizing: A catalytic reforming version developed by Axens, a subsidiary of Institut Francais du Petrole (IFP), designed for continuous catalyst regeneration.

between the UOP and the Axens reforming processes

Platforming Process by UOP	Octanizing Process by Axens
1. High utilization of feed due to low operating pressure. 2. Flexibility to process a wide variety of feedstock. 3. Stacked reactors for economical design. 4. On stream factor of more than 95%. 5. Only two catalyst lifts for minimal catalyst attrition. 6. Optimized heat and compression integration for on every unit. 7. Liquid recovery optimized on every unit. 8. An elegant design that rejuvenates spent catalyst to like-fresh condition while maximizing catalyst life. 9. A safe transition between hydrocarbon and oxygen-containing equipment is automatically assured by UOP's reliable Catalyst Regeneration Control System. 10. Valveless control of catalyst flow is extremely reliable without the maintenance costs of expensive control valves. 11. Operability and reliability has steadily increased through years of improvements.	1. Long and active catalyst service 2. Ease of operation and maintenance 3. Continuous, smooth, non-pulsating and gentle lifting system to ensure low catalyst attrition. 4. The side-by-side reactor arrangement allows easy access for construction, inspection and modifications. 5. The reactor arrangement also provides shorter transfer lines between reactors and heaters and also for catalysts, which yields immediate and longer-term savings when compared to the stacked reactor design. 6. No chloride-removal equipment is required since the regeneration process discharges a clean vent gas. 7. Operating at low pressure improves the yield of reformate and hydrogen. 8. The catalyst regeneration system completely restores the catalyst activity while maintaining its specific area for more than 600 cycles.

Coker Unit

The three main suppliers of this technology are listed below.

1. FosterWheeler Delayed Coker
2. ConocoPhillips Delayed Coker
3. ABB Lummus Delayed Coker

The technologies offered by these companies are similar in terms of their environmental impacts. It is important that the selected technology licensors and process designers would take into consideration the mitigation measures to ensure the compliance with the Egyptian and international environmental laws and regulations.

Many alternatives may be used for coke disposal. Coke may be collected and sold to any cement manufacturer or iron and steel plant which are predominant at Great Cairo.

Alternatively, provided the coke can be transported to the Mediterranean coast, there is a large import of coke into Europe from North America, South America and Caribbean, and ERC should be able to attract some of this market.

If no sales outlets can be found then the alternate route is to use the coke to generate electric power. The most straightforward way of doing this is to burn the coke in a fluidized bed boiler to generate steam and then produce power in a condensing turbine. This option has been evaluated. Unfortunately, the projected power price in Egypt is low, as it is expected that the Egyptian natural gas (which has been found in large quantities), will be made available to Egyptian power companies at low cost. This means additional investment in producing power from coke is not practically attractive and would reduce the overall rate of return of the project. The power production option is not currently recommended but should be borne in mind if sales for coke proof difficult to find and/or the price of power in Egypt increases significantly.

Coke disposal alternatives

Many alternatives may be used for coke disposal.

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Sulfur Recovery Unit

Hydrogen sulfide scrubbing is a common treating process in which the hydrocarbon feedstock is first scrubbed, to prevent catalyst poisoning. Depending on the feedstock and the nature of contaminants- desulfurization methods vary from ambient temperature activated charcoal adsorption to high-temperature catalytic hydrogenation followed by zinc oxide treating.

Vacuum Distillation

In most systems, the vacuum inside the fractionator is maintained with steam ejectors and vacuum pumps, barometric condensers or surface condensers.

If barometric condensers are used in vacuum distillation, significant amounts of oily waste water can be generated.

Vacuum pumps and surface condensers have largely replaced barometric condensers in many refineries to eliminate this oily waste water stream.

Concerning vacuum residue two alternatives are considered. The first alternative considered a coker size for 50-60% of the vacuum residue so as to maintain around 1.2 MTPA fuel oil production. The second alternative deals with coking of all the vacuum residue.

Alternative -1- improves the overall project economics but the need to dispose of the coker in a site that is already quite congested presents a major drawback.

However, alternative 2 requires higher investment, thus alternative 1 is preferred after following mitigation techniques.

Vacuum Residue Alternative

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The second alternative deal with coking of all the vacuum residue.

According to alternative 1 improve the overall project economics but the need to dispose of the coke produced and the high plot space required for a coker in a site that is already quite congested present major drawbacks.

And alternative 2 required higher investment.

So alternative 1 was preferred after following the mitigation techniques.

Waste Water Treatment Plant

Physical treatment may include:

- The use of a series of settling ponds with a long retention time.
- The use of dissolved air flotation (DAF) in which air is bubbled through waste water, and both oil or suspended solids are skimmed off the top.
- Use of chemicals such as ferric oxide or Al hydroxide to coagulate impurities into a froth or sludge which can be more easily skimmed of the top.

Comparison Between Alternatives from Environmental Standpoint

The ERC complex is designed to minimize releases to the environment, efficiently utilize energy, materials and resources to meet industrial best practices and IFC requirements. The various alternatives are compared with selected alternative from the point of view of environmental aspects.

1- Concerning octane number inhencing techniques, the alternative of using the conventional older refineries technology that uses lead compounds as an octane number enhancer and generate hazardous waste streams of lead sludge from tank bottoms. This technology will be eliminated and a reformate will be used to produce aromatics such as benzene and toluene, which will be blended with produced gasoline to enhance octane value. As a result no hazardous waste will be generated.

2- The ERC flare height is designed to promote proper air dispersion keeping in line with IFC requirements.

3- The ERC Axens project will generate the least catalyst wastes (4 years) compared to UOP technology.

4- Hot separators will be provided for ERC project improving performance and energy efficiency as well as preventing fouling compared to UOP process.

5- The ERC project will generate minimum solid waste from organic nitrogen compared to Chevron process.

6- The ERC storage tanks will be designed with additional internal floating roofs for bulk storage of volatile liquids such as jet fuel and gasoline to prevent excessive emissions, compared to normal floating roof tanks used in other technologies.

   Other relatively less volatile liquids such as diesel oil will be stored in fixed roof tanks with conservation vents.

   Based on published literature on emission controls provided by floating roof tanks and conservation vents, it is expected that emissions of volatile organic compounds to the environment are minimized up to 75%.

7- ERC project will use burners capable of firing multiple fuels and will be of low NO_x design compared to the single fuel burners of the other alternatives.

8- Concerning the Hydrogen Plant Production, ERC uses steam reforming combined with pressure swing absorption rather than partial oxidation to reduce emission of carbon oxides and carbon dust.

13.1.1. Design Alternatives from Social Standpoint

The following alternatives have been considered for minimizing social and health impacts to the local communities:

- As previously mentioned in the process description, the raw material used is a distillation fraction obtained from atmospheric distillation of crude petroleum. In case of the selection of any other site than Mostorod, the transfer of the raw material to the plant will affect people negatively and may require large resettlement plans and the use of areas of agricultural land.

  ERC is considering to reduce the requirements from agricultural land and houses through the use of existing industrial area in Mostorod.

- Because of their relative high population and low income, as well as the high percentage of unemployment, Mostorod will be preferred to any other new city. The component of labor force is maximized in the weight score selection method, so Mostorod will add positive impact on the majority of the community.
- Among the many alternatives available for extending project benefits to the social communities, the three alternatives will be accompanied with implementation of CDP which depends on the location. But the most promising benefit will be that of Mostorod site due to improverished conditions of this location.