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MANGALORE REFINERY & PETROCHEMICALS LTD

Technical Prefeasibility Report for BS V/VI Autofuel Quality Compliance & Associated projects

EXPANSION & REVAMP STUDIES GROUP
PROCESS ENGINEERING
TECHNICAL SERVICES

PRE FEASIBILITY REPORT

LIST OF ABBREVIATIONS

ACRONYM	EXPANSION
ATF	Aviation Turbine Fuel
CDU	Crude Distillation Unit
CPP	Captive Power Plant
DCU	Delayed Coker Unit
DHT	Diesel Hydrotreater
EPCM	Engineering Procurement Construction Management
FCCU	Fluid Catalytic Cracking Units
FO	Fuel Oil
GOHDS	Gas Oil Hydrodesulphurizer
HCU	Hydro Cracker Unit
HGU	Hydrogen Generating Unit
HSD	High Speed Diesel
LSHS	Low Sulphur Heavy Stock
KTPA	Kilo Tonnes Per Annum
MMTPA	Million Metric Tonnes Per Annum
MRPL	Mangalore Refinery & Petrochemicals Limited
MS	Motor Spirit
NSU	Naphtha Splitter Unit
ONGC	Oil and Natural Gas Corporation
PRU	Propylene Recovery Utility
VBU	Visbreaker Unit
VDU	Vacuum Distillation Unit
VGO	Vacuum Gas Oil
VGO HDT	Vacuum Gas Oil Hydrotreater
SDA	Solvent DeAsphalting
SKO	Superior Kerosene Oil
SRU	Sulphur Recovery Unit
TPA	Tonnes Per Annum
TPD	Tonnes Per Day

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1. Executive Summary

1.1 Mangalore Refinery & Petrochemicals Limited (MRPL), a subsidiary of Oil & Natural Gas Corporation (ONGC) proposes to produce products that comply with BS V/VI specifications. Post Phase III complex commissioning MRPL is in a position to produce BS III and IV compliance MS and HSD. "Auto-fuel Vision and Policy (2014)" report by Expert Committee (chaired by Shri. Saumitra Chaudhuri) submitted to The Government of India outlines specifications and tentative schedule for the nation to switch over to BS V/VI.

In view of the nation switching over to BS V/VI fuel specifications in 2019-20, MRPL intends to explore possibilities for new process units/up gradation of existing process units to comply with the specifications. Also, MS demand in the nation is increasing year-on-year with CAGR more than 10% and so it may be prudent for MRPL to look at boosting of its MS production potential. Based on the above requirement, this Technical PFR evaluated the following for MRPL:

1. Treatment/Upgradation/Augmentation facilities for MS& HSD to comply with BS V/VI specifications
2. Other debottlenecking/operational flexibility improvement projects in the refinery complex

The aforesaid facilities are to be designed for processing low cost, high sulphur & heavier crude such as Arab Heavy.

1.2 MRPL has decided to prepare a Technical Pre-Feasibility Report (Technical PFR) to access the technical feasibility, in-house, based on the aforesaid feedstock and objectives. This report pertains to technical study covering briefly project location, configuration, project description and product slate to enable MRPL prove technical feasibility, take necessary clearances and approvals. Subject to technical pre- feasibility, MRPL will consider hiring an expert external consultant to carry out detailed techno-economic configuration study. The financials and land requirement study are excluded from the study scope.

1.3 Crude Basis: Arab Heavy crude is considered as the basis crude. The typical distillation yield of the crude for 15 MMTPA capacity is as per Table 1 below:

Table 1: Typical distillation yield of 15 MMTPA Arab Heavy crude

STRAIGHT RUN STREAM	QUANTITY, KTPA	WT %
OFF GAS	4	0.03
ST RUN LPG	220	1.5
LIGHT NAPTHA (C5 - 90)	730	4.9
MIDDLE NAPHTHA(90 -110)	272	1.8
HEAVY NAPHTHA (110 - 145)	661	4.4
KERO (145 - 240)	1868	12.5
GAS OIL (240-360)	2605	17.4
VACUUM GAS OIL (360-550)	3830	25.5
SHORT RESIDUE (550+)	4812	32.1
TOTAL	**15000**	**100.0**

1.4 Capacity Basis: The existing capacity of 15 MMTPA refinery with Phase I, II & III complexes is considered as the basis for capacity. Aromatic complex, which is the subsidiary of MRPL is excluded from the study and hence from the capacity basis. However, the streams exchanged between the refinery and the aromatic complex are shown in the refinery complexes' material balance as feed and products.

1.5 Objectives for study:

The following objectives were identified and defined for the prefeasibility study:

1.5.1 BS V/VI specifications: The objective is to study and identify technically suitable refinery configuration for the auto fuel products (MS&HSD) to comply/boost BS V/VI specifications while processing 15 MMTPA of Arab Heavy crude. The adequacy of existing process units, units to be revamped/modified/augmented to comply with BS V/VI specifications will be brought out.

1.5.2 Debottlenecking/Operational Flexibility improvement projects: The objective is to revamp/augment units in order to debottleneck/ improve operational flexibility.

1.6 Configuration and capacities: The Technical PFR study was carried out with the objectives mentioned above and the resultant configuration were presented below:

1.6.1 BSV/VI Compliance Projects:

a) A new feed preparation unit (FPU) of PFCC to reduce sulphur from its MS product. The FPU will give an added benefit of reducing sulphur in HSD streams also.

b) New selective desulphurization of gasoline from PFCC unit and a new MS upgradation unit from other hydrocarbons to attain sulphur levels less than 7 ppmw in the total MS pool

c) Sour Water Stripper Units revamp to accommodate the incremental sour water generated from the deep hydroprocessing in the revamped/new units.

d) Revamp of one of the Hydrogen generation units to offer operation flexibility for sustained meeting of the incremental hydrogen demand from hydroprocessors for meeting BS V / VI specifications.

e) New Sulphur Recovery Unit to recover sulphur from additional H_2S generated

f) New tankages and allied facilities along with new pipeline to New Mangalore Port to enable contamination-free delivery of BS V/VI grade auto fuels

g) ETP revamp for additional effluents generated, if necessary.

h) Offsite and infrastructure facilities including logistics support is required to handle the treated products. The facilities needed are to be finalized during detailed engineering.

1.6.2 Debottlenecking/Operational Flexibility Improvement Projects:

a) Revamp of CCR II unit along with reformate splitter unit to increase aromatic streams production

b) Revamp of CCR I unit to increase aromatic streams production

c) New splitting unit to split the full range naphtha generated at various hydrotreaters and or imported full range naphtha/reformate.

d) DHDT revamp in the downstream of reactor circuit to provide more hydraulics for treated naphtha.

e) Infrastructure to import power form grid.

f) Reduction of existing Phase III flare load by suitable flare gas recovery, diverting top one or two hydrocarbon flaring process units while depressurization during emergencies to a new flare along with modification of associated facilities or relocating the existing flare to a less prominent location.

2. Objective and Background

Mangalore Refinery & petrochemicals limited (MRPL), a subsidiary of Oil & Natural Gas Corporation (ONGC) is in process of expanding its existing facilities to meet BS V/VI specifications for its MS and HSD products.

MRPL is interesting in the following objectives of upgradation are as follows:

- Treatment facilities for MS & HSD to comply with/boost BS V/VI specifications for MS & HSD
- Revamp/augment units in order to debottleneck/ improve operational flexibility

MRPL developed the Technical Pre-Feasibility Report in-house after carrying out studies in line with the above objectives.

2.1 Switching over to BS V/VI specifications

Further, based on current directives and reviews being taken by MOP & NG, the entire country has to move towards meeting BS V/VI / BS V/VII quality specifications for MS &HSD by year 1-4-2020 (Products from Refinery complex are expected to meet the stipulated quality from January 2020 onwards).Also, MS demand in the nation is increasing year-on-year with CAGR more than 10% and MRPL, currently, is unable to meet the domestic demand of MS of the nation. Hence it is high time for MRPL to boost it's the MS production potential. The major specifications of BS III, BS IV &BS V/VI grade MS & HSD are given in Table 2 and Table 4 below.

Table 2: MS Product Specifications (Major)-Basis Auto Fuel Policy Report

S.no	Key Qualities	Unit	BS III MS	BS IV MS	BS V/VI MS
1	Sulphur	ppmwt	150	50	10
2	RON	Min	91	91	91
3	Density	kg/m^3	720 –775	720 –775	720 –775
4	Benzene, Max	% Vol	1	1	1
5	Aromatics, Max	% Vol	42	35	35
6	Olefins, Max	% Vol	21	21	21

As per Auto Fuel policy, the following is envisaged / stipulated for production / supply of BS IV grade MS & HSD, the details of roll out plans are as in Table 3 below

Table 3: BS IV / BSV HSD / MS Roll out Plans

S No	Proposed Year of product specification implementation	States where the specifications are to be implemented
1	BS IV – 01-04-2015 (MS & HSD)	The whole of Northern India covering Jammu & Kashmir, (except Leh/Kargil18), Punjab, Haryana, Himachal Pradesh, Uttarakhand, Delhi and the bordering districts in Rajasthan and Western Uttar Pradesh.
2	BS IV – 01-04-2016 (MS & HSD)	All of Goa will be covered. All of Kerala, Karnataka, Telangana, Odisha, and the Union Territories of Daman & Diu, Dadra-Nagar-Haveli and Andaman & Nicobar. Parts of Maharashtra (Mumbai, Thane and Pune districts) will be covered. Parts of Gujarat (Surat, Valsad, Dangs and Tapi districts) will also be converted. In addition a corridor spanning the highway link through Gujarat and Rajasthan linking Northern India to the ports on the West Coast will also be sought to be covered.
3	BS IV – 01-04-2017 (MS & HSD)	The rest of the country
4	BS V/VI / BS V/VII – 2019-20	Entire country

Table 4: HSD Product Specifications (Major)- Basis Auto Fuel Policy Report

S.no	Attribute	Unit	BS III HSD	BS IV HSD	BS V/VI HSD
1	Sulphur	ppmwt	350	50	10
2	Flash point, Abel, Min	°C	35°	35°	42°
3	Density	kg/m^3	820-845	820-845	820-845
4	Cetane Number	Min	51	51	51
5	Viscosity @ 40 ° C	CSt	2.0-4.5	2.0-4.5	2.0-4.5

The main changes from BS IV specifications are:

- Reduction in sulphur to 10ppm for both MS and HSD which would need desulphurisation.
- Increase in Flash point of HSD to 42°C, reducing the amount of Heavy Naphtha / Kerosene which otherwise is accommodated in HSD currently.

2.2 Debottlenecking/Operational Flexibility Improvement

The objectives of following facilities need to be debottlenecked in MRPL:

2.2.1 MRPL needs to increase aromatic streams production to improve the total BS V/VI potential in MRPL and/or to supply additional aromatic streams as feed to the aromatic complex.

2.2.2 Capacity for treating olefinic naphtha such as paraffinic raffinate from aromatic complex, delayed coker heavy naphtha etc is required in MRPL to improve the operational flexibility.

The objectives of facilities to be augmented in MRPL are:

2.2.3 To split the full range naphtha generated at various hydrotreaters and/or imported full range naphtha/reformate. This will enable MRPL to derive more value from captive or imported full range naphtha streams by upgrading to aromatic streams via catalytic reforming to either MS pool or as feed to aromatic complex.

2.2.4 Infrastructure to meet the additional power demand from new or revamped units mentioned above. Otherwise MRPL has to run all the existing machines in the captive power plant giving no room for maintenance of the captive power plant machines and the reliability of the machines has to be 100%. This will curb the operational flexibility and reliability.

2.2.5 Facility to mitigate the high noise level issue from the Phase III complex's flare during any Phase III refinery complex wide emergencies where depressurization of hydrocarbons from almost all units is flared.

3. MRPL - Present MS & HSD Capability

3.1 MS Capability

The average MS domestic production for the last five years on an average is 913 TMT/ year. Currently, offtake from MRPL is an average about 70 – 75 TMT / month (840 – 900 TMT / year) of MS meeting BS III and BS IV specifications. The average MS offtake during the last two financial years is 882 TMT with BS IV accounting for 14 % and balance was BS III. MRPL refinery is capable of producing MS meeting BS IV specifications. Based on in-house estimates the MS quantity available would be about 800 TMT – 900 TMT. At 15 Million TPA throughput, the MS streams from refinery that requires further treatment to meet BS V/VI specifications are given in Table 5 below.

Table 5 : Current and Future Hardware to meet MS product quality

Stream	MS BS IV (KTPA)	Requirement of BS V/VI Hardware (KTPA)
Reformate streams (A7 & A9)	250-275	Existing is adequate
Isomerate (Light & Heavy)	400-437	Existing is adequate
PFCC Light gasoline	70-110	Units for reduction in S required
PFCC Middle Naphtha	74	
HCU LN or Mixed Pentanes	4-6	Existing is adequate
TOTAL MS BS IV Streams	**800-900**	

About 208 – 278 KTPA of reformate streams from CCR I & II is considered as Aromatic Complex feedstock and 55 – 60 KTPA considered towards MS Mauritius grade blending in the table above. Reformate streams quantity shown in the table above is after deducting the aforesaid aromatic complex feedstock and MS Mauritius grade blending quantities.

PFCC LN quantity shown in the table above is the blend-able range in MS BS IV grade. About 30 to 35 KTPA is considered to be blended in MS Mauritius grade. Absorption into MS BS IV grade is limited by benzene, RVP, olefins and VLI specifications. Incremental production to be routed to DHDT (~ 39 to 153 KTPA)

PFCC MN quantity shown in the table above is a about 35-50% of production potential in PFCC. About 35 to 40 KTPA is considered to be blended in MS Mauritius grade. Incremental production is considered to be routed to aromatic complex as feed stock (~ 53 to 95 KTPA)

The following alternatives are available to meet MS BS V/VI specification:

- ✓ Unit for reducing the sulphur in PFCC gasoline streams to less than 7 ppmw.
- ✓ To study the option by utilizing PFCC unit & DCU unit LPG stream and produce MS blend streams to increase the MS production from the refinery while meeting the aromatic complex feed stock

3.2 HSD Capability

At 15 MMTPA refining capacity, the production of HSD and available treatment facilities in MRPL are as follows:

Table 6 : SKO + HSD production potential from MRPL

Stream	Quantity, MMTPA
SKO + ATF from CDUs	1.95 - 2.25
Gas oil from CDUs	3.25 – 3.75
Gas oil from DCU & PFCC	1.10 – 1.30
SKO from HCUs	0.60 – 0.75
HSD from HCUs	0.80 – 1.15
Blending stream (PFCC Bottom Naphtha)	0.20 – 0.25
TOTAL SKO +HSD	**7.85 – 9.30**

Range is provided considering the type of crude and mode of operation of HCUs. MRPL can convert the entire volume of HSD supplied from the Refinery within the country to BS IV (about 85% of the total HSD potential from MRPL). Diesel Hydrotreater (DHDT - 3.5 MMTPA) and Gas Oil Hydrodesulphuriser (GOHDS - 1.7 MMTPA) can produce HSD of 35 – 50 ppmw. Hydrocracker (HCU) can produce about 1.4 MMTPA of about 12 ppmw HSD.

For achieving the entire HSD + SKO pool of BS IV sulphur specification, revamping / providing additional hydrotreating hardware for about 1 Million Tonnes may be required. Further any incremental gas oil produced beyond 15 MMTPA, existing hydrotreaters capacity would not be adequate.

Current treatment facilities and streams which meet BS IV and which may need treatment for meeting BS V/VI are as follows:

Table 7 : Current and Future Hardware to meet HSD product quality

Product/Stream	Available Feed / stream, MMTPA	BS IV HSD Hardware Available, MMTPA
HSD HSD(MAU) HSD (EXP) Unfulfilled HSD Potential	4.20-4.50 0.30-0.35 0.75-1.20 0.70-0.25	HCU 1&2 – 1.4 DHDT - 3.5 GOHDS - 1.70
Sub – Total	5.95 – 6.30	6.60
HSD blend from SKO-ATF	~1 max from 1.95- 2.2	-
TOTAL HSD Stream	**6.95 – 7.30**	**6.60**

4. Basis of the Study

The technical prefeasibility for BS V/VI compliance and capacity expansion are studied with the crude feedstock and key unit capacities basis as depicted in this section.

4.1 Crude Basis

MRPL currently have the capability to process crudes varying between 22 to 48 API. The basis crude for expansion studies to be reasonably high in sulphur, heavy in yield and to be openly traded in the international market with reasonable risk-free availability option to MRPL. Considering aforesaid points, Arab Heavy crude is considered as the basis crude for both expansion and compliance studies. The typical distillation yield of Arab Heavy crude for 15 MMTPA capacity is as follows:

STRAIGHT RUN STREAM	QUANTITY, KTPA	WT %
OFF GAS	4	0.03
ST RUN LPG	220	1.5
LIGHT NAPTHA (C5 - 90)	730	4.9
MIDDLE NAPHTHA(90 -110)	272	1.8
HEAVY NAPHTHA (110 - 145)	661	4.4
KERO (145 - 240)	1868	12.5
GAS OIL (240-360)	2605	17.4
VACUUM GAS OIL (360-550)	3830	25.5
SHORT RESIDUE (550+)	4812	32.1
TOTAL	**15000**	**100.0**

4.2 Capacity Basis

The existing capacities of key units designed/consistently operated for 15 MMTPA refineries with Phase I, II & III complexes are considered as the basis for capacity. Aromatic complex, which is the subsidiary of MRPL is excluded from the study and hence in the capacity basis. However, the streams exchanged between the Refinery and the aromatic complex was shown in the refinery complexes' material balance as feed and products. The capacity basis considered for existing key units are given in Table 8below.

Table 8 : Capacity basis considered for existing key units

S.NO	UNIT	CAPACITY (KTPA)	CAPACITY (TPD)	CAPACITY (m^3/h)
1	CDU 1	4800	14400	675
2	CDU 2	7200	21600	1013
3	CDU 3	3000	9000	422
4	HGU 1	30	90	42030
5	HGU 2	30	90	42030
6	HGU 3	67	200	93401
7	LIGHT NAPHTHA HYDROTRAETER/PENEX*	690/493*	2070/1480*	126/90*
8	NHT/CCR 1	465	1395	78
9	NHT/CCR 2	465	1395	78
10	RSU	804	2413	123
11	MXU	729	2188	106
12	GOHDS	1758	5273	260
13 A	DHDT NAPHTHA SECTION	230	690	44
13 B	DHDT KERO + GAS OIL SECTION	3470	10410	520
14	HCU 1	1600	4800	217
15	HCU 2	1700	5100	231
16	CHT	650	1950	85
17	PFCCU	2200	6600	313
18	PPU	440	1320	100
19	DCU	3000	9000	365
20	BBU	82	245	10
21	SRU Ph 1, 2 &3	290	870	
22	CPP 1/2 (MW)	115.5		
23	STG PH 3(MW)	52		
24	FRAME V GTG PH 3 (MW)	25		
25	FRAME VI GTG PH 3 (MW)	37		

*On fresh feed basis

5. Scope of the Study & Exclusions

The scope of the current study is to analyze the capacity adequacy of the existing units for complying with BS V/VI auto-fuels and to estimate the extent of revamp/capacity augmentation required along with the kind of new process technology requirement in case of capacity inadequacy/debottlenecking/operational flexibility requirement in line with the objective of the study.

The cost, financials, land and manpower estimation etc are excluded from the scope of the current study.

6. Configuration Studies

As discussed in earlier sections, MRPL intends to explore the following objectives of upgradation:

- Treatment facilities for MS & HSD to comply with BS V/VI specifications for MS & HSD
- Revamp/augment units in order to debottleneck/ improve operational flexibility.

The study to cover refinery configuration required to process 15 MMTPA of Arab Heavy crude and the auto fuel products to comply with BS V/VI specifications. The capacity adequacy of existing process units along with units that can be revamped or modified and new process units to meet the objectives mentioned above will be brought out. The approach followed in this study is the bottoms up approach wherein mass balance along with treatment adequacy is carried out from the bottoms (short residue) till the lighters (Gas) in the sections below. Mass balance of each straight run stream from the primary processing crude distillation is assessed from the bottom up and then the treatment unit adequacy of the process units along with utility treatment units to meet the aforesaid objectives are assessed.

6.1. Short Residue (SR) (550 ºC+ cut): SR balance for 15 MMTPA capacity carried out as per basis mentioned in Section 4 above and is attached as Annexure 2. Evidently, at for heavy crudes with around 32 wt% SR yield of around 4800 KTPA will be excess generated. After discounting SR for internal fuel oil and Mauritius grade fuel oil, it can be inferred from Annexure 2 that SR will be available beyond the delayed coker capacity. Therefore, one of the visbreakers has to be operated to handle the additional short residue and MRPL hence may have to export fuel oil to the tune of 645 KTPA. The existing Short Residue& fuel oil storage facilities may not be sufficient and may hinder MRPL complex's BS V/VI grads auto fuels switch over. Additional storage tank/s would be required to handle the SR / fuel oil produced considering all the three crude units operating on Arab Heavy crude.

6.2. Vacuum Gas Oil (VGO) (360º - 550ºC cut) stream's mass balance is presented as Annexure 3. The mass balance considers both the existing hydrocrackers to run at once through mode of operation. From the annexure, it is clear that about 361 KTPA of VGO will be excess than the Hydrocrackers (HCUs) treatment capacity in MRPL complex. PFCC will have spare capacity to crunch this SR VGO but a feed pretreatment units need to be augmented in order to reduce the VGO sulphur as the PFCC design sulphur is about 900 ppmw. The new facility has to be sized for 2000 KTPA so that PFCC can be sustained even the HCUs are shutdown.

6.3. Gas Oil (240° - 360° C cut) stream's mass balance is given as Annexure 4 and Kero (150° - 240° C cut) stream's mass balance is given as Annexure 5. As the Gas Oil Hydrodesulphuriser (GOHDS) is designed to produce < 40 ppmwt S, the unit may have to be rerated for a lower capacity (high reactor LSHV) to produce < 10 ppmwt S product (BS V/VI HSD S sulphur spec). It is assumed that the unit will be rerated from 1750 KTPA to 1015 KTPA with changeover to new generation catalyst that can produce less than 10 ppmwt S diesel, however the aspect needs further focus and investigation and will be known during detailed feasibility. From Annexure 4, it can be understood that only 510 KTPA straight run kero stream can be accommodated for treatment and absorption in BS V/VI HSD. This is despite the fact that the cetane and flash point specifications give room to absorb about 1000 KTPA of kero into diesel pool.

6.4. Also, it is prudent to note that there are no treatment units designed in MRPL complex to handle olefinic naphtha from Delayed Coker and PFCCU other than DHDT. Currently the olefinic heavy naphtha from DCU and PFCCU are considered as feedstock for aromatic complex and there is no other avenue for this olefinic naphtha during annual turndown of the aromatic complex. Also, the paraffinic raffinate return stream from aromatic complex is rich in olefins (~8 vol%) and can be treated only in the Hydrogen Generation Unit of Phase III (HGU III). With change in feed quality and higher throughputs, the paraffinic raffinate stream is excess than HGU III capacity. The said olefinic naphtha streams cannot be blended in open spec naphtha or Motor Spirit due to olefin and RON constraints respectively. Therefore, it is worthwhile to revamp DHDT unit to enable processing/handling of additional olefinic naphtha and thereby bring in operational flexibility in the refinery complex. All the aforesaid olefinic naphtha may not be excess simultaneously and hence a judicious hydraulic naphtha handling capacity downstream of DHDT reactor section needs to be created by revamping. The design case for naphtha circuit revamp in DHDT may be as per the Table 9 below:

Table 9 : Capacity basis assumed for DHDT revamp

S.No	Naphtha streams to DHDT	Design Quantity, m³/h	Additional Quantity, m³/h
1.	PFCC Heavy Naphtha	-	33
2.	PFCC Light Naphtha	20	-
3.	DCU Heavy Naphtha	-	28
4.	Raffinate stream from Aromatic Complex	-	12
5.	DCU Light Naphtha	24	-

To summarize, the existing diesel treatment infrastructure is adequate to upgrade all the gas oil to BS V/VI grades, however kero absorption infrastructure is limited to 510 KTPA only. Minor revamp in the downstream of reactor circuit is required in DHDT, to bring in operational facility.

6.5. Naphtha material balance for 15 MMTPA crude refining capacity with the basis assumed in the study is depicted in Annexure 5. To boost the BS V/VI MS and aromatic streams production capability, revamp of both the Continuous Catalytic Reforming (CCR/Platforming) units are proposed. The revamped capacity of the units shall be 90 m3/h each. Import of heavy naphtha is required to saturate the revamped CCR capacities, as the design basis heavy crude (Arab Heavy) does not yield much heavy naphtha. However, in actual operation MRPL may procure more naphtha bearing crudes/condensate depending on the economics and therefore the CCR units have to be revamped. With revamp of the CCR units, its downstream PSA and Reformate Splitting Unit (RSU) are also to be revamped for matching capacity. Also, PFCC full range gasoline has sulphur more than 40 ppmw and superior octane number characteristics. While their octane number can be attributed to high olefin and aromatic content, hydrotreatment of PFCC gasoline streams' to remove sulphur may prove detrimental to octane number. Therefore, a new selective desulphurization unit needs to be installed, as the technology will selectively desulphurize with minimum octane number reduction and will help in the absorption of FCC gasoline streams to BS V/VI grade MS.

6.6. Also, there are full range low sulphur naphtha generated in hydrotreaters like CHT, and DHDT. These full range naphtha streams can be to be split in order to maximize 90□ – 150□C cut feed to Aromatic complex and/or blending to BS V/VI HSD product pool. Hence a new naphtha splitter of about 680 KTPA is required. The splitter column shall also be designed to operate in dual mode in order to enable batch import naphtha or reformate splitting. Strategically, this will help in operation of MS/aromatic streams generation units during turnaround of crude units/processing heavy crudes etc. Annexure 6 details out the naphtha material balance as discussed above. In summary, new selective desulphurization unit of PFCC gasoline is required for the stream to be upgraded to BS V/VI MS and the existing CCRs along with RSUs are to be revamped along with installation of new dual mode splitters are required for boosting the aromatic streams production.

6.7. LPG material balance for 15 MMTPA capacity as per the basis mentioned above is outlined in Annexure 7. As MRPL complex intends to comply with and boost its BS V/VI MS make capability, a new conversion unit which can convert olefinic C4= into BS V/VI MS blend stock or any other similar suitable conversion technology facility using a suitable hydrocarbon stream as feed to produce BS V/VI is proposed to be installed. Summing up, a new conversion facility for MS blend stock production using a suitable technology and hydrocarbon stream is required for boosting the BS V/VI MS production in MRPL complex.

6.8. Incremental hydrogen is required for deep hydrotreatment to ultra low sulphur levels of less than 10 ppmw and also for hydroprocessing in new/revamped units. Annexure 8 depicts the hydrogen balance for the 15 MMTPA BS V/VI MRPL complex. From the annexure, though it is clear that existing Hydrogen Generation Units are sufficient to cater the incremental demand from hydroprocessors, it is of paramount importance to revamp both HGU I and II in order to boost the hydrogen supply and prevent overall complex shutdown if HGU III goes for annual turn around. To summarize, the existing hydrogen generation infrastructure is adequate to meet the demand of hydroprocessors post-BS V/VI upgradation, however to ensure operational flexibility it is proposed to revamp both HGU I and HGU II units to produce hydrogen of 150 TPD more.

6.9. At 15 MMTPA BS V/VI compliant MRPL complex, the adequacy of sulphur recovery units to handle additional H2S load generated due to additional crude processing and deep desulphurization to less than 10 ppmw S levels is checked. Annexure 9 details out the sulphur balance of the same and it is observed that a new Sulphur Recovery Unit capacity of about 185 TPD is required to recover sulphur from sour gases/water considering the fact that one of the installed SRUs will be always down for maintenance. Also the two stage sour water strippers from which the H2S from HCU I and HCU II is stripped needs to be revamped for higher loads. The capacity revamp intent is as per Table 10 below:

Table 10: Capacity revamp intent for SWS unit

S.No	Unit	Design Quantity, MT/h	Revamp capacity intent, MT/h
1.	HCU I Sour Water Stripper	16.3	27
2.	HCU II Sour Water Stripper	28.35	45

6.10. The power and steam requirement of units for the proposed configuration are depicted in Annexure 10. It can be observed that, the existing power plant machines are sufficient to generate and meet the power demand of the BS V/VI compliant complex. However, it is to be noted that all the available machines needs to be loaded more than the current level of operations and are to be operated on a continuous basis in order to cater the power and steam demand. In order to ensure reliability and sustained operation, it is recommended to install 220 KV grid power import infrastructure. Strategically, it is worthwhile to size the power import infrastructure for 150 MW so that the refinery complex can smoothly sail through any emergency power blackout situation in Captive Power Plants.

6.11. Logistics & Tankages: Based on the logistics adequacy for the product slate in Annexure 11, the storage tanks are to be installed additionally are given in Table 11 below

Table 11 : New tanks required

S.No	Product	Capacity (m^3)	Dimensions (Dia in m X height in m)	Type
1.	HSD	4 X 30000	46.2 X 20	External Floating Roof
2.	HSD	1 X 39250	52 X 20	External Floating Roof
3.	ATF	1 x 33700	51 x 20	Internal Floating Roof
4.	FO	2 x 32100	47 x 20	Fixed Roof

Along with the above allied infrastructure such as pumps and manifold for circulation, internal transfer, MBPL transfer connection, Coastal Terminal connection etc will be required. The numbers, connection and capacity etc will be known after carrying out a detailed feasibility study.

6.12. Also, to prevent BS V/VI HSD contamination with other high sulphur HSD grades it is proposed to install a new costal terminal pipeline identical in size & pumping capacity to the existing HSD pipeline facility is required. To summarize, logistically 8 new tanks and a new pipeline to coastal terminal will be required to handle the upgraded BS V/VI compliant MRPL's logistics.

6.13. ETP: Effluent generation levels can be ascertained only if the types of the process technology of the proposed units above are known. Prima Facie, effluent from the units is expected to increase after upgradation to BS V/VI as new units and revamp of existing units are carried out. Hence, revamp of ETP I and/or is expected. The ETP to be revamped, details and extent of revamp can be assessed during the detailed feasibility study.

6.14. During power or any such emergencies where depressurization of hydrocarbons from almost all units are vented to the Phase III complex's flare, high noise levels have been observed. Therefore it is also proposed to carry out any of the following after due detailed feasibility study:

6.14.1. Reduction of existing Phase III flare load by installing a suitable flare gas recovery unit

6.14.2. Reduction of existing Phase III flare load by diverting top one or two hydrocarbon flaring process units while depressurization during emergencies to a new flare along with modification of associated facilities and/or

6.14.3. Relocating the existing flare to a less prominent location.

For the upgraded refinery complex, the overall material balance is detailed in Annexure 11. Annexure 12 depicts the estimated SOx emission post expansion and Annexure 13 details Block Flow diagram of the proposed BS V/VI compliant 15 MMTPA MRPL Refinery Complex.

7. Summary

The new process units and revamp of existing units that were identified at the outcome of the study is summarized as follows:

7.1. BSV/VI Compliance Projects

7.1.1. A new feed preparation unit of PFCC to reduce sulphur from its MS product

7.1.2. New selective desulphurization of gasoline from PFCC and a new MS upgradation unit from other hydrocarbons to attain sulphur levels less than 7 ppmw in the total MS pool

7.1.3. Sour Water Stripper Units revamp to accommodate the incremental sour water generated from the deep hydroprocessing in the revamped/new units.

7.1.4. Revamp of one of the Hydrogen generation units to offer operation flexibility for sustained meeting of the incremental hydrogen demand from hydroprocessors

7.1.5. New Sulphur Recovery Unit to recover sulphur from additional H2S generated

7.1.6. New tankages and allied facilities along with new pipeline to coastal terminal to enable contamination-free delivery of BS V/VI grade auto fuels

7.1.7. ETP revamp for additional effluents generated, if necessary

7.1.8. Offsite and infrastructure facilities including logistics support is required to handle the treated products. The facilities needed are to be finalized during detailed engineering.

Table 12 below outlines the BS V/VI autofuels compliance with capacity details:

Table 12: BS V/VI Compliance Projects

NEW/ REVAMPED PROCESS UNIT	REVAMPED / NEW CAPACITY, KTPA	REMARKS
NEW FEED PREPARATION UNIT FOR PFCC UNIT	2000	New unit TO reduce sulphur from PFCC's MS product stream
NEW SELECTIVE DESULPHURIZATION OF GASOLINE FROM PFCC	400	To attain sulphur levels less than 7 ppmw
NEW UNIT TO PRODUCE BSV/VI GRADE GASOLINE	590	New unit to comply with & boost MS BS V/VI production
HCU I & II SOUR WATER STRIPPERS (SWS) REVAMP	216 & 360 KTPA	Revamp of HCU I & II SWS to handle incremental sour water generated in the units from

		16.3 & 28.35 TPH of design to 27 and 45 TPH
SULPHUR RECOVERY UNIT	185 TPD	Handles incremental H_2S load due to deep hydrotreating
HGU I & II REVAMP	120 TPD & 120 TPD	Revamp to cater hydrogen incase one of the other hydrogen units are down (operational flexibility)
TANKAGES (NEW)	8	To handle segregated ULHSD, backed out ATF from HSD pool and additional FO generated
PIPELINE TO NEW MANGALORE PORT (NEW)	1	To prevent BS V/VI HSD pipeline contamination
ETP REVAMP	TO BE ASCERTAINED	
OFFSITE AND INFRASTRUCTURE FACILITIES		Appropriate offsite facilities including logistics support to be finalised during detailed engineering

7.2. **Debottlenecking/Operational Flexibility Improvement Projects:**

7.2.1. Revamp of CCR I and II units along with matching capacity for downstream reformate splitting unit to increase aromatic streams production.

7.2.2. New splitting unit to split the full range naphtha generated at various hydrotreaters and or imported full range naphtha/reformate.

7.2.3. DHDT revamp in the downstream of reactor circuit to provide more hydraulics for treated naphtha.

7.2.4. Infrastructure to import power form grid.

7.2.5. Reduction of existing Phase III flare load by suitable flare gas recovery, diverting top one or two hydrocarbon flaring process units while depressurization during emergencies to a new flare along with modification of associated facilities or relocating the existing flare to a less prominent location.

Table 13 below outlines the BS V/VI auto fuels compliance with capacity details.

Table 13: Debottlenecking/Operational Flexibility Improvement Projects:

NEW/ REVAMPED PROCESS UNIT	REVAMPED / NEW CAPACITY, KTPA	REMARKS
CCR -1 REVAMP	536	Revamp of the unit to comply with & boost MS V production
CCR -2 REVAMP	536	Revamp of the unit to comply with & boost MS V production
RSU REVAMP	1020	145 m3/h is the expected matching capacity for reformate generated from revamped CCR II & I
NAPHTHA SPLITTER UNIT (NEW)	681	Splitter for combined full range naphtha from hydrotreaters & imports
POWER IMPORT INFRASTRUCTURE	150 MW	In order to ensure reliability as all the available machines in CPP III has to be operated in BS V compliant complex
DHDT REVAMP	3852	Debottleneck naphtha section downstream of the reactor to handle 382 KTPA (73 m^3/h) against 230 KTPA (44 m^3/h) as per original design. Total unit capacity expected to increase from 3700 KTPA to 3852 KTPA due to additional 152 KTPA naphtha capacity augmentations.
PHASE IIII REFINERY COMPLEX'S FLARE GAS RECOVERY/ FLARE RELOCATION/DIVERSION TO A NEW FLARE	NA	To reduce the high noise levels, during emergencies where depressurization of hydrocarbons from almost all process units in Phase III complex are flared

ANNEXURES

Annexure 1 : Typical crude distillation yields of Arab Heavy at 15 MMTPA

STRAIGHT RUN STREAM	QUANTITY, KTPA	WT %
OFF GAS	4	0.03
ST RUN LPG	220	1.5
LIGHT NAPTHA (C5 – 90)	730	4.9
MIDDLE NAPHTHA(90 -110)	272	1.8
HEAVY NAPHTHA (110–145)	661	4.4
KERO (145 – 240)	1868	12.5
GAS OIL (240–360)	2605	17.4
VACUUM GAS OIL (360–550)	3830	25.5
SHORT RESIDUE (550+)	4812	32.1
TOTAL	**15000**	**100.0**

Annexure 2 : Short Residue Material Balance

PRODUCTION	KTPA	CONSUMPTION	KTPA
SR FROM CDU (360-550)	4812	SR TO LSHS (From LS)	572
		SR TO BBU	270
		SR TO MAURITIUS FO	348
		SR TO DCU	3000
		SR TO VBU	622
	4812		4812

DCU MATERIAL BALANCE

FEED	KTPA	PRODUCT	KTPA	WT%
SHORT RESIDUE	3000	HYDROGEN SULPHIDE	45	1.5%
		COKER OFF GAS	111	3.7%
		COKER LPG	90	3.0%
		COKER LIGHT NAPHTHA	119	4.0%
		COKER HEAVY NAPHTHA	159	5.3%
		COKER LCGO	919	30.6%
		COKER HCGO	668	22.2%
		PETROLEUM COKE	889	29.6%
TOTAL FEED	3000	TOTAL PRODUCTS	3000	100.0%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	3.0%	89	KTPA
LP Steam	-1.5%	-6	TPH
MP Steam	3.2%	12	TPH
HP Steam	13.4%	50	TPH
Power Consumption, KWH	12.38	4.6	MWh

VBU MATERIAL BALANCE

FEED	KTPA	PRODUCT	KTPA	WT%
SHORT RESIDUE	622	VBU H2S	2	0.3%
		VBU OFF GASES	14	2.2%
		VBU NAPHTHA	14	2.3%

		VBU LGO	73	11.7%
		VBU VGO	84	13.6%
		VBU VFR	435	69.9%
TOTAL FEED	622	TOTAL PRODUCTS	622	100.0%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	1.1%	7	KTPA
LP Steam	2.3%	9	TPH
MP Steam	2.4%	9	TPH
HP Steam	0.0%	0	TPH
Power Consumption, KWH	5.27	0	MWh

Annexure 3 : Vacuum Gas Oil Material Balance

VGO BALANCE

PRODUCERS	KTPA	TREATERS	KTPA
VGO FROM CDU (360-550)	3830	HCU I FC	1619
DEASPHALTED OIL (DAO)	0	HCU II FC	1766
COKER HCGO	668	HCGO TO CHT	668
		VGO TO PFCC FEED PREP UNIT	444
TOTAL FEED CAPACITY	4497	TREATERS	4497

HCU 1 BALANCE

PRODUCERS	KTPA	TREATERS	KTPA	WT%
VGO FROM CDU (360-550)	1619	HCU NH3	4	0.2%
HYDROGEN	40	HCU H2S	49	3.0%
		HCU OFF GAS	5	0.3%
		HCU LPG	34	2.0%
		HCU LN	41	2.5%
		HCU HN	104	6.3%
		HCU SKO	296	17.9%
		HCU HSD	419	25.3%
		HCU UCO TO PFCC	707	42.6%
TOTAL	1660		1660	100.0%

UTILITIES

UTILITY	*WT%/WT FEED*		
S.R.Fuel	*2.9%*	*49*	KTPA
LP Steam	-9.2%	-19	TPH
MP Steam	3.6%	8	TPH
HP Steam	14.1%	29	TPH
Power Consumption, KWH	54.94	11.4	MWh

HCU 2 BALANCE

PRODUCERS	KTPA	TREATERS	KTPA	WT%
VGO FROM CDU (360-550)	1766	HCU NH3	4	0.2%
HYDROGEN	47	HCU H2S	54	3.0%

		HCU OFF GAS	2	0.1%
		HCU LPG	40	2.2%
		HCU LN	46	2.5%
		HCU HN	114	6.3%
		HCU SKO	323	17.8%
		HCU HSD	456	25.2%
		HCU UCO TO PFCC	774	42.7%
TOTAL	1814		1814	100.0%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	2.0%	37	KTPA
LP Steam	8.0%	18	TPH
MP Steam	3.6%	8	TPH
HP Steam	12.2%	28	TPH
Power Consumption, KWH	42.79	9.7	MWh

CHT BALANCE

PRODUCERS	KTPA	TREATERS	KTPA	WT%
HCGO TO CHT	668	CHT NH3	5	0.8%
VGO TO CHT	0	CHT H2S	40	5.8%
HYDROGEN	15	CHT OFF GAS	3	0.4%
		CHT FRN	14	2.0%
		CHT HSD	89	13.1%
		CHT BOTTOMS	533	78.1%
TOTAL	682		684	100.2%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	1.4%	10	KTPA
LP Steam	-18.7%	-16	TPH
MP Steam	14.0%	12	TPH
HP Steam	20.4%	17	TPH
Power Consumption, KWH	29.21	2.5	MWh

NEW PFCC FEED PREPARATION UNIT (FPU) BALANCE

PRODUCERS	KTPA	TREATERS	KTPA	WT%
VGO FROM CDU (360-550)	444	NEW FPU NH3	3	0.7%
DEASPHALTED OIL (DAO)	0	NEW FPU H2S	26	5.8%
GO FROM CDU (240-360)	0	NEW FPU OFF GAS	2	0.4%
SKO FROM CDU (150-240)	0	NEW FPU FRN	9	2.0%
PRS FROM AROMATIC COMPLEX	0	NEW FPU HSD	60	13.1%
HYDROGEN	11	NEW FPU BOTTOMS	355	78.1%
TOTAL	455		455	100%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	1.4%	7	KTPA
LP Steam	-18.7%	-11	TPH
MP Steam	14.0%	8	TPH
HP Steam	20.4%	12	TPH
Power Consumption, KWH	36.89	2.1	MWh

PFCC FEED BALANCE

PRODUCERS	KTPA	TREATERS	KTPA
CHT BOTTOMS	203	PFCC FEED	2039
NEW VGO FPU BOTTOMS	355	TO IFO	0
HCU I UCO	707		
HCU II UCO	774		
TOTAL	2039	TOTAL	2039

PFCC BALANCE

PRODUCERS	KTPA	TREATERS	KTPA	WT%
PFCC FEED	2039	PFCC NH3	0	0.0%
		PFCC H2S	1	0.1%
		PFCC OFF GAS	73	3.6%
		PFCC PROPYLENE	433	21.3%
		PFCC C4= LPG	239	11.7%
		PFCC NON C4= LPG	108	5.3%

		PFCC LCN	178	8.8%
		PFCC MCN	204	10.0%
		PFCC HCN	229	11.3%
		PFCC LCO	416	20.4%
		PFCC COKE LOSS	156	7.7%
TOTAL	2039		2038	100.0%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	0.5%	9	KTPA
LP Steam	-11.2%	-29	TPH
MP Steam	20.5%	52	TPH
HP Steam	-13.6%	-35	TPH
VHP Steam	80.4%	205	TPH
Power Consumption, KWH	45.63	11.6	MWh

PP BALANCE

PRODUCERS	KTPA	TREATERS	KTPA	WT%
PFCC PROPYLENE	433	POLY PROPYLENE	397	91.7%
		CARRIER GAS TO PFCC	36	8.3%
HYDROGEN	0.3			
TOTAL	434	TOTAL	434	100.0%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	0.0%	0	KTPA
LP Steam	1.8%	1	TPH
MP Steam	0.0%	0	TPH
HP Steam	1.8%	1	TPH
VHP Steam	0.0%	0	TPH
Power Consumption, KWH	500	27.1	MWh

Annexure 4: Gas Oil Material Balance

GO BALANCE

PRODUCERS	KTPA	TREATERS	KTPA
GO FROM CDU (240-360)	2605	DHDT	3581
COKER LCGO	919	GOHDS	1014
CHT HSD	89	GO TO NEW HDT	0
PFCC HCN	229	GO TO FO	207
PFCC LCO	416	LCO TO GTG	3
KERO TO HSD POOL	543		
TOTAL FEED CAPACITY	4802	TREATERS	4802

GOHDS BALANCE

PRODUCERS	KTPA	TREATERS	KTPA	WT%
GO FROM CDU (240-360)	1014	GOHDS H2S	2.0	0.2%
HYDROGEN	5	GOHDS NH3	0.1	0.0%
		GOHDS OFF GAS	0.2	0.0%
		GOHDS NAPHTHA	2.7	0.3%
		GOHDS HSD	1014	99.5%
TOTAL	1019		1019	100.0%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	0.3%	3	KTPA
LP Steam	-0.9%	-1	TPH
MP Steam	2.0%	3	TPH
HP Steam	2.7%	3	TPH
Power Consumption, KWH	14.99	1.9	MWh

DHDT BALANCE

PRODUCERS	KTPA	TREATERS	KTPA	WT%
GO FROM CDU (360-550)	1384	DHDT NH3	2	0.1%
COKER LCGO	919	DHDT H2S	75	2.0%
SKO FROM CDU (150-240)	546	DHDT OFF GAS	1	0.0%
COKER LIGHT NAPHTHA	119	DHDT F.R. NAPHTHA	320	8.6%

PFCC LCN	0	DHDT KERO	485	13.0%
PFCC HCN	229	DHDT HSD	2853	76.4%
PFCC LCO	413			.
CHT HSD	89			
HYDROGEN	37			
TOTAL	3737		3737	100.0%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	0.3%	12	KTPA
LP Steam	-2.6%	-12	TPH
MP Steam	7.0%	33	TPH
HP Steam	2.4%	11	TPH
Power Consumption, KWH	14.99	7.0	MWh

Annexure 5 : Kero Material Balance

PRODUCERS	KTPA	TREATERS	KTPA
KERO FROM CDU (150° - 240° C)	1680	DHDT	546
HCU I SKO	296	NEW HDT	0
HCU II SKO	323	ATF/KERO MEROX 1	544
HNSC FROM CDU II	188	ATF/KERO MEROX 2	162
		ATF/KERO MEROX 3	374
		HCU SKO TO HSD	619
		HNSC TO A.C.	188
		KERO TO FO	53
TOTAL FEED CAPACITY	2487	TREATERS	2487

Annexure 6 : Naphtha Material Balance

PRODUCERS	KTPA	DESTINATION	KTPA
LN FROM CDU (C5 - 90)	730	LN TO ISOM	569
MN FROM CDU (90-110)	272	MN TO AROMATIC COMPLEX	272
HN FROM CDU (110-150)	661	HN TO CCR 1	239
LIGHT REFORMATE	198	LR TO ISOM	0
MIXED PENTANES	152	MIXED PENTANES TO NAPHTHA/MS BLENDING	152
DHDT F.R. NAPHTHA	320	HCU1 LN TO HGU 1	41
HCU 1 LN	41	SR LN TO HGU 1	35
HCU 2 HN	104	HCU1 HN TO CCR 1	104
HCU 2 LN	46	HCU2 LN TO HGU 2	46
HCU 2 HN	114	SR LN TO HGU 2	44
CHT FRN	14	HCU2 HN TO CCR 2	114
NEW FPU FRN	9	NEW NSU LN TO NAPHTHA	275
PFCC LCN	178	NEW NSU MN TO AROMATIC COMPLEX	182
PFCC MCN	204	NEW NSU HN TO AROMATIC COMPLEX	52
PFCC HCN	229	PFCC LCN TO DHDT	0
COKER LIGHT NAPHTHA	119	PFCC MCN TO SELECTIVE DESULPHURISATION/AROMATIC CMPX	204
COKER HEAVY NAPHTHA	159	PFCC HCN TO DHDT	229
PRS FROM AROMATIC COMPLEX	216	COKER LIGHT NAPHTHA TO DHDT	119
HEAVY NAPHTHA IMPORT TO NEW NSU	346	COKER HEAVY NAPHTHA TO NEW HDT	0
VBU NAPHTHA	14	PRS FROM AROMATIC COMPLEX TO NAPHTHA	26
		PRS FROM AROMATIC COMPLEX TO HGU 3	190
		LN TO NAPHTHA	82
		HN TO CCR 2	422
		VBU NAPHTHA TO CCR 1	14
		NEW NSU HN TO CCR 1	179
		LR TO NAPHTHA	198
		PFCC LCN TO SELECTIVE DESULPHURISATION	178
		COKER HEAVY NAPHTHA TO AROMATIC CMPX	159
TOTAL MASS IN	4127	TOTAL MASS OUT	4127

HYDROGEN 1 MASS BALANCE

FEED	KTPA	PRODUCT	KTPA	WT%
HCU1 LN TO HGU 1	41	HYDROGEN	25.3	33%
SR LN TO HGU 1	35	NAPHTHA AS PURGE GAS	50.6	67%
TOTAL	76		76	

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	151.0%	38	KTPA
LP Steam	45.4%	1	TPH
MP Steam	0.0%	0	TPH
HP Steam	-771.9%	-24	TPH
Power Consumption, KWH	194.59	0.6	MWh

HYDROGEN 2 MASS BALANCE

FEED	KTPA	PRODUCT	KTPA	WT%
HCU2 LN TO HGU 2	46	HYDROGEN	27.0	33%
SR LN TO HGU 2	35	NAPHTHA AS PURGE GAS	54.0	67%
TOTAL	81		81	

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	151.0%	41	KTPA
LP Steam	45.4%	2	TPH
MP Steam	0.0%	0	TPH
HP Steam	-771.9%	-26	TPH
Power Consumption, KWH	194.59	0.7	MWh

HYDROGEN 3 MASS BALANCE

FEED	KTPA	PRODUCT	KTPA	WT%
PRS FROM AROMATIC COMPLEX	190	HYDROGEN	63	33%

		NAPHTHA AS PURGE GAS	127	67%
TOTAL	190		190	100%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	136.0%	86	KTPA
LP Steam	-496.9%	-39	TPH
MP Steam	0.0%	0	TPH
HP Steam	-91.7%	-7	TPH
Power Consumption, KWH	75.43	1.8	MWh

ISOM BALANCE

FEED	KTPA	PRODUCT	KTPA	WT%
LN TO ISOM	569	ISOM H2S	4	1%
LR TO ISOM	0	ISOM OFF GAS	12	2%
HYDROGEN	19	ISOM LPG	34	6%
		MIXED PENTANES	152	26%
		LIGHT ISOMERATE	172	29%
		HEAVY ISOMERATE	214	36%
TOTAL	589	TOTAL	589	100%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	0.7%	4	KTPA
LP Steam	33.8%	25	TPH
MP Steam	16.9%	12	TPH
HP Steam	0.7%	1	TPH
Power Consumption, KWH	23.95	1.8	MWh

NHT -CCR 1 BALANCE

FEED	KTPA	PRODUCT	KTPA	WT%
HCU1 HN TO CCR 1	104	CCR 1 H2S	4	1%
HN TO CCR 1	239	CCR 1 OFF GAS	34	6%
VBU NAPHTHA TO CCR 1	14	CCR 1 LPG	9	2%
HEAVY NAPHTHA IMPORT TO NEW NSU	179	CCR 1 HYDROGEN	17	3%

HYDROGEN	0.31	CCR 1 REFORMATE	469	87%
		COKE LOSS	4	1%
TOTAL	537	TOTAL	537	100%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	6.1%	33	KTPA
LP Steam	-13.8%	-9	TPH
MP Steam	2.9%	2	TPH
HP Steam	7.3%	5	TPH
Power Consumption, KWH	80.00	5.4	MWh

NHT -CCR 2 BALANCE

FEED	KTPA	PRODUCT	KTPA	WT%
HCU2 HN TO CCR 2	114	CCR 2 H2S	4	1%
HN TO CCR 2	422	CCR 2 OFF GAS	34	6%
HYDROGEN	0.48	CCR 2 LPG	9	2%
		CCR 2 HYDROGEN	17	3%
		CCR 2 REFORMATE	469	87%
		COKE LOSS	4	1%
TOTAL	537	TOTAL	537	100%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	6.6%	35	KTPA
LP Steam	-18.5%	-12	TPH
MP Steam	-14.8%	-10	TPH
HP Steam	24.6%	16	TPH
Power Consumption, KWH	68.52	4.6	MWh

RSU BALANCE

FEED	KTPA	PRODUCT	KTPA	WT%
CCR 1 REFORMATE	469	LIGHT REFORMATE	198	21.1%
CCR 2 REFORMATE	469	HEAVY REFORMATE	740	78.9%
TOTAL	937	TOTAL	937	100.0%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	0.0%	0	KTPA
LP Steam	0.0%	0	TPH
MP Steam	8.1%	9	TPH
HP Steam	0.0%	0	TPH
Power Consumption, KWH	2.79	0.3	MWh

MXU BALANCE

FEED	KTPA	PRODUCT	KTPA	WT%
HEAVY REFORMATE	740	C7 STREAM	296	40.0%
		MIXED XYLENES (C8)	259	35.0%
		C9 STREAM	185	25.0%
TOTAL	740	TOTAL	740	100.0%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	1.3%	9	KTPA
LP Steam	-3.0%	-3	TPH
MP Steam	2.0%	2	TPH
HP Steam	0.0%	0	TPH
Power Consumption, KWH	5.36	0.5	MWh

COMBINED NAPHTHA SPLITTER

PRODUCERS	KTPA	TREATERS	KTPA	WT%
NEW FPU FRN	9	NEW NSU LN	275	39.9%
DHDT F.R. NAPHTHA	320	NEW NSU MN	182	26.5%
CHT FRN	14	NEW NSU HN	231	33.6%
IMPORTED FRN	346			
TOTAL	688		688	100%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	1.3%	9	KTPA
LP Steam	-3.0%	-3	TPH
MP Steam	2.0%	2	TPH
HP Steam	0.0%	0	TPH
Power Consumption, KWH	5.36	0.5	MWh

SELECTIVE DESULPHURISATION UNIT

PRODUCERS	KTPA	TREATERS	KTPA	WT%
PFCC LCN	178	H2S	0.06	0.01%
PFCC MCN	204	OFF GAS	2	0.5%
HYDROGEN	0.8%	SELECTIVE DESULPHURISATION LT. GASOLINE	135	35.4%
		SELECTIVE DESULPHURISATION HY. GASOLINE	245	64.1%
TOTAL	382	TOTAL	382	100%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	0.3%	1	KTPA
LP Steam	-1.2%	-1	TPH
MP Steam	3.4%	2	TPH
HP Steam	0.0%	0	TPH
VHP Steam	22.9%	11	TPH
Power Consumption, KWH	18	0.9	MWh

Annexure 7 : LPG Material Balance

PRODUCERS	KTPA	TREATERS	KTPA
LPG FROM CDU	220	LPG MEROX 1	70
		LPG MEROX 2	105
		LPG MEROX 3	44
NHT & CCR 1 LPG	9	ATU	9
NHT & CCR 2 LPG	9		9
ISOM LPG	34		34
HCU 1 LPG	34		34
HCU 2 LPG	40		40
DCU LPG	90		67
PFCC NON C4= LPG	108	FEED TO MS CONVERSION UNIT	370
PFCC C4= LPG	239		
CARRIER GAS FROM PPU	36	CARRIER GAS FROM PPU	36
TOTAL	819		819

MS CONVERSION UNIT BALANCE

FEED	KTPA	PRODUCT	KTPA	WT%
PARAFFIN LPG	195	RETURN LPG	2	0.6%
PFCC C4=	175	TO MS	368	99.4%
HYDROGEN	0.6			
TOTAL	371		371	

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	2.5%	9	KTPA
LP Steam	35.8%	133	TPH
MP Steam	1.2%	4	TPH
HP Steam	0.0%	0	TPH
Power Consumption, KWH	16.89	6	MWh

Annexure 8 : Hydrogen Balance

PRODUCERS	KTPA	TPD	TREATERS	KTPA	TPD
HGU 1	25	76	ISOM	19	58
HGU 2	27	81	NHT1	0.3	1
HGU 3	63	189	NHT2	0.5	1
CCR 1	17	50	GOHDS	5	15
CCR 2	17	50	DHDT	37	111
AROMATIC COMPLEX	29	87	HCU I FC	40	121
			HCU II FC	47	141
			CHT	15	45
			POLYPROPYLENE	0.3	1
			SELECTIVE DESULPHURISATION	0.01	0.02
			MS CONVERSION UNIT	0.60	1.79
			SLIP TO OFFGAS	1	3
TOTAL FEED CAPACITY	178	533	TREATERS	178	533

Annexure 9 : Sulphur Balance

S BALANCE

PRODUCERS	KTPA	% S	PRODUCT	KTPA	S (PPM W)
LS CRUDE	2287	0.5%	LPG	819	150
HS CRUDE	12713	3.1%	NAPHTHA	1585	116
			MS & AROMATICS	1863	2
			SKO	720	2036
			ATF	360	2036
			HSD	5907	5
			POLYPROPYLENE	397	0
			FUEL OIL MAU EXPORT	555	25000
			FUEL OIL 380 cSt EXPORT	645	38000
			PET COKE	889	64680
			BITUMEN	270	58800
			SULFUR EMISSIONS	13	
TOTAL FEED CAPACITY	15000	2.7%			
SULFUR IN (KTPA)	399		SULFUR OUT (KTPA)	114	

SULFUR TREATMENT CAPACITY REQUIRED (MIN)	285	KTPA	855	TPD
SRU CAPACITY AVAILABLE (CONSIDERING 1 SRU UNDER MAINTENANCE)	685	TPD		
SRU CAPACITY SPARE	0	TPD		
NEW SRU NEEDED	**185**	**TPD**		

Annexure 10 : Power& Steam Balance

PHASE I /II UTILITY BALANCE

UNIT	LP STEAM (TPH)	MP STEAM (TPH)	HP STEAM (TPH)	SHP STEAM (TPH)	POWER CONSUMPTION, (MWh)
CDU I & II	25	68	0	0	15.0
HGU I	1	0	-24	0	0.6
HGU II	2	0	-26	0	0.7
ISOM	25	12	1	0	1.8
CCR I	-9	2	5	0	5.4
CCR II	-12	-10	16	0	4.6
RSU	0	9	0	0	0.3
MXU	-3	2	0	0	0.5
GOHDS	-1	3	3	0	1.9
HCU 1	-19	8	29	0	11.4
HCU 2	18	8	28	0	9.7
VBU-1	9	9	0	0	0.4
SRU/ATU					1.5
CPP I/II (INTERNAL)	79	0	54	0	7.7
UTILITIES & TANKAGES	-62	-111	123	0	15
TOTAL	53	0	209	0	76.3

PHASE III UTILITY BALANCE

UNIT	LP STEAM (TPH)	MP STEAM (TPH)	HP STEAM (TPH)	SHP STEAM (TPH)	POWER CONSUMPTION, (MWh)
CDU III UTILITIES	4	44	0	0	4.8
HGU III	-39	0	-7	0	1.8
DHDT	-12	33	11	0	7.0
CHT	-16	12	17	0	2.5
PFCC	-29	52	-35	205	11.6
PPU	1	0	1	0	27.1
DCU	-6	12	50	0	4.6
SRU/ATU					3.0
CPP III (INTERNAL)	26	24	80	0	7.0
UTILITIES & TANKAGES	-51	-6	-53	48	14
TOTAL	-121	171	65	253	83.5

NEW UNITS UTILITY REQUIREMENT

UNIT	LP STEAM (TPH)	MP STEAM (TPH)	HP STEAM (TPH)	SHP STEAM (TPH)	POWER CONSUMPTION, (MWh)
NEW SELECTIVE DESULPHURISATION	-1	2	0	11	0.9
NEW MS CONVERSION UNTI	133	4	0	0	6.3
NEW FEED PREP UNIT	-11	8	12	0	2.1
NEW SRU					1.5
TOTAL	121.3	14.0	11.6	10.9	10.7
Phase III Existing & New units	**0**	**185**	**77**	**264**	**94.2**

CPP I/II

UTILITY	BOILER	STG	PRDS	INTERNAL	EXPORT
SHP (TPH)	628	579	21	29	0
HP (TPH)		248	15	54	209
LP (TPH)		132		79	53
CONDENSATE (TPH)		199			
POWER (MW)		84		7.7	76
SRF (KTPA)	340				

CPP III

UTILITY	BOILER	STG	FRAME V	FRAME VI	PRDS	INTERNAL	EXPORT
SHP (TPH)	618	416	55	80	68		264
HP (TPH)		180			68	80	77
MP (TPH)		144			91	24	185
LP (TPH)					26	26	0
CONDENSATE (TPH)		92					
POWER (MW)		44	22	36		7.7	94.2
SRF (KTPA)	361		8.9	10.5			

Annexure 11 : Overall Material Balance of BS V/VI Compliant MRPL complex

S.NO	PRODUCTS	QUANTITY	%
1	LPG	451	2.9%
2	POLYPROPYLENE	397	2.5%
3	NAPHTHA - EXPORT/DOMESTIC	732	4.7%
4	SR MN TO AROMATIC COMPLEX	272	1.7%
5	NEW NSU MN TO AROMATIC COMPLEX	182	1.2%
6	SR HNSC TO AROMATIC COMPLEX	188	1.2%
7	NEW NSU HN TO AROMATIC COMPLEX	52	0.3%
8	DCU HN TO AROMATIC COMPLEX	159	1.0%
10	C7 & C9 TO AROMATIC COMPLEX	180	1.2%
11	C8 TO AROMATIC COMPLEX	259	1.7%
12	MS BS V	1229	7.9%
13	MS 95 RON	195	1.3%
14	SKO/ATF	1080	6.9%
15	HSD BS V (DOM/EXPORT)	5907	37.9%
16	FUEL OIL MAU EXPORT	555	3.6%
17	FO - 380 cSt EXPORT	645	4.1%
18	BITUMEN	270	1.7%
19	PETCOKE	889	5.7%
20	SULPHUR	285	1.8%
		13928	89.3%

FUEL BREAKUP (KTPA)

GASEOUS FUEL	530
LIQUID FUEL	927
PFCC COKE FUEL	156
CCR 1& 2 COKE FUEL	8
LOSS	42
FUEL & LOSS (KTPA)	1663
FUEL & LOSS %	10.7%

FEED (KTPA)

CRUDE	15000
HEAVY NAPHTHA IMPORT	346
PRS FROM AROMATIC COMPLEX	216
HYDROGEN FROM AROMATIC COMPLEX	29
	15591

Annexure 12 : Sox emission expected

FUEL	KTPA	S (WT%)	SOx (TPD)
GASEOUS FUEL	530	0.0%	1
LIQUID FUEL	927	0.8%	44
PFCC COKE FUEL	156	0.5%	5
CCR 1& 2 COKE FUEL	8	0.0%	0
LOSS	42	1.0%	3
FUEL & LOSS	1663		52

Note:
1. Phase I & II liquid fuel is of 1 wt% Sulphur whereas Phase III liquid fuel is of 0.5 wt% sulphur and hence weighted average liquid fuel sulphur is 0.8 wt%
2. Worst Case sulphur is considered for PFCC coke.

Annexure 13 : Block Flow Diagram of MRPL 15 MMTPA Refinery Complex upgraded for BS V/VI Autofuels