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MANGALORE REFINERY & PETROCHEMICALS LTD

Technical Prefeasibility Report for BS VI Autofuel Quality Compliance & Associated Projects Facilities

PRE FEASIBILITY REPORT

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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 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 Indiaoutlines specifications and tentative schedule for the nation to switch over to BS VI.

In view of the nation switching over to BS 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 its MS production potential. Based on the above requirement, thisTechnical PFRevaluated the following for MRPL:

1. Treatment/Upgradation/Augmentation facilities for MS& HSD to comply with BS VI specifications
2. Otherdebottlenecking/operational flexibility improvement projects inthe refinery complex

The aforesaid facilities areto 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 andapprovals. Subject totechnical 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 VI specifications: The objective is to study and identify technically suitable refinery configuration for the auto fuel products (MS&HSD) to comply/boostBS 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 VI specifications will be brought out.

1.5.2 Debottlenecking/Operational Flexibility improvement projects: The objective is to revamp/augment unitsin 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) ANew 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

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

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

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

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

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

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

d) Infrastructure to import power form grid.

e) 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 VI specifications for its MS and HSD products.

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

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

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

2.1 Switching over to BS VI specifications

Further, based on current directives and reviews being taken by MOP & NG, the entire country has to move towards meeting BS VI 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 VI grade MS & HSD are given in Table 2andTable 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 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 inTable 3below

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

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

The objectives of facilities to be augmented in MRPLare:

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 unitsmentioned 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.

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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 VI specifications are given in Table 5below.

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

Stream	MS BS IV (KTPA)	Requirement of BS VI Hardware (KTPA)
Reformate streams (A7 & A9)	250-275	Existing isadequate
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 alternative is available to meet MS BS VI specification:

- ✓ Unit for reducing the sulphur in PFCC gasoline streams to less than 7ppmw.

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 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 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 crudeis 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 %
7OFF 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 refinerieswith 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 HYDROTREATER/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

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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 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 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 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 °C+ cut): SR balance for 15 MMTPA capacitycarried out as per basis mentionedin Section 4 above andis 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 2that 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 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) (360° - 550°C cut) stream's mass balance is presented asAnnexure 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

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 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 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 9below:

Table 9 : Capacity basis assumed for DHDT revamp

S.No	Naphtha streams to DHDT	Design Quantity, m^3/h	Additional Quantity, m^3/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 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 inAnnexure 5.To boost the BS VI MS and aromatic streams production capability, revamp of the Continuous Catalytic Reforming (CCR/Platforming) unit-IIisproposed. The revamped capacity of the units shall be 90 m^3/h. Import of heavy naphtha is required to saturate the revamped CCR capacity, 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 unit have to be revamped. With revamp of the CCR unit, 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 numbercharacteristics. 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 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 VI HSD product pool.Hence a new naphtha splitter of about 1000KTPA is required, considering margin for heavier crude than the design basis. 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/aromaticstreams generation units during turnaround of crude units/processing heavy crudes etc.Annexure 6details out the naphtha material balance as discussed above. In summary, new selective desulphurization unit of PFCC gasolineis required for the stream to be upgraded to BS VI MS and the existing CCR-IIalong with RSU are to be revamped along with installation of

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newdual 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 inAnnexure 7.

6.8. Incremental hydrogen is required for deep hydrotreatment to ultra low sulphur levels of less than 10 ppmw and alsofor hydroprocessing in new/revamped units. Annexure 8depicts the hydrogen balance for the 15 MMTPA BS VI MRPL complex. From the annexure, it is clear that existing Hydrogen Generation Units are sufficient to cater the incremental demand from hydroprocessors..

6.9. At 15 MMTPA BS 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 9details 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 inAnnexure 10. It can be observed that, the existing power plant machines are sufficient to generate and meet the power demand of the BS 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 PowerPlants.

6.11. Logistics & Tankages: Based on the logistics adequacy for the product slate inAnnexure 11, the storage tanks are to be installed additionally are given inTable 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 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 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 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 12depicts the estimated SOx emission post expansion and Annexure 13 detailsBlock Flow diagram of the proposedBS VI compliant 15 MMTPA MRPL Refinery Complex.

ms

7. Summary

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

7.1. **BSV/VI Compliance Projects**

7.1.1. 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

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

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

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

7.1.5. ETP revamp for additional effluents generated, if necessary

7.1.6. 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 VI autofuels compliance with capacity details:

Table 12: BS VI Compliance Projects

NEW/ REVAMPED PROCESS UNIT	REVAMPED / NEW CAPACITY, KTPA	REMARKS
NEW SELECTIVE DESULPHURIZATION OF GASOLINE FROM PFCC	800	To attain sulphur levels less than 7 ppmw
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
TANKAGES (NEW)	8	To handle segregated ULHSD, backed out ATF from HSD pool and additional FO generated
PIPELINE TO NEW MANGALORE	1	To prevent BS VI HSD pipeline

PORT (NEW)		**contamination**
ETP REVAMP	MATCHING	To cater Additional Flow
OFFSITE AND INFRASTRUCTURE FACILITIES		**Appropriate offsite facilities including logistics support to be finalised during detailed engineering**
NITROGEN/INSTRUMENT AIR/PLANT AIR	MATCHING	To cater Additional Flow

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

7.2.1. Revamp of CCR II unit 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 VI auto fuels compliance with capacity details.

Table 13: Debottlenecking/Operational Flexibility Improvement Projects:

NEW/ REVAMPED PROCESS UNIT	REVAMPED / NEW CAPACITY, KTPA	REMARKS
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)	1000	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	1500 Nm^3/h flare gas recovery	To reduce the high noise levels, during emergencies where depressurization of hydrocarbons from almost all process units in Phase III complex are flared

my

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%

my

		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

my

Annexure 3: Vacuum Gas Oil Material 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 CHT	83
		EXCESS VGO TO PFCC	361
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	0.7%
VGO TO CHT	83	CHT H2S	44	5.8%
HYDROGEN	17	CHT OFF GAS	3	0.4%
		CHT FRN	16	2.0%
		CHT HSD	100	13.1%
		CHT BOTTOMS	599	78.1%
TOTAL	767		767	100.1%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	1.4%	11	KTPA
LP Steam	-18.7%	-18	TPH
MP Steam	14.0%	13	TPH
HP Steam	20.4%	20	TPH
Power Consumption, KWH	29.21	2.8	MWh

PFCC FEED BALANCE

PRODUCERS	KTPA	TREATERS	KTPA
CHT BOTTOMS	268	PFCC FEED	2111

NEW VGO FPU BOTTOMS	0	TO IFO	0
HCU I UCO	707		
HCU II UCO	774		
SR VGO	361		
TOTAL	2111	TOTAL	2111

PFCC BALANCE

PRODUCERS	KTPA	TREATERS	KTPA	WT%
PFCC FEED	2111	PFCC NH3	0	0.0%
		PFCC H2S	1	0.0%
		PFCC OFF GAS	76	3.6%
		PFCC PROPYLENE	450	21.3%
		PFCC C4= LPG	247	11.7%
		PFCC NON C4= LPG	112	5.3%
		PFCC LCN	185	8.8%
		PFCC MCN	211	10.0%
		PFCC HCN	238	11.3%
		PFCC LCO	431	20.4%
		PFCC COKE LOSS	161	7.6%
		PFCC Sox	0	0.0%
TOTAL	2111		2111	100.0%

UTILITIES

UTILITY	WT%/WT FEED	TREATERS	
S.R.Fuel	0.5%	10	KTPA
LP Steam	-11.2%	-30	TPH
MP Steam	20.5%	54	TPH
HP Steam	-13.6%	-36	TPH
VHP Steam	80.4%	212	TPH
Power Consumption, KWH	45.63	12.0	MWh

PP BALANCE

PRODUCERS	KTPA	TREATERS	KTPA	WT%
PFCC PROPYLENE	450	POLY PROPYLENE	412	91.7%
		CARRIER GAS TO PFCC	37	8.3%
HYDROGEN	0.3			
TOTAL	450	TOTAL	450	100.0%

my

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	28.1	MWh

my

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%

my

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

my

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

my

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	185	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	16	HCU2 HN TO CCR 2	114
NEW FPU FRN	0	NEW NSU LN TO NAPHTHA	271
PFCC LCN	185	NEW NSU MN TO AROMATIC COMPLEX	180
PFCC MCN	211	NEW NSU HN TO AROMATIC COMPLEX	122
PFCC HCN	238	PFCC LCN TO DHDT	0
COKER LIGHT NAPHTHA	119	PFCC MCN TO SELECTIVE DESULPHURISATION/AROMATIC CMPX	211
COKER HEAVY NAPHTHA	159	PFCC HCN TO DHDT	238
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	108
		LR TO NAPHTHA	185
		PFCC LCN TO SELECTIVE DESULPHURISATION	185
		COKER HEAVY NAPHTHA TO AROMATIC CMPX	159
TOTAL MASS IN	4128	TOTAL MASS OUT	4128

HYDROGEN 1 MASS BALANCE

my

FEED	KTPA	PRODUCT	KTPA
HCU1 LN TO HGU 1	41	HYDROGEN	25.3
SR LN TO HGU 1	35	NAPHTHA AS PURGE GAS	50.6
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
HCU2 LN TO HGU 2	46	HYDROGEN	27.0
SR LN TO HGU 2	35	NAPHTHA AS PURGE GAS	54.0
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
PRS FROM AROMATIC COMPLEX	190	HYDROGEN	63
		NAPHTHA AS PURGE GAS	127
TOTAL	190		190

my

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
LN TO ISOM	569	ISOM H2S	4
LR TO ISOM	0	ISOM OFF GAS	12
HYDROGEN	19	ISOM LPG	34
		MIXED PENTANES	152
		LIGHT ISOMERATE	172
		HEAVY ISOMERATE	214
TOTAL	589	TOTAL	589

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
HCU1 HN TO CCR 1	104	CCR 1 H2S	4
HN TO CCR 1	239	CCR 1 OFF GAS	29
VBU NAPHTHA TO CCR 1	14	CCR 1 LPG	8
HEAVY NAPHTHA IMPORT TO NEW NSU	108	CCR 1 HYDROGEN	15
HYDROGEN	0.31	CCR 1 REFORMATE	406
		COKE LOSS	3
TOTAL	465	TOTAL	465

my

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	6.1%	28	KTPA
LP Steam	-13.8%	-8	TPH
MP Steam	2.9%	2	TPH
HP Steam	7.3%	4	TPH
Power Consumption, KWH	80.00	4.7	MWh

NHT -CCR 2 BALANCE

FEED	KTPA	PRODUCT	KTPA
HCU2 HN TO CCR 2	114	CCR 2 H2S	4
HN TO CCR 2	422	CCR 2 OFF GAS	34
HYDROGEN	0.48	CCR 2 LPG	9
		CCR 2 HYDROGEN	17
		CCR 2 REFORMATE	469
		COKE LOSS	4
TOTAL	537	TOTAL	537

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
CCR 1 REFORMATE	406	LIGHT REFORMATE	185
CCR 2 REFORMATE	469	HEAVY REFORMATE	690
TOTAL	875	TOTAL	875

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
HEAVY REFORMATE	690	C7 STREAM	276
		MIXED XYLENES (C8)	242
		C9 STREAM	173
TOTAL	690	TOTAL	690

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
NEW FPU FRN	0	NEW NSU LN	271
DHDT F.R. NAPHTHA	320	NEW NSU MN	180
CHT FRN	16	NEW NSU HN	230
IMPORTED FRN	346		
TOTAL	681		681
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	185	H2S	0.12	0.01%
PFCC MCN	211	OFF GAS	4	0.5%
PY.GAS. FROM OPaL	404			
HYDROGEN	0.8%	SELECTIVE DESULPHURISATION LT. GASOLINE	283	35.4%
		SELECTIVE DESULPHURISATION HY. GASOLINE	513	64.1%
TOTAL	800	TOTAL	800	100%

UTILITIES

UTILITY	WT%/WT FEED		
S.R.Fuel	0.3%	2	KTPA
LP Steam	-1.2%	-1	TPH
MP Steam	3.4%	3	TPH
HP Steam	0.0%	0	TPH
VHP Steam	22.9%	23	TPH
Power Consumption, KWH	18	1.8	MWh

ms

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	8	ATU	8
NHT & CCR 2 LPG	9		9
ISOM LPG	34		34
HCU 1 LPG	34		34
HCU 2 LPG	40		40
DCU LPG	90		449
PFCC NON C4= LPG	112		
PFCC C4= LPG	247		
CARRIER GAS FROM PPU	37	CARRIER GAS FROM PPU	37
TOTAL	831		831

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	15	44	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	17	50
			POLYPROPYLENE	0.3	1
			SELECTIVE DESULPHURISATION	0.01	0.02
			MS CONVERSION UNTI	0.00	0.00
			SLIP TO OFFGAS	1	3
TOTAL FEED CAPACITY	176	526	TREATERS	168	504

my

Annexure 9: Sulphur Balance

PRODUCERS	KTPA	% S	PRODUCT	KTPA	S (PPM W)
LS CRUDE	2287	0.5%	LPG	831	150
HS CRUDE	12713	3.1%	NAPHTHA	1636	118
			MS & AROMATICS	1861	3
			SKO	720	2036
			ATF	394	2036
			HSD	5848	5
			POLYPROPYLENE	412	0
			FUEL OIL MAU EXPORT	555	25000
			FUEL OIL 380 cSt EXPORT	645	38000
			PET COKE	889	64680
			BITUMEN	270	58800
			SULFUR EMISSIONS	10	
TOTAL FEED CAPACITY	15000	2.7%			
SULFUR IN (KTPA)	399		SULFUR OUT (KTPA)	114	

SULFUR TREATMENT CAPACITY REQUIRED (MIN)	285	KTPA	854	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	-8	2	4	0	4.7
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	-63	-110	123	0	16
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	-18	13	20	0	2.8
PFCC	-30	54	-36	212	12.0
PPU	1	0	1	0	28.1
DCU	-6	12	50	0	4.6
SRU/ATU					3.0
CPP III (INTERNAL)	26	24	80	0	7.0
UTILITIES	75	1	-42	29	14

&TANKAGES					
TOTAL	1	181	77	241	85.2

NEW UNITS UTILITY REQUIREMENT

UNIT	LP STEAM (TPH)	MP STEAM (TPH)	HP STEAM (TPH)	SHP STEAM (TPH)	POWER CONSUMPTION, (MWh)
NEW SELECTIVE DESULPHURISATIO N	-1	3	0	23	1.8
NEW SRU					1.5
NEW OFFSITES					5.0
TOTAL	-1.2	3.4	0.0	22.9	8.3
Phase III Existing & New units	**0**	**185**	**77**	**264**	**93.5**

TOTAL FUEL	**KTPA**	**SRF**	**4167**
OFF GASES GENERATED	**KTPA**	**SRF**	**1047**
LIQUID FUEL	**KTPA**	**SRF**	**3120**
PFCC COKE FUEL INTERNAL LIQUID FUEL	**KTPA**		**2719**

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)	616	414	55	80	68		264
HP (TPH)		180			68	80	77
MP (TPH)		144			91	24	185
LP (TPH)					26	26	0
CONDENSATE (TPH)		90					
POWER (MW)		43	22	36		7.7	93.5
SRF (KTPA)	359		8.9	10.5			

Annexure 11: Overall Material Balance ofBS VI Compliant MRPL complex

S.NO	PRODUCTS	QUANTITY	%
1	LPG	831	5.2%
2	POLYPROPYLENE	412	2.6%
3	NAPHTHA - EXPORT/DOMESTIC	715	4.5%
4	SR MN TO AROMATIC COMPLEX	272	1.7%
5	NEW NSU MN TO AROMATIC COMPLEX	180	1.1%
6	SR HNSC TO AROMATIC COMPLEX	188	1.2%
7	NEW NSU HN TO AROMATIC COMPLEX	122	0.8%
8	DCU HN TO AROMATIC COMPLEX	159	1.0%
10	C7 & C9 TO AROMATIC COMPLEX	180	1.1%
11	C8 TO AROMATIC COMPLEX	242	1.5%
12	MS BS V	1245	7.8%
13	MS 95 RON	195	1.2%
14	SKO/ATF	1114	7.0%
15	HSD BS V (DOM/EXPORT)	5848	36.6%
16	FUEL OIL MAU EXPORT	555	3.5%
17	FO - 380 cSt EXPORT	645	4.0%
18	BITUMEN	270	1.7%
19	PETCOKE	889	5.6%
20	SULPHUR	285	1.8%
		14346	89.7%

FUEL BREAKUP

GASEOUS FUEL	529
LIQUID FUEL	906
PFCC COKE FUEL	161
CCR 1& 2 COKE FUEL	8
LOSS	43
FUEL & LOSS (KTPA)	1649
FUEL & LOSS %	10.3%

FEED (KTPA)

CRUDE	15000
HEAVY NAPHTHA IMPORT	346
PY.GAS. FROM OPaL	404
PRS FROM AROMATIC COMPLEX	216
HYDROGEN FROM AROMATIC COMPLEX	29
	15995

Annexure 12: Sox emission expected

FUEL	KTPA	S (WT%)	SOx (TPD)
GASEOUS FUEL	529	0.0%	0.6
LIQUID FUEL	906	0.8%	43.5
PFCC COKE FUEL	161	0.5%	4.8
CCR 1& 2 COKE FUEL	8	0.0%	0.0
LOSS	43	1.0%	2.6
FUEL & LOSS	1649		51.6

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.

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