Problem Description of Refinery Material Balance

Prepared by: Technical Service Planning

Introduction

Numaligarh Refinery is located at Numaligarh in Golaghat District, Assam at a distance of 264 km from Guwahati, the Capital of Assam. The National Highway No. 39 passes close to the refinery complex making a road junction with N.H. 37 at a distance of about 7 km to the North. The nearest airports to the refinery are located in Jorhat (1 hr. drive), Dibrugarh (4 hrs. drive) and Guwahati (5 hrs. drive).

The primary distillation unit Crude Distillation Unit along with the Vacuum Distillation Unit (CDU/VDU) is designed to process 9000 MT of Assam Mix Crude Oil (API of 28.31, Sulphur 0.2% Wt. and high wax content of 10.2%) per day. The refinery has a Delayed Coker Unit (DCU) as a bottom upgradation unit to process 1020 MT of Vacuum Residue (10.8% of Crude Oil) per day which is available from the CDU/VDU unit. The Hydrocracker Unit (HCU) is designed to process 4370 MT Vacuum Gas Oil from the CDU/VDU unit and Coker Distillate from DCU as combined feed for maximization of middle distillates primarily ATF, Kerosene and HSD in the refinery. DHDT unit is designed to process 2106 MT per day of Straight Run Gas Oil available from CDU unit primarily for removal of sulphur of Gas Oil. The unit was commissioned to meet BSVI specification of HSD. The refinery has a MS Plant consisting of Naphtha Hydro-Treating Unit (NHTU) to process 998 MT of Straight Run Naphtha per day from CDU, along with a Catalytic Reforming Unit (CRU) and a Isomerization Unit (ISOM) for production of Reformate and Isomerate respectively which are two primary blend streams for production of MS. The CRU has a capacity of processing 759 MT per day of Heavy Hydro-Treated Naphtha and the ISOM has a capacity of processing 331 MT per day of Light Hydro-Treated Naphtha from the NHTU.

The refinery has a Paraffin Wax Production Block with a Solvent De-Oiling Unit (SDU) of capacity to process 727 MT per day of Vacuum Gas Oil from the CDU/VDU along with a Wax Hydro-Finishing Unit (WHFU) of capacity to process 186 TMT per day of De-oiled Wax from the SDU and Automated Slabbing and Packaging Unit for production of Solid Wax Slabs from the Molten Hydro Finished Wax from the WHFU unit. The plant has a capacity to produce 48 TMT of Paraffin Wax in a year, which is the highest capacity in India.

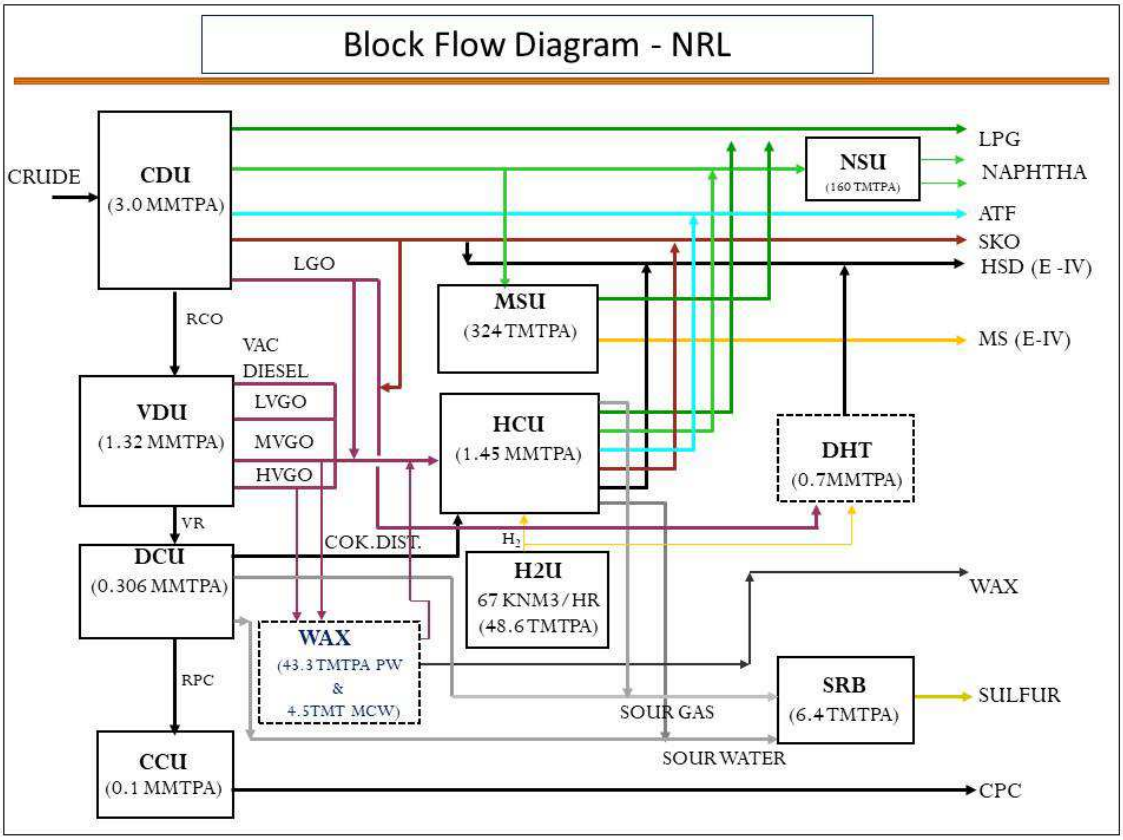
The Raw Petroleum Coke (RPC) from the DCU unit is processed in Coke Calcination Unit (CCU) with a capacity of processing 312 MT of RPC per day to produce anode grade Calcined Petroleum Coke suitable for Aluminium Industry.

The refinery has a Hydrogen Generation Unit with a capacity of production of 6068 KG of Hydrogen per Hour of 99% purity. The unit can operate with a combined feed of Natural Gas and Naphtha. Hydrogen generated in the unit is consumed in secondary hydro-processing units, HCU, DHDT and WHFU units.

The refinery has a Sulphur recovery block with Amine Treating Unit, Amine Regeneration Unit and Tail Gas Treating Unit for removal of sulphur from Soar Gas and Soar Water generated in the refinery.

Block Flow Diagram

A block flow diagram of the refinery is shown below:



Process Flow Description

Crude oil from domestic crude oil suppliers (OIL and ONGC) is received in dedicated storage tanks. Imported crude oil is also received in the same tanks from time to time by bringing the crude oil in Railway Wagons to refinery. A designated tank is used to receive crude oil from supplier and quantity of crude oil received is measured from the initial level of crude oil before receipt started and final level of crude oil after completion of receipt.

The crude oil is fed to the atmospheric column of CDU / VDU unit to obtain different atmospheric fraction in crude oil. A dedicated tank is used to feed the atmospheric column and crude oil fed into the CDU / VDU unit can be measured from the change in tank level (and corresponding volume) and also from the flow meter reading at the inlet of the CDU unit.

The products obtained from atmospheric distillation or vacuum distillation of crude oil in the CDU / VDU unit are either stored in product tanks or in intermediate tanks to either blend it in final product pool or to process as feed to a secondary processing units to produce the final products.

LPG produced from the CDU/VDU unit directly goes to mounded bullets for storage of LPG as a finished product. Naphtha generated from the unit goes to Naphtha storage tanks for using as feed to NHTU unit of the MS Plant. Kerosene produced in the unit either goes to storage tanks at

Marketing Terminal or to ATF tank in the refinery for production of ATF. It also goes as feed to the DHDT unit or to the Gas Oil storage tanks in the refinery. Gas oil generated from atmospheric distillation of crude oil is either directly fed to the DHDT unit or stored in Gasoil Storage tanks.

The Vac Diesel and Vacuum Gas Oil (VGO) from the VDU section is either fed to HCU unit or stored in the VGO tanks. The Vacuum Residue (VR) received from the bottom of the VDU is stored in VR storage tanks.

The feed to the DHDT unit is a mixture of Gas Oil from CDU, Gas Oil storage tank and Kero from CDU unit. A small quantity of Naphtha obtained from DHDT unit goes to Naphtha storage tank in the refinery. The finished High Speed Diesel (HSD) generated in the DHDT unit is stored in HSD storage tank for blending into finished HSD product.

VR from the storage tank goes as feed to the DCU unit, where more than 60% of the feed is converted into LPG and Cooker Distillate (CD) and some quantity of slop. The remaining feed is converted in Petroleum Coke (RPC). LPG generated from the unit goes to goes directly to the mounded bullet for storage as LPG. CD and Slop generated goes to the designated storage tank in the refinery. RPC produced in the DCU is stored in Coke Yard inside the refinery.

The feed to the HCU unit is a combination of VGO either from VDU or from tank and CD from the storage tank. Sometimes Gasoil from CDU or storage tank is also put as a portion of the feed to the unit in order to maximize its capacity. LPG produced in the unit goes to the mounded bullet for storing as finished LPG. Naphtha generated in the unit is stored separately at designated tank in the refinery. Kerosene generated in the unit either goes to ATF tank or to Kerosene tank in Marketing Terminal or to the HSD storage tank in the refinery. HSD obtained from the HCU goes to HSD tank in the refinery for blending as finished HSD.

Straight run Naphtha from CDU stored in designated tanks is fed to the Naphtha Hydro Treating Unit (NHTU). The Light Hydro-treated Naphtha from NHTU goes to ISOMERIZATIN unit (ISOM) as feed and the Heavy Hydro-treated Naphtha from NHTU goes to Catalytic Reforming Unit (CRU) as feed. A portion of Heavy Naphtha generated in HCU is also directly fed to the CRU. Isomerate generated in ISOM is stored in tank for blending in MS product pool. Refromate generated in the CRU goes to designated storage tank for blending in MS product pool. LPG produced in the CRU goes to mounded bullets for storage as finished LPG.

The Paraffin Wax Plant consists of three units Solvent De-Oiling Unit (SDU), Wax Hydro Finishing Unit (WHFU) and the Automated Slabbing & Packaging Unit (ASPU). The feed to the SDU is VGO either from the CDU or from VGO storage tank in Wax Area. About 25% of the feed is converted into De-Oiled Wax (DOW) and is stored designated tanks. Remaining unconverted oil is called Foots Oil and it goes back to VGO tanks in refinery. Feed to the WHFU is DOW from the tank and is converted into Liquid Paraffin Wax which is stored in tanks. Liquid wax in the tank is fed to the ASPU for manufacturing solid Paraffin Wax Slabs through a process of chilling.

In the refinery H2 is used as a process gas for chemical conversion process in reactors of HCU, DHDT and WHFU. The H2 required in these units is generated in the Hydrogen Unit (H2U). H2U uses Natural Gas or Naphtha as feed and fuel. Natural Gas used in the refinery is purchased from OIL and it comes to the refinery through a dedicated Pipe Line.

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There are 41 nos. of tanks inside the refinery for storage of crude oil, intermediates and finished products. There are also another 17 nos. of tanks in the refinery area for storage of intermediates for production of paraffin wax and finished liquid wax.

Finished products from refinery are pumped to the storage tanks in Marketing Terminal for despatch to customer by Tank Trucks and Rail Wagons. Finished product is also transported by Numaligarh Siliguri Pipeline to the Marketing Terminal at Siliguri. There are 23 Nos. of tanks in the Marketing Terminal at Numaligarh.

Refinery Fuel Network

The refinery uses Fuel Gas (FG) which is generated in the refinery units during the atmospheric distillation process or other conversion process. The FG is basically the lighter gas fraction generated in the units which is lighter than LPG. FG generated in the units is contaminated with H2S and therefore it is taken to the Sulphur Recovery Unit (SRU) to remove the sulphur. The sweet gas is then sent to the refinery fuel gas network, from where it is consumed by the units for firing in the furnaces. If total generation of FG in the units is less than the consumption in the units NG is put into the network for makeup.

In addition to FG, Fuel Oil (FO) is used to fire in some furnaces. FO is generated in DCU and stored in FO tanks and supplied in the FO network for consumption in the units.

The H2U reformer uses NG or Naphtha as fuel which either supplied from a designated Naphtha tank or NG header.

The cogeneration power plant of the refinery mostly uses purchased NG. However, in case of shortage or stoppage of NG supply, Naphtha and HSD is also used as fuel in Gas Turbines and Utility Boilers in the plant.

H2 Production

As described above H2 in the refinery for requirement in hydro processing (DHDT, WHFU) and hydro cracking unit (HCU) is produced from H2U unit. The reformer gas generated in the H2U unit is goes to the H2 PSA for purification. In addition to reformer gas, CLPS off gas from HCU and H2 rich gas from CRU also comes to PSA for recovery of H2 in the gas and final production of H2 in the refinery.

Refinery Material Balance

The refinery material balance establishes the balance between all inputs consumed in the refinery and sum of all products and intermediates generated along with fuel consumed and loss.

$\sum$All inputs = $\sum$ All products + $\sum$ All intermediates + $\sum$ Fuel + $\sum$ Loss

Preparation of the material balance of the refinery for a period (Day or Month) involves measuring, validating, reconciling and finally establishing a balanced between all the flow meter readings, tank inventories and sales /despatch quantities and identifying fuel consumed and loss incurred in the operation of the refinery.

The refinery material balance is prepared at two levels:

1. Overall Material Balance of the refinery as a black box
2. Unit wise material balance across all the individual units

The problem statement

The refinery material balance is prepared by accumulating data from different sources viz, tank transaction data (quantity receipt in a tank or delivered from tank), sales / delivery data of products, purchase / receipt data of input materials, flow transmitters data, etc.

The data directly collected from the sources have errors and the person who reconciles the data has to use his or her judgement in adjusting the errors from experience.

Solution sought

An automated system with the following automated capabilities:

(1) Collect data from all the available sources periodically
(2) Identify error in tank data
(3) Identify errors in flow transmitter data
(4) Adjust the errors
(5) Reconcile fuel consumption
(6) Reconcile loss
(7) Reconcile product pools
(8) Prepare the material balance of the refinery at defined interval (day, month, year)
(9) Prepare the material balance of individual units at defined interval (day, month, year)
(10) Generate alerts for recurring trends of errors
(11) Generate alerts for recurring trends of fuel consumption and loss

Data Interfaces

There are two sources of data available in the refinery from which real time data of Tank Level, Flow Meters, Temperature Indicators, etc. can be collected:

Source	Type	Data Types	Frequency	Access Method
IP21	Database	Real Time, History	30 Sec	SQL Query, Web Service Call (To be developed during implementation)
OPC Server	OPC	Real Time	1 Sec	DCOM, Tunneller (An OPC client is required to get the data from OPC servers or Developers may develop their own DCOM Query)

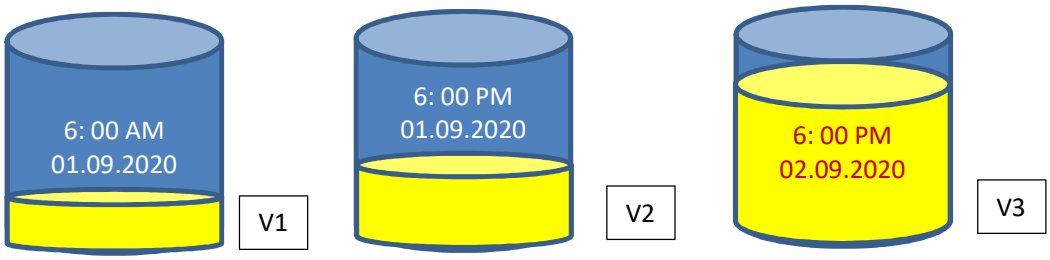
Scalability of solution and opportunity

NRL is looking for a solution which is generic and can be replicated in any other refinery with any configuration of units. Selected startup is expected to use NRL's data as a test case for validation of their solution which can be offered to the oil & gas industry and any other process industry in India and abroad.

Successful implementation of the solution will offer an opportunity to the selected startup to productise the solution. A seamless solution to the problem can be a boost to the on-going digitalization initiative in the industry.

Annexure 1: A depiction of sample decisions taken while reconciliation

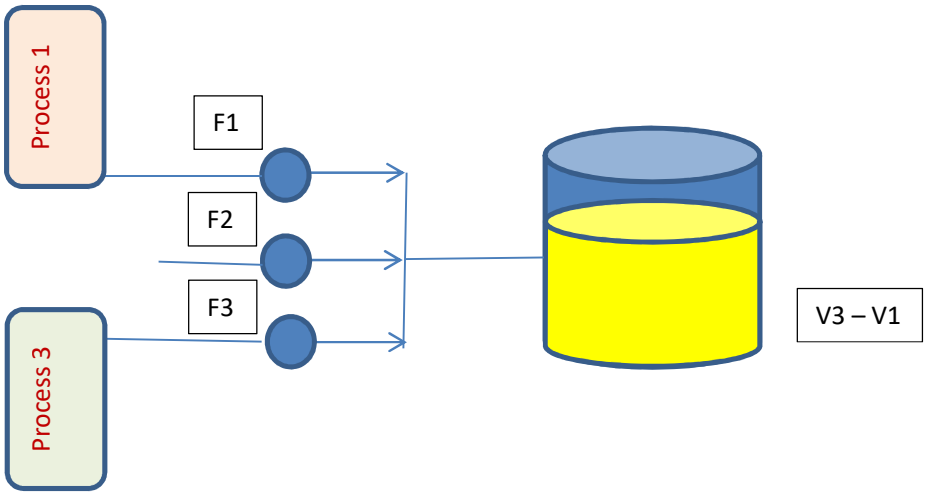
A. Receipt quantity in storage tank



Manual inference

Tank is under receipt and receipt quantity is (V3 – V1)

B. Error distribution & adjustment



Manual inference

Tank receipt quantity, V3 – V1 = F1 + F2 + F3 + e

e = e1 + e2 + e3

Design Yield of process 1 = F1 + e1

Annexure 2: Process Units and Capacities

S. N.	UNIT NAME	DESIGN CAPACITY (MT/DAY)
1	Crude Distillation Unit / Vacuum Dist Unit (CDU/VDU)	9000
2	Delayed Coker Unit (DCU)	1020
3	Hydrocracker Unit (HCU)	4373
4	Hydrogen Unit (H2U)	*6068 Kg/Hr
5	Motor Spirit Plant (MSP)	
	Naphtha Hydro-treating Unit (NHTU)	996
	Catalytic Reforming Unit (CRU)	759
	Isomerization Unit (ISOM)	331
6	Diesel Hydro-treating Unit (DHDT)	2106
7	Paraffin Wax Plant	
	Solvent De-waxing Unit (SDU)	727
	Wax Hydro Finishing Unit (WHFU)	186
	Automatic Slabbing and Packaging Unit (ASPU)	
8	Coke Calcination Unit (CCU)	312
9	Sulphur Recovery Block (SRB)	*19

Note: Capacities expressed in terms of input / throughput except H2U and SRB where design capacity is terms of production of Hydrogen and Sulphur respectively

Annexure 2: Storage Tank Details

Refinery Storage Tank Details:

S. N.	MATERIAL	TANK TAG NO	Tanks
1	Crude oil	40-TT-FR-101A/B/C/D	4 nos
2	Slop Oil	41-TT-CR-113A/B , 41-TT-FR-114A/B/C	5 Nos
3	Internal Fuel Oil	41-TT-CR-106A/B/C	3 nos
4	Vacuum Residue	41-TT-CR-107A/B	2 nos
5	Reduced Crude Oil	41-TT-CR-108A/B	2 nos
6	Vacuum Distillate	41-TT-CR-109A/B	2 nos
7	Coker Distillate	41-TT-CR-110A/B	2 nos
8	Naphtha	44-TT-FR-102A/B/C,44-TT-CFR-115A/C	5 nos
9	Aviation Turbine Fuel	44-TT-CFR-103A/B/C	3 nos
10	High Speed Diesel	44-TT-FR-105A/B/C	3 nos
11	Gas Oil	44-TT-FR-104A/B/C,44-TT-FR-121A/B	5 Nos
12	Reformate	44-TT-FR-117A	1 no
13	Isomerate	44-TT-FR-117B	1 no
14	Motor Spirit	44-TT-CFR-118A/B	2 nos
15	Flushing Oil	44-TT-CFR-115B	1 nos

Paraffin Wax Tank Details:

S. N.	MATERIAL	TANK TAG NO	TANKS
1	MVGO	43-TT-CR-101A/B	2 nos
2	HVGO	43-TT-CR-002	1 no
3	De-oil Paraffin Wax	43-TT-FR-103A/B	2 nos
4	De-oil Micro crystalline Wax	43-TT-FR-104A/B	2 nos
5	Liq. Finished Wax	43-TT-FR-105A/B/C/D, 43-TT-FR-106A/B	6 nos
6	Wax Slop	43-TT-FR-108A/B	2 nos

Storage Tanks in Marketing Terminal:

S. N.	MATERIAL	TANK TAG NO	TANKS
1	MS Blend Component	45-TT-FR-001A, 45-TT-FCR-006A	2 nos
2	Motor Spirit	45-TT-FR-001B/C, 45-TT-FR-002, 45-TT-FR-004A/B/C, 45-TT-FR-009A/B/C/D	9 nos
3	Aviation Turbine Fuel	45-TT-FCR-003A/B/C	3 nos
4	Superior Kerosene Oil	45-TT-FR-008A/B/C	3 nos
5	High Speed Diesel	45-TT-FR-005A/B/C, 45-TT-FR-006A/B/C	6 nos

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