UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
DEHRADUN

SUMMER INTERNSHIP REPORT
ON

REFINERY OPTIMIZATION USING LINEAR PROGRAMMING

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT OF THE DEGREE OF

MBA (Oil & Gas)

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डाकघर : जवाहरनगर,
जिला – वडोदरा, गुजरात - 391 320.

Indian Oil Corporation Limited
Refineries Division : Gujarat Refinery,
P.O. Jawaharnagar,
Dist. : Vadodara, Gujarat - 391 320.
Website : www.iocl.com

इंडियन ऑयल
IndianOil

DNV

रिफ़ाइनरी प्रभाग
Refineries Division

JR/TD/2013/0139

Date: 26/07/2013

Certificate

This is to certify that **Mr. Abhisek Sinha**, student of **MBA (Oil Gas Managment)** programme from **University of Petroleum & Energy Studies, Dehradun , Dehradun** , has undergone Industrial Training at Indian Oil Corporation Limited, Gujarat Refinery, Vadodara from **27/05/2013 to 26/07/2013** as a part of the course curriculum.

He/She has successfully completed the training and submitted a report with his/her overall performance being **Good**.

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ACKNOWLEDGEMENT:-

It gives me a great sense of pleasure to present the report of the MBA (Oil & Gas) of the project undertaken during Internship program. I owe special debt of gratitude to my mentor Mr. Harsh Kumar for his constant support and guidance throughout the course of my work. His sincerity, thoroughness and perseverance have been a constant source of inspiration for me. It is only through his cognizant efforts that my endeavor has seen light of the day.

I also take the opportunity to acknowledge the contribution of Mr.S.K.Chakraborty (DGM, Technical service) for his full support and assistance during the development of the project. He guided us through all the stages of the project gave constant advice and feedback to our queries.

I also do not like to miss the opportunity to acknowledge the contribution of all faculty members of the department for their kind assistance and cooperation during the development of our project. Last, but not the least, I acknowledge our friends for their contribution in the completion of the project.

Signature:

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Roll No: R020212004

Date: 25/07/2013

BONAFIDE CERTIFICATE

Certified that this project report titled "***REFINERY OPTIMIZATION USING LP PROGRAMMING***" is the bonafide work of "**ABHISEK SINHA, APOORVA RAGHUWANSHI, PRATIM BHATTACHARJEE**", who carried out the project work under my supervision. Certified further, that to the best of my knowledge the work reported herein does not form any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

SIGNATURE

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Abstract:-

Indian Oil Corporation is one of the largest National Oil Company in the downstream sector. It has many divisions across different parts of the country. The main division are situated in mumbai and delhi and the largest refining division(capacity wise) is situated in Vadodara, Gujarat.

Refining profitability is one of the main concern of any refinery and subsequent time and effoert has been incorporated in optimizing the different processes in the refinery so as to maximize the overall profit margin of the refinery.

The main refinery optimization process in Gujarat IOCL refinery has been done by HONEYWELL corporation limited which comprised of the optimizing and monitoring of each and every unit and the related processes with each unit which is done with the help of a optimizing tool which has been developed by the HONEYWELL itself.

In this project we were provided with a small division of the Gujarat refinery and we tried to estimate the profitability margin of the company with the datas which we have collected from the refinery. The data's were collected mainly from the refinery division and also from the particular unit which were under study. Some of the data were also obtained from the technical service division of the company . After the analysis we have also tried to do a comparative study of the profit margin of the previous years and tried to look into the factors which effect the profit margin of the company. Apart from these we have also looked into the ISOM unit of the plant and did a study on the NHT unit. All the dats and observation were later reviwed by our mentor and Mr. S.K. Chakraborty to provide us further informqtion regarding the study conducted.

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1. INTRODUCTION:-

The **Gujarat Refinery** is an oil refinery located at Koyali (Near Vadodara) in Gujarat, Western India. It is the largest refinery owned by Indian Oil Corporation limited. The refinery was commissioned in 1965-1966. It has five atmospheric distillation units' .The major units include CRU, FCCU and the first hydrocracking unit of the country. It is operating with an installed crude processing capacity of 13.7 mmtpa.

When the refinery was commissioned, it had an installed capacity of 2 mmtpa and was designed to process crude from Ankleshwar, Kalol and Nawagam oilfields of Gujarat. The refinery was modified to handle imported and Bombay High crude.

The Gujarat refinery was the first refinery in India to have completed the diesel hydrodesulphurization project in June 1999.

Figure 1.1: Gujarat Refinery

Gujarat refinery is the largest public sector refinery in India and is also the biggest and most energy efficient refinery of the Indian oil corporation limited. It began operation in the year 1965.

The 13.5 MMTPA refinery features five atmospheric distillation column, a crude reformer unit, a fluid cracking unit and a hydrogen cracking unit which is one of the first in India. The Gujarat Refinery is the first refinery in India to have completed the diesel hydrodesulfurization project in June 1999, when the refinery started production of HSD with low sulfur content of 0.25% wt (max).

When the refinery was commissioned in the year 1965, it was designed to process crude from Ankleshwar, Kalol and Nawagam oilfields of ONGC in Gujarat. Its initial capacity of 2 MMTPA was increased to 4.3 MMTPA by revamping three of its five atmospheric distillation columns. In 1978 its refining capacity was again increased to 7.3 MMTPA by the addition of a crude distillation column. In 1981, a Fluidized catalytic cracking was also added to increase the production of its middle distillates like Diesel and LPG. The capacity of the refinery was further increased to 9.5 MTPA in 1990. In 1993-1994, Gujarat commissioned the country's first hydrocracker unit of 1.2 mmtpa for conversion of heavier ends of crude oil to high value superior products. A Methly tertiary butyl unit was commissioned in September 1999 to eliminate Lead from motor fuels. The facility conceptualized and commissioned South Asia's largest centralized effluent treatment plant by dismantling the four old ETP's in June 1999. By September 1999 with the commissioning of an atmospheric distillation unit, Gujarat Refinery further augmented its capacity to 13.7 mmtpa making it the largest public sector undertaking refinery of the country.

GUJARAT REFINERY OVERVIEW:-

Gujarat refinery has three divisions

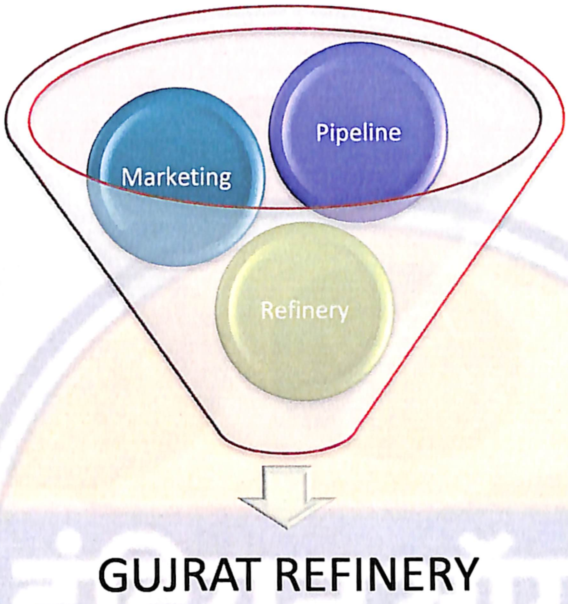


Fig 1.2: Three divisions of Gujarat refinery

As the marketing department do not have any storage facilities they tell what is the demand of the product and the refinery division produces only that product pattern that is currently in demand.

ORGANISATION VISION:-

Figure 1.3: Organisation Vision

Indian Oil has worked to foster and cultivate a culture that has made possible the development of core competencies of its workforce which has helped in the growth of its business. Even during economic meltdown and fluctuating crude oil prices it has achieved highest throughput compared to its competitors.

Sharing of innovative ideas between its different refineries has led to increasing in its refining margin and has led to tremendous growth of Indian oil refineries.

Indian Oil Refineries strives to improve the energy efficiency of its processes and operations as well as increasing flexibility so that the refinery can process any type of crude basket and increase its refining margin.

OBJECTIVES OF IOCL:-

- *To serve the national interests in oil and related sectors in compliance with government policies.*
- *To ensure continuous , uninterrupted supply of petroleum products by crude oil refining, transportation and marketing activities and to provide assistance to customers to conserve and use petroleum products efficiently.*
- *To enhance countries self sufficiency in crude oil refining and build expertise in lying of crude oil and petroleum product pipelines.*
- *To enhance marketing infrastructure and reseller network so as to provide assured service to customer throughout the country.*
- *To create strong research and development base in refinery processes, product formulation, pipeline transportation and alternative fuels with a view to minimizing or eliminating imports and to have next generation products.*
- *To optimize utilization of refining capacity and maximize distillate yield and gross refinery margin.*
- *To maximize utilization of existing facilities for improving efficiency and increasing productivity.*
- *To minimize hydrocarbon loss and fuel consumption in refineries to effect energy conservation*
- *To earn a reasonable rate of return on investment.*
- *To avail all available viable opportunities both national and global arising out of government of India's policy of liberalization and reforms.*
- *To achieve higher growth through mergers acquisition and diversification by harnessing new business opportunities in oil exploration and production, petrochemicals, natural gas and downstream opportunities downstream.*

- *To inculcate strong core values among the employees and continuously update skill sets for full exploitation of business opportunities.*
- *To develop operational synergies with subsidiaries and joint ventures and continuously engage across the hydrocarbon value chain for the benefit of the society at large.*

ORGANISATION MISSIONS:-

- To achieve international standards of excellence in all aspects of energy and diversified business with focus on customer delight through value of products and services, and cost reduction.
- To maximize creation of wealth, value and satisfaction for the stakeholders.
- To attain leadership in developing, adopting and assimilating state-of- the-art technology for competitive advantage.
- To provide technology and services through sustained Research and Development.
- To foster a culture of participation and innovation for employee growth and contribution.
- To cultivate high standards of business ethics and Total Quality Management for a strong corporate identity and brand equity.
- To help enrich the quality of life of the community and preserve ecological balance and heritage through a strong environment conscience.

ABOUT THE SITE/OFFICE:-

The office where we are doing our internship consists of three floors dedicated to different departments. The details of the departments which are held by prestigious posts are referred in Appendices with an appropriate figure (Fig. 1.4). The basement of the Administrative building consists of OIL A/C (Oil Accounting) Department. The department deals with maintaining records regarding crude oil transactions, terms and conditions of spot /term contracts for crude oil procurement, shipping arrangements are recorded with the help of SAP by the oil accounting Department. Gate passes are allotted to the products by this department. Stock Valuation is also done in the basement by Mr Vijay Sethi. It deals with valuation of the stocks in a refinery which can be crude oil, intermediate product or final products.

The ground floor consists of the Finance Department which deals with maintenance of balance sheet of the organization; the floor also consists of payroll department. The Finance Department is headed by Mr G Murali.

The first floor has two wings: The DGM wing and the ED wing .As we enter the DGM wing the first office on the right side is of DGM (MN): DGM Maintenance and on the left side we have DGM (TS) i.e. Technical Services .As we move further we have DGM (IT) on the right side and DGM (HSE) on the left side. As we move further we have DGM (P&U) (power and utilities) and DGM (T) Technical's office. The second wing consists of the ED wing which has the office of Mr Gautam Roy.

The office also consists of two conference rooms and pantry for uninterrupted supply of snacks to all the employees of IOCL.

2. LITERATURE REVIEW:-

The literature reviewed includes Annual Operating Reports of IOCL of the past 10 years which give the feed and products of the various process units. It also gives information about the losses from the various processing as well as the material balance of each process unit.

We also analyzed the manuals of each process unit which gives the feed and the product specifications, the flow rates of each feed stream and the product stream.

Secondary data was collected from the following papers and research articles:

1 .Optimizing FCC catalyst selectivity for processing difficult feeds, Martin Evans

The paper discusses fccu unit, the importance of the unit, the optimization tools that are used for the unit and the most important variable that affects the product yield i.e. catalyst selectivity. It also discusses the catalyst optimization strategies.

2. Optimization of refinery products blending, Julija Ristic

The paper discusses how the optimization of the blending of refinery products is done, formulation of a linear programming model for the blending process, the methodology for this optimization, the properties which blend linearly, and the properties which do not blend linearly.

3. Oil refining planning under price and demand uncertainties: case of Algeria, Abderrezak benyoucef

The paper discusses how linear programming model is a helpful tool

For planning under the highly volatile price and demand uncertainties. What are the variables which need to be balanced, how formulation of linear programming model is done.

4. Simple Linear Programming Model, Katie Pease

The paper discusses the formulation of linear programming problems, identification of variables for an LP problem and the constraints for a particular case of LP problem.

5. lp modeling of operation of vdu, cdu and visbreaker units of tehran refinery for profit maximization by proplan simulator

Sepehr Sadighi, Reza Seif Mohaddecy, Majid Bahmani, Sorood Zahedi

3. OBJECTIVES AND SCOPE OF THE PROJECT:-

- The project will help us to know how to formulate an LP model for process units in the refinery where there are hundreds of constraints and conflicting objectives.
- The project focuses on formulation of LP model of the refinery and study the variables for some of the process units that affect their yield.
- It will tell what is the maximum profit that can be obtained by the section of the refinery after applying all constraints related to market demand, quality constraints on products and capacity constraints on process units.
- The project will help us to do a sensitivity analysis and we will be able to analyze the key variables in the objective function that affect the profit of the refinery.
- The project will help us to know what is the allowable increase and allowable decrease for each variable that does not change the optimal value of the objective function.
- We will also come to know product pattern and crude slate of IOCL Refinery.
- We will come to know the various refinery process and the variables that affect the yield of these processes.
- We will come to know about the crude slate of IOCL Koyali Refinery.

4. PROPOSED PLAN /METHODOLOGY OF THE PROJECT:-

The methodology for the project involves the following phases:

1 Defining the Research Problem: Refinery Optimisation using Linear Programming Model

5. Reviewing Literature: It involves reviewing concepts and theories relating to the problem at hand and also reviewing research papers which deal with the problem at hand. The present problem involves study of the various process units in the refinery , the variables that affect the yield of the various process units and the constraints related to process units like capacity of the process unit, market demand and the quality constraints related to the final products.

So our literature review would involve study of what is crude basket for IOCL Koyali Refinery and the product pattern of the refinery, the current prices of all these products , the capacity of the process units and the feed and product specification.

6. Selecting a research design and sample design: The research problem at hand is an exploratory research type in which we are studying the various process units and variables related to these process units that have an impact on the product yield. These variables define the profitability of the refinery. In our problem we will collect data from P&C Department (Planning and Commissioning) ,and production department who will tell about the feed and the product quality specification, from marketing department we come to know about the minimum demand for each product, from the ISOM production department we come to know about the flow rates, the yield ,the quality of each feed and product. The data we would collect would be Quantitative data .

7. Collection of data: The data collected was mostly secondary data from published reports of IOCL, annual reports of IOCL, annual operating report of IOCL and the primary data collected was through interviews and discussion with the mentor Mr. S.K Chakraborthy, DGM (Technical Services) and Mr. Harsh Kumar, Senior Finance Manager. The data collected would involve
    - General idea of all the operations carried out in the refinery as well as the work carried out by all the departments in IOCL Koyali Refinery
    - It would include the study of what crude slate is being used by IOCL Koyali Refinery, the price of the crude basket, the product pattern of the refinery, the current price of the products manufactured by the refinery, the feed and the product specifications ,the quality specifications of each product ,the constraints related to each property of each and every product.

8. Analyze Data: we will do analysis by first formulation of LP problem of the refinery section that would be provided by the the mentor then defining the

constraints of each process unit ,formulation of each constraint and then using EXCEL Solver to solve the LP Problem.

9. Interpret the results: After we have analyzed the data we will interpret the results i.e Answer Report , Sensitivity Analysis and the Limits Report to identify the key variables which affect the profit of the refinery.

10. Recommendations and Conclusions: After we have studied all the three reports related to the LP Problem we will identify the variables that need to changed in order to get maximum profit , we will get the range in which the variables can be changed so that there is maximum profit, we will get the range of the operating cost of the various units which will give the maximum profit and if the actual operating cost of the particular unit is not within that particular range then measures should be taken to decrease the operating cost.

5. LEARNING AND OBSERVATIONS:-

Refiner's objectives and constraints

As in most industries operating in a competitive environment, refineries must maximize their economic result. To do that they must maximize their margin that is the difference between their revenues from the product they manufacture and their cost. The latter comprise purchase of raw material i.e., crude oil and other feed stock and operating cost which consist of the fixed cost(manpower, maintenance, overhead) and variable cost(chemical, catalyst etc.)

Refining has a characteristic that the products manufactured from the various crude oil are interdependent in nature. It is not possible to manufacture just one product for example: - motor, gasoline from the treatment and conversion unit that make up a traditional refinery. The refiner has no choice but to produce gas, gas oil, fuel oil etc. as well, in quantities related to the volume of motor gasoline produced.

The relative proportion of the products depends on different feedstock processed, process unit used and the unit operating conditions. Therefore it is not possible to calculate the actual manufacturing cost for a single product without an arbitrary allocation of the raw material and operating coast among different products.

The oil products are manufactured by blending two or more different fractions whose quantities and physicochemical properties depend on the crude oil type, the way and conditions of processing. The quality of the oil products (fuels) for sale has to comply with the current standards for liquid fuels, and the produced quantities have to comply with the market needs. It is in producer's interest to do the blending in an optimal way, namely, to satisfy the requirements for the oil products quality and quantity with a maximal usage of the available fractions and, of course, with a maximal profit out of the sold products. The optimization of refinery products blending is accomplished by applying linear programming.

Among the mathematical methods commonly used by operations research analysts in modeling system; and organizations are the following: mathematical programming (linear, nonlinear, integer, dynamic, goal programming etc), network modeling, inventory modeling, queuing theory, game theory, simulation, forecasting and others.

Linear programming (LP) is the most often used method for solving optimization problems. Since the development of the simplex algorithm or solving linear programming problems by George Dantzig, LP has been used to solve optimization problems in fields as diverse as petroleum, banking, education and many others, and has a great importance in operations research methods.

Situations in which various inputs must be blended in some desired proportions to produce goods for sale are often amenable to linear programming analysis. Such problem are called blending problem. The blending problem are typical for the oil refining industry where various types of fractions and components are blended to produce different types of gasoline and other oil products.

The linear programming software employs powerful optimization algorithms leading to dramatically reduced solution time of the optimization procedure when the problem contains a large number of variables and constraints.

The Gujarat refinery is one of the oldest and largest refining divisions of the Indian Oil Corporation (IOCL).

The main units in the Gujarat IOCL refinery are: -

- Atmospheric distillation unit 1
- Atmospheric distillation unit 2
- Atmospheric distillation unit 3
- Atmospheric distillation unit 4
- Atmospheric distillation unit 5
- FCC Gasoline splitter
- Sour water stripping unit
- Sulphur recovery unit
- Amine regeneration unit
- ATF merox
- Naphtha Splitter
- Feed preparation unit 1
- Feed preparation unit 2
- Vacuum distillation unit
- FCC gasoline MEROX

- Amine Absorber
- ARU
- SRU 1
- MSQC and SR-CRU
- UDEX
- FGH
- LAB
- MTBE+ Butene-1
- FCCU
- HGU
- HCU
- Bitumen blowing unit
- VBU
- HGU 2
- SRU 2 (2*35 TPD)
- DHDS
- Delayed coker unit(DCU)
- ISOM unit
- Coker LPG Merox
- HGU-3
- FCC LPG Merox.
- DHDT(diesel hydrotreating unit)

The main input and outputs of these individual units are as follows:-

Atmospheric distillation unit 1

Input:- SG+NG

*Output:-*Gas, LPG, Naphtha, ATF, LABFS, HSD and RCO.

Atmospheric distillation unit 2

Input:- SG+NG

Output:- Gas, LPG, Naphtha, ATF, LABFS and RCO

Atmospheric distillation unit 3:-

Input:- NG+IMP

Output:- Gas, LPG, Naphtha, SKO, HSD and RCO.

Atmospheric distillation unit 4:-

Input:- IMP/BH/NIG

Output:- Gas, LPG, Naphtha, SKO/LABFS, LGO/HGO, RCO(IMP) and RCO(BH/SG)

Atmospheric distillation unit 5:-

Input:- IMP/BH/NIG

Output:- Gas, LPG, Naphtha, SKO, HSD, RCO(IMP) and RCO(BH/NIG)

FCC Gasoline Splitter:-

Input :- Gasoline

*Output:-*FCC Hydrogenised gasoline

Sour water Stripping unit:-

Input:- Sour water from unit.

Output:- Sulphur and Stripped sour water to CETP.

Sulphur recovery unit:-

Input:- Sulphur from the sour water stripping unit and amine regeneration unit.

Output:- Sulphur to DCU.

Amine regeneration unit:-

Input: - Rich amine from units.

Output: - Lean amine to DCU/DHDT/VGO-HDT.

ATF merox:-

Input: - SKO

Output: - Kerosene

Naphtha Splitter

Input: - Naphtha from the Atmospheric distillation unit.

Output: - Feed for MSQC and SR-CRU.

Feed for ISOM unit.

Feed preparation unit 1

Input: - RCO from the atmospheric distillation unit.

Output: - HHSD, VGO, SLOP and VR.

Feed preparation unit 2

Input: - RCO ex AU- I, II and III

Output: - HHSD, VGO, SLOP and VR

Vacuum distillation unit

Input: - RCO from ADU I, II and III.

Output: - HHSD, VGO, SLOP and VR

FCC gasoline MEROX

Input: - Feed from FCC gasoline splitter

Output: - MS

Amine Absorber

Input: - Gas and lean amine

Output: - Rich amine and gas

ARU

Input: - Rich amine

Output: - Feed for SRU1 and Lean amine to amine absorber

SRU 1

Input: - Feed from ARU

Output:- Sculpture

MSQC and SR-CRU

Input: - Naphtha and FCC Hay. Gasoline

Output: - Gas, LPG, Drag steam, B- reformate and MS reformate.

UDEX

Input: - B- reformate from MSQC and SR-CRU

Output:- Toulene, benzene and feed for FGH unit.

FGH

Input: - Feed from UDEX.

Output: - Naphtha

LAB

Input: - LABFS and benzene.

Output: - Linear alkyl benzene, Heavy alkyl benzene and LABRS

MTBE+ Butene-1

Input: - Methanol and LPG

Output: - MTBE and Butene 1

FCCU

Input: - VGO from FPU and VDU unit.

Output: - LPG, Gasoline, LCO, CLO and Gas.

HGU

Input: - VGO and light Naphtha

Output: - Hydrogen.

HCU

Input: - Hydrogen and VGO

Output: - Gas, LPG, Light Naphtha, Heavy Naphtha, SKO/ATF, HSD and HCB

Bitumen blowing unit

Input: - VR

Output: - Bitumen

VBU

Input: - VR and RCO

Output: - MS, VBGO, VB Tar and Naphtha to DHDS/FCC Feed.

HGU 2

Input: - Naphtha

Output: - Feed for DHDS unit

SRU 2 (2*35 TPD)

Input: - Gas

Output:- Sulphur

DHDS

Input: - Feed from HGU 2 and LCO

Output: - Gas, Naphtha and Sweet Diesel

Delayed cokerunit (DCU)

Input: - RCO and VR

Output: - Coker LPG, Coker Naphtha and LCGO.

ISOM unit

Input: - Feed from Naphtha splitter.

Output: - MS

Coker LPG Merox

Input: - Coker LPG

Output: - LPG

HGU-3

Input: - Coker Naphtha and Naphtha from ADU.

Output: - Hydrogen

FCC LPG Merox.

Input:- Naphtha

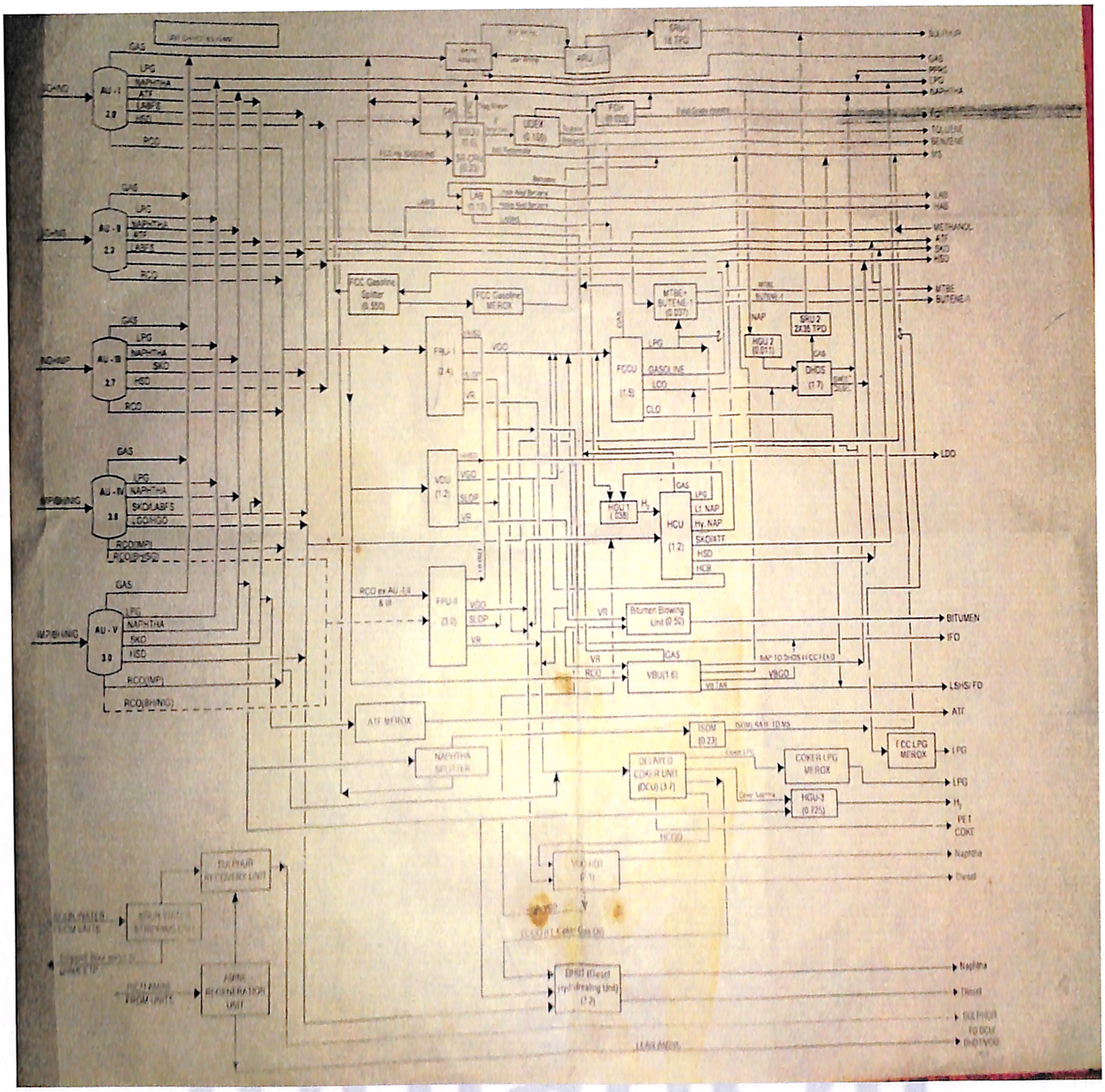
Output: - LPG

DHDT (diesel hydrotreating unit)

Input: - LGCO, Naphtha and LGO/HGO

Output: - Naphtha and Diesel

Fig 5.1: Flow diagram of Gujarat refinery:-



PRIMARY AND SECONDARY DATA COLLECTION:

TABLE 5.1: TYPEWISECRUDERECEIPT/PROCESSING		
TYPE	**RECEIPT**	**PROCESSING**
	MT	MT
SOUTHGUJARAT	1675852	1671276
NORTHGUJARAT	3857708	3853580
BOMBAYHIGH	391839	409606
IMPORTED(LS)	2447870	2479896
IMPORTED(HS)	5886159	5838627
TOTAL	**14259428**	**14252985**

TABLE 5.2: DISTILLATEYIELDS:		
ITEM	**YIELD** MT	**%wt** ONCRUDE
LIGHTDISTILLATE	3117047	21.9
MIDDLEDISTILLATE	7984242	56.0
TOTALDISTILLATES	**11101289**	**77.9**
HEAVYENDS	2341433	16.4
FUEL&LOSS* ISD	1398832	9.8
TOTAL	7336	0.1
LESSMEOH	**14848890**	**104.2**
LESSMTBE	-7707	-0.1
NATURALGASTOHGU-3	0	0.0
LESSN-PARAFFIN LESS-	-140805	-1.0
BENEZENE	0	0.0
LESSNATURALGAS	-4722	0.0
TOTAL	-442671	-3.1
	14252985	**100.0**

TABLE 5.3: SALIENTOPERATINGFEATURESOFPROCESSUNITS:

UNIT	T'PUT MT	ONSTREAM DAYS
PRIMARYUNITS:		
AU-1	1781787	352.6
AU-2	1780189	340.6
AU-3	2776372	351.8
AU-4	4026718	354.3
AU-5	3887919	351.1
SECONDARYUNITS:		
CRU	0	
BTRUN	0	
MIXEDRUN	303682	318.0
MS RUN TOTAL	303682	334.7
UDEX	145379	307.5
LAB	602430	364.9
VDU	1061868	
IMPRUNVBU	621550	
FORUN	320669	242.0
LSHSRUN TOTAL	942219	317.0
BBU#	545395	366.0
FPU-I	2480540	361.0
FCCU	1868489	348.2
FPU-II	3124242	348.4
HCU	1482144	342.5
H2U-I	72890	364.2
CCRU	662396	320.1
FGH	87883	365.0
DHDS	1326070	191.4
H2U-II	13475	338.8
MTBE	206454	

TABLE 5.4: UNITWISE/CRUDEWISEBREAKUP:

UNIT	SG	NG	BH	IMP-LS	IMP-HS	TOTAL
AU-1	1273203	508584	0	0	0	1781787
AU-2	361736	647946	336824	433683		1780189
AU-3	0	2697050	31774	47548	0	2776372
AU-4	29454	0	22348	1901681	2073235	4026718
AU-5	6883	0	18660	96984	3765392	3887919
TOTAL	**1671276**	**3853580**	**409606**	**2479896**	**5838627**	**14252985**

TABLE 5.5: IMPORTED CRUDE BREAK

IMPORTED HIGH SULPHUR CRUDE

	RECEIPT	PROCESSED	%ONIMP
KUWAIT	3043290	2994688	36.00
BASARHLIGHT	2208727	2209796	26.56
ARABMIX	88623	88622	1.07
IRANMIX	361729	361730	4.35
UPPERZAKUM HOUT	3826	3826	0.05
KHAFJI MANGLA	32269	32269	0.39
SUB-TOTAL	102345	102345	1.23
	45351	45351	0.55
	5886160	**5838627**	**70.19**

TABLE 5.6: IMPORTEDLOWSULPHURCRUDE

ESCRAVOS	149116	149117	1.79
BONYLT	268122	268122	3.22
GIRASSOL	0	0	0.00
AZERILIGHT	0	0	0.00
NEMBA	53487	53487	0.64
KISSANJE	58510	58510	0.70
BONGA	254975	254975	3.07
QUAIBOE	345331	367494	4.42
SERIALIGHT	0	0	0.00
APKO	31270	31270	0.38
DJENO	18420	18420	0.22
LABUAN	0	0	0.00
EACRUDE	209725	209725	2.52
FORCADOS	394615	402617	4.84
ERHA	0	0	0.00
AMENUM	41383	41383	0.50
ZAFIRO	187173	189032	2.27
CABINDA	0	0	0.00
HUNGO	123228	123228	1.48
YOHO	233932	233934	2.81
BRASSRIVER	34449	34449	0.41
KOLE	44133	44133	0.53
SUB-TOTAL	**2447869**	**2479896**	**29.81**
TOTAL	**8334029**	**8318523**	**100.00**

TABLE 5.7: PRODUCT PATTERN OF THE REFINERY

CRUDEINTAKE:	MT	% wt
SOUTHGUJARAT	1671276	11.73
NORTHGUJARAT	3853580	27.04
BOMBAYHIGH	409606	2.87
IMPORTED-LS	2479896	17.40
IMPORTED-HS	5838627	40.96
SUBTOTAL	**14252985**	**100.0**
NATURAL GAS	442671	3.11
MEOH	7707	0.05
OFFSPECPRODUCTS	0	0.00
NATURALGASTOHGU-3	140805	0.99
MTBE	0	0.0
GRAND TOTAL	**14848890**	**104.18**
PRODUCT OUTPUT:		
LPG(GROSS)	544338	3.82
MSREFORMATE	57401	0.40
BENZENE	-1143	-0.01
TOLUENE	435	0.00
NAPHTHA	1159337	8.13
MS EURO-IV	195394	1.37
MS EURO-III	1185746	8.32
MTBE	-501	0.00
FGH	1805	0.01
PGH	3504	0.02
LIGHTDISTILLATES	**3117047**	**21.87**
MTO	2510	0.02
ATF	406872	2.85
SKO	932203	6.54
LABFS	399587	2.80
LABLMW	89479	0.63
LABHMW	12163	0.09
	0	0.00
PFRCB	8861	0.06
HAB	2028	0.01
HSDEURO-IV	405913	2.85
LSHFHSD	357754	2.51
HSDEURO-III	5684605	39.88
LDO	19664	0.14
LESSNIRMA R/S	-337397	-2.37
MIDDLEDISTILLATES	**7984242**	**56.02**

SULPHUR	65923	0.46
BUNKERFO	12024	0.08
FO	813427	5.71
LSHS	488314	3.43
BITUMEN	546149	**3.83**
COKE	415596	2.92
HEAVYENDS	**2341433**	**16.43**
STOCKDIFFER	7335	0.05
FUELOIL	329688	2.31
FUELGAS	950689	6.67
COKE	76795	0.54
FLARELOSSES	11830	0.08
OTHERLOSSES	**29831**	**0.21**
GRANDTOTAL	**14848890**	**104.18**

Table 5.8: ATMOSPHERIC UNIT NO-1(AU-I)

OPERATION	**DAYS**	**CRUDEPROCESSED:**	**(MT)**
ONSTREAMDAYS	352.9	SOUTHGUJARAT	1273203
SHUTDOWNDAYS	13.1	NORTHGUJARAT	508584
PLAN	0.0	IMPORTED(LS)	
EMERGENCY	12.5		
IDLE	0.5	**TOTAL**	**1781787**

Table 5.9: CATALYTIC REFORMING UNIT (CRU)

OPERATION	**DAYS**	**FEEDPROCESSED:**	**(MT)**
ONSTREAMDAYS	318.0	BTRUN	**0**
SHUTDOWNDAYS	48.0	MSRUN	**303682**
PLAN	20.7	MIXEDRU	**0**
EMERGENCY	0.0		
IDLE	27.4	**TOTAL**	**303682**

Table 5.10: ATMOSPHERIC UNIT-4(AU-IV)

OPERATION	DAYS	CRUDE PROCESSED:	(MT)
ONSTREAMDAYS	354.3	SOUTHGUJARAT	29454
SHUTDOWNDAYS	11.8	BOMBAYHIGH	22348
PLAN	0.0	IMPORTED(LS)	190168
EMERGENCY	0.5	IMPORTED(HS)	207323
IDLE	11.3	**TOTAL**	**402671**

Table 5.11: VACUUM DISTILLATION UNIT (VDU)

OPERATION (MT)	DAYS	FEED PROCESSED:	
ONSTREAMDAYS	364.9	BOMBAYHIGH	0
SHUTDOWNDAYS	1.1	IMPORTED(LS)	0
PLAN	0.0	IMPORTED(HS)	1061868
EMERGENCY	0.7		
IDLE	0.5	**TOTAL**	**1061868**

Table 5.12: FLUIDIZED CATALYTIC CRACKING UNIT

OPERATION (MT)	DAYS	FEED PROCESSED:	
ONSTREAMDAYS	361.0	VGO	186848
SHUTDOWNDAYS	5.0	**TOTAL**	**186848**
PLAN	5.0		
EMERGENCY	0.0		
IDLE	0.0		

Table 5.13: ATMOSPHERIC UNIT-V (AU-V)

OPERATION (MT)	DAYS	FEEDPROCESSED:	
ONSTREAMDAYS	351.1	SOUTHGUJARAT	6883
SHUTDOWNDAYS	14.9	BOMBAYHIGH	18660
PLAN	0.0	IMPORTED(LS)	96984
EMERGENCY	0.0	IMPORTED(HS)	376539
IDLE	14.9	**TOTAL**	**388791**

MATERIAL BALANCE OF PROCESS UNITS:-

Table 5.14: Atmospheric Unit (1)

	MT	%wt
Input		
South Gujarat	1273203	71.5
North Gujarat	508584	28.5
Bombay High	0	0.0
Imported-LS	0	0.0
Total	**1781787**	**100.0**
Output		
Gas	2484	0.1
LPG	26234	1.5
K8Top	59025	3.3
K9Top	59500	3.3
K10Bottom	84096	4.7
K9Bottom	132157	7.4
SR Kerosene	206075	11.6
ATF component	115948	6.5
SR Gas Oil	283133	15.9
RCO	807502	45.3
Loss	5633	0.3
Total	**1781787**	**100.0**

Table 5.15: Atmospheric Unit (I1)

	MT	%wt
Input		
SouthGujarat	361736	20.3
NorthGujarat	647946	36.4
BombayHigh	336824	18.9
Imported-LS	433683	24.4
Total	**1780189**	**100.0**
Output		
Gas	2793	0.2
LPG	18377	1.0
K8TOP	45713	2.6
K9TOP	46081	2.6
K10BOTTOM	65312	3.7
K9BOTTOM	105852	5.9
SRKerosene	231465	13.0
ATFcomponent	56304	3.2
SRGasOil	295843	16.6
RCO	906703	50.9
Loss	5745	0.3
Total	**1780189**	**100.0**

Table 5.16: Atmospheric Unit (3):

	MT	%wt
Input		
SouthGujarat	29454	0.7
BombayHigh	22348	0.6
Imported-LS	1901681	47.2
Imported-HS	2073235	51.5
Total	**4026718**	**100**
Outpu		
t Gas	7792	0.2
LPG	53530	1.3
D02Naphtha	171289	4.3
C06Naphtha	379583	9.4
HYNaphtha	117866	2.9
SRKerosene	521830	13.0
Lt.GasOilHy	297602	7.4
.GasOilRCO	532949	13.2
Loss	1930387	47.9
Total	13890	0.3
	4026718	**100**

Table 5.17: Atmospheric Unit(4)

	MT	%wt
Input		
SouthGujarat	6883	0.2
BombayHigh	18660	0.5
Imported-	96984	2.5
lsImported-	3765392	96.8
hs**Total**	**3887919**	**100.0**
Outpu		
t Gas	4090	0.1
LPG	58903	1.5
Lt.Naphtha	480619	12.4
Hy.Naphtha	112690	2.9
SRKerosene	461758	11.9
SRGasOil	721839	18.6
RCO	2035072	52.3
Loss	12948	0.3
Total	**3887919**	**100.0**

Atmospheric unit(1,2,3,4)

Input		
SouthGujarat	1671276	11.7
NorthGujarat	3853580	27.0
BombayHigh	409606	2.9
Imported-LS	2479896	17.4
Imported-HS	5838627	41.0
Total	**14252985**	**100.0**
Slops	0	0.0
Total	**14252985**	**100.0**
Output		
Gas	19098	0.1
LPG	165805	1.2
Lt. Naphtha	1464080	10.3
HY Naphtha	442234	3.1
SRKerosene	1678077	11.8
ATFcomponent	172252	1.2
SRGasOil	2619727	18.4
RCO	7644277	53.6
Loss	47435	0.3
Total	**14252985**	**100.0**

Table 5.18: CATALYTIC REFORMING UNIT:-

	MT	%wt
MSQ		
Feed		
FCCGaoline	448860	51.7
SRNNaphtha	419747	48.3
Total	**868607**	**100.0**
H2	23728	2.7
Gas	33931	3.9
LPG	492	0.1
MeroxR/D	206211	23.7
LtReformate	166006	19.1
HyReformate	435908	50.2
Loss	2331	0.3
Total	**868607**	**100.0**

Table 5.19: MATERIALBALANCEOF PROCESS UNITS:-

Vacuum Distillation Unit (VDU):-

	MT	%wt
Feed	**1061868**	**100.00**
SlopOil	9330	0.9
Hy.HSD	84129	7.9
LVGO	201475.9	19.0
HVGO	211189.1	19.9
Slop Distillate	70107	6.6
VR	481912	45.4
Loss	3725	0.4
Total	**1061868**	**100.0**

Feed Preparation Unit:-

	MT	%wt
Feed	2480540	100.00
SlopOil	19009	0.77
Hy.HSD	262280	10.57
LVGO	520670	20.99
HVGO	554812	22.37
VR	1115084	44.95
Loss	8685	0.35
Total	**2480540**	**100**

Fluid Catalytic cracking Unit:-

	MT	%wt
Feed		
INDVGO	0	0.0
mixed VGO	1836567	98.3
IMPHSVGO	0	0.0
VDU HSD	0	0.0
Total	**1868489**	**100**
Gas	67343	3.6
CrackedLPG	243217	13.0
Gasoline	642221	34.4
HyNaphtha	204086	10.9
LCO	485897	26.0
HCO	0	0.0
CLO	142378	7.6
Coke	76795	4.1
Loss	6552	0.4
Total	**1868489**	**100**

	NOS	MT
PRODUCTION		196954
DISPATCH BULK-TTL	9511	157234
PACK-DRUMS	214498	33446
Sub total		**190680**

Table 5.20: OIL MOVEMENT AND STORAGE:-

LPG:

	NOS	MT
PRODUCTION		544338
DISPATCH	0	0
WAGONS		39687
PPFS		502017
DUMAD:PPL		**541704**
total		

BITUME:

GRADE: VG-30

	NOS	MT
PRODUCTION		333042
DISPATCH BULK-TTL	17979	303487
PACK-DRUMS	189395	29555
Sub total		**333042**

GRADE: VG-10

PRODUCTION		**546149**
BULK-TTL	27490	476874
PACK-	403893	63001
DRUMS		539875
Total		

6. DATA ANALYSIS, INTERPRETATION AND CONCLUSION:

Current refining scenario is fraught with tough competition, strict Government laws and environmental regulations. Optimization, ERP, reliability centered maintenance, risk based inspection, corporate sustainability reporting are the challenges for survival and sustainability in the business. It also requires rigorous monitoring and analysis of performances and applying corrective adjustment to the actual operations.

In this we will try to optimize the refinery constraints under different condition depending on the different variables and hence will try to find out the profit rate of the refinery and thus give various recommendations on how to increase it and so on.

For this we have used the linear programming method to optimize the operations of a simple refinery and try to find the constraints effecting the model formulation. This will include

- Developing the objective function from the cost or profit of the process or plant
- the constraint equations from the availability of raw materials
- the demand for products in the market
- Equipment capacity limitations for the different units in the refinery.
- Conversion capabilities of the different processing units.

In this we have considered the prototype of a simple petroleum refinery which will be used to illustrate these procedures. This prototype of this refinery was provided by the company itself as it was not feasible to optimize the entire refinery.

Here the main aim was to generate an optimal solution will be obtained using a large linear programming code to illustrate the use of one of these types of programs available on a large system which will then be subjected to some optimizing tools. After that the optimal solution of the general linear programming problem will be extended to a sensitivity analysis, and these results will be illustrated using the information computed from the large linear programming code corresponding to the prototype refinery.

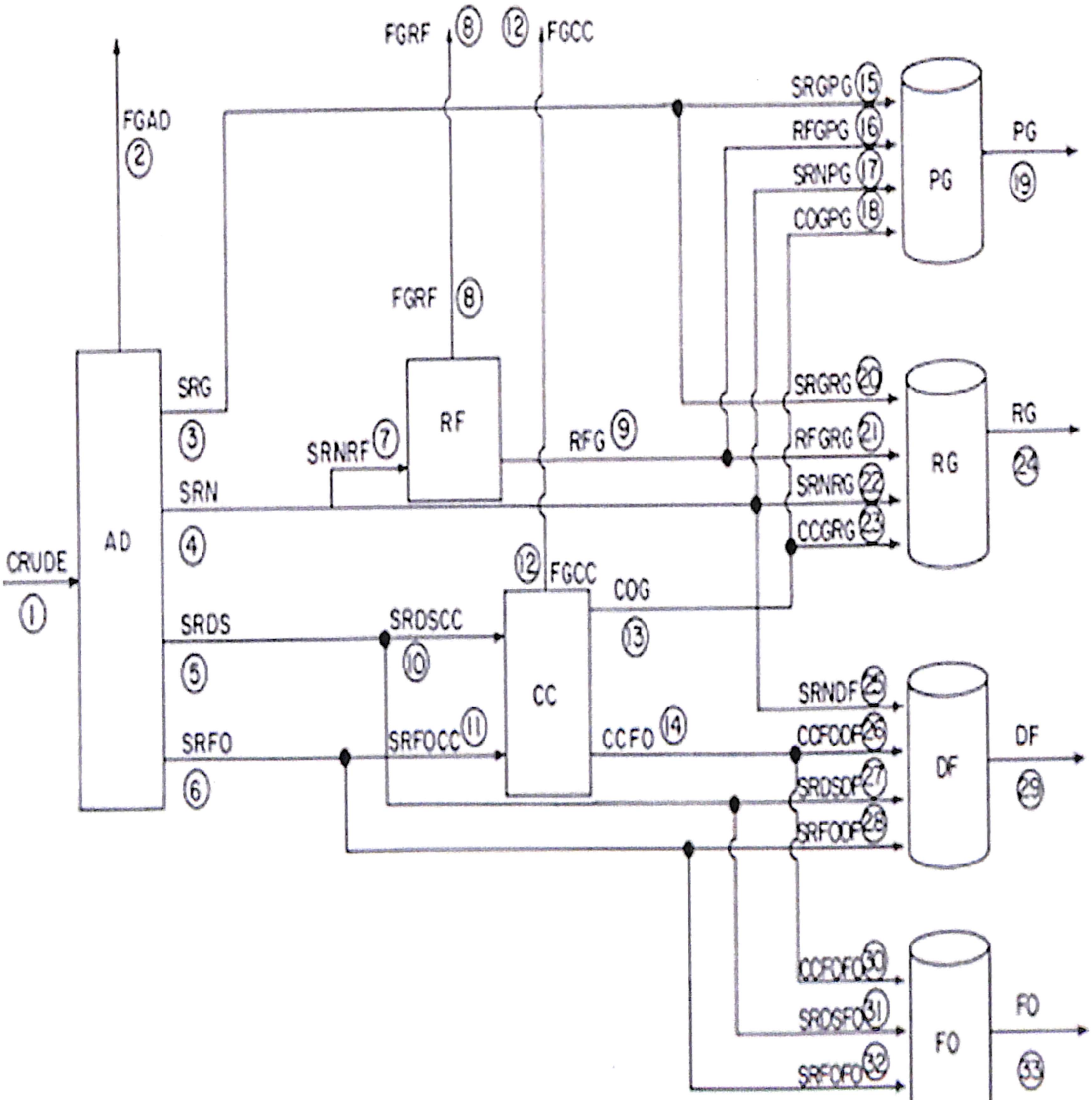


Fig 6.1: Process Flow Diagram of Simple Refinery

The figure shows the flow diagram for the simple petroleum refinery which was provided to us by the organization to optimize its operation and find out the profitability content related to this simple refinery.

There are only three process units in this refinery and these are

- Crude oil atmospheric distillation column
- Catalytic cracking unit
- Catalytic reformer

- The crude oil distillation column separates the crude oil into five streams: are fuel gas, straight-run gasoline, straight-run naphtha, straight-run distillate, and straight run fuel oil.
- Part of the straight run naphtha is processed through the catalytic reformer to improve its quality, i.e., increase the octane number.
- Parts of the straight run distillate and straight-run fuel oil are processed through the catalytic cracking unit to improve their quality so they can be blended into gasoline.
- The refinery produces four products: premium gasoline, regular gasoline, diesel fuel and fuel oil.

For this simple refinery there are 33 flow rates for which the optimal values have to be determined. This makes it highly difficult to solve large linear programming problems.

The formulation of the objective function is quite straight-forward but the major accounting problem arises in keeping track of a large number of variables, and the collection of reliable data to go with these variables which is really very tedious and time consuming.

Table 6.1: Names of each of the process streams:-

CRUDE
FGAD
SRG
SRN
SRDS
SRFO
SRNRF
FGRF
RFG
SRDSCC
SRFOCC
FGCC
CCG
CCFO
SRGPG
RFGPG
SRNPG
CCGPG
PG
SRGRG
RFGRG
SRNRG
CCGRG
RG
SRNDF
CCFODF
SRDSDF
SRFODF
DF
CCFOFO
SRDSFO
SRFOFO
FO

They are the flow rates of the streams as given in the diagram.

The following table lists the capacities, operating costs, process stream, mass yields, and volumetric yields for the three process units in the refinery. These are typical of a medium size refinery which was provided by the organization itself:-

UNIT	CAPACITY	OPERATING COST	INPUT	OUTPUT	MASS YIELD	VOLUMETRIC YIELD
ADU	100,000	1$/BARREL	CRUDE	FGAD	.029	35.42
				SRG	.236	.270
				SRN	.223	.237
				SRDS	.087	.087
				SRFO	.426	.372
C R	25000	8.32	SRNRF	FGRF	.138	158.7
				RFG	.862	.928
C C	30000	7.326	SRDSCC	FGCC	.273	336.9
				CCG	.536	.619
				CCFO	.191	.198
			SRFOCC	FGCC	.277	386.4
				CCG	.526	.668
				CCFO	.196	.220

The quality specification and physical properties for the different processed streams are given by the organization for this particular refinery:-

STREAM	OCTANE NUMBER	VAPOUR PRESSURE	DENSITY	SULPHUR CONTENT
PG	>=93	=<12.7	-	-
RG	>=87	=<12.7	-	-
DF	-	-	=<306	=<.5
FO	-	-	=<352	=<3
SRG	78.5	18.4	-	-
RFG	104	2.57	-	-
SRN	65	6.5	272	.283
CCG	83	6.90	-	-
CCFO	-	-	294	.353
SRDS	-	-	292	.526
SRFO	-	-	295	.980

The crude oil cost and the product sales prices are given in the table and the data's in the table were obtained from the refinery journal of the organization:-

CRUDE COST - 110 $/BARREL

Premium Gasoline cost - 151.0488 $/barrel

Regular gasoline - 145.45 $/barrel

Diesel fuel - 134 .26 $/barrel

Fuel oil – 43.7562 $/barrel

Fuel gas - .06543 $/barrel

The information which is provided in the above table will help us to formulate the objective equation and also the constraints equation for the linear programming refinery optimization model. The different constraints equation is formulated and the optimization is done on the basis of the products purchased and sold in the market. Generally the linear programming optimization models are solved in matrix form by incorporating the different details which we have derived from the data's collected in the earlier case.

For our observation we have chosen to maximize the profitability of the refinery on the basis of the purchasing cost of the cost, operating cost of the different components and finally the selling price of the individual products. The sales prices are shown as positive, and the cost are shown as negative, so the problem is formulated to maximize the profit. These numbers were taken from the data provided to us and it was convenient to combine the crude cost ($109.00/barrel) with the operating cost of the crude oil atmospheric distillation column ($1.00/barrel) to show a total cost of $110.00 per barrel of crude oil processed. Consequently, the other values for the different input and outputs were formulated to obtain the objective function:-

OBJECTIVE FUNCTION:-

-110CRUDE + .06543 FGAD -8.325 SRNRF + .06543 FGRF –7.326 SRDSCC -7.326 SRFOCC + .06543 FGCC + 151.0488 PG + 145.4544 RG + 134.2656 DF + 43.7562 FO

CONSTRAINTS:-

Material balancing:-

These are the first set of constraints obtained by doing balance at points at which a stream splits into two and blend into products. The stream to be divided is given a coefficient of 1, and the resulting streams have a coefficient -1. For example, the straight-run naphtha from the crude oil distillation is split into four streams. One is sent to the catalytic reformer, and the other three are used in blending premium gasoline, regular gasoline, and diesel fuel. The equation for this split is:

SRN - SRNRF - SRNPG - SRNRG - SRNDF = 0

Correspondingly the other equation of material balancing was formulated using the above mentioned method:-

- SRN – SRNRF –SRNPG – SRNRG – SRNDF = 0
- SRG – SRGPG – SRGRG = 0
- SRDS – SRDSCC – SRDSDF – SRDSFO =0
- SRFO – SRFOCC – SRFODF – SRFDFO =0
- RFG – RFGPG – RFGRG =0
- CCG – CCGPG – CCGRG =0
- CCFO – CCFODF – CCFOFO =0

Quality constraints (assuming that the qualities linearly blend)

Now the crude availability constraint limiting the refinery is around 110,000 barrels/day. This is followed by the four quantity and quality constraints associated with each product. These are the daily production and blending requirements and two quality constraints. These have been extracted from the data provided in the above tables. The minimum production constraint states that the refinery must produce at least 10,000 bbl/day of premium gasoline to meet the company's marketing division's requirements. The blending constraints state that the sum of the streams going to produce premium gasoline must equal the daily production of premium gasoline. The quality constraints use linear blending, and the sum of each component weighted by its quality must meet or exceed the quality of the product. This is illustrated with premium gasoline octane rating blending constraint, which is written as the following

$$78.5\ SRGPG + 104\ RFGPG + 65\ SRNPG + 93.7\ CCGPG - 93PG >= 0$$

Now corresponding inequality constraints are specified in the above tables are used and same procedure is used for formulating the equation for premium gasoline vapor pressure, regular gasoline octane number and vapor pressure, diesel fuel density and sulfur content, and fuel oil density and sulfur content which are given as follows :-

<u>For Premium Gasoline:-</u>

- $PG >= 10{,}000$ (MARKET DEMAND CONSTRAINT)
- $SRGPG + RFGPG + SRNPG + CCGPG - PG = 0$ (PG Blending)
- $78.5\ SRGPG + 104\ RFGPG + 65\ SRNPG + 93.7\ CCGPG - 93PG >= 0$ (Octane Blending)
- $18.4\ SRGPG + 2.57\ RFGPG + 6.54\ SRNPG + 6.90\ CCGPG - 12.7\ PG <= 0$ (Vapour Pressure)

For Regular Gasoline:-

- RG >= 10,000 (Market Demand)
- SRGRG + RFGRG + SRNRG + CCGRG – RG =0 (RG Blending)
- 78.5 SRGRG + 104 RFGRG + 65 SRNRG +93.7 CCGRG – 87 RG >= 0 (Octane Blending)
- 18.4 SRGRG + 2.57 RFGRG + 6.54 SRNRG + 6.90 CCGRG – 12.7 RG <= 0

For Diesel Fuel:-

- DF >= 10,000 (Market Demand)
- SRNDF + CCFODF + SRDSDF + SRFODF – DF = 0 (DF Blending)
- 272 SRNDF + 294.4 CCFODF + 292 SRDSDF + 295 SRFODF – 306 DF <=0 (Density Specification)
- .283 SRNDF + .353 CCFODF + .526 SRDSDF + .980 SRFODF - .5DF <= 0 (Sulphur Specification)

For Fuel Oil:-

- FO >= 10,000 (Market Demand)
- CCFOFO + SRDSFO + SRFOFO – FO = 0 (FO Blending)
- 294.4 CCFOFO + 292 SRDSFO + 295 SRFOFO – 352 FO <= 0 (Density Specification)
- .353 CCFOFO + .526 SRDSFO + .980 SRFOFO – 3 FO <=0

Other constraints:-

The next set of data is the description of the operation of the process unit using the volumetric yield. Referring to the volumetric yields for the crude oil distillation column, this data states that 35.42 times the volumetric flow rate of crude produces the flow rate of fuel gas from the distillation column, FGAD :-

35.42 CRUDE - FGAD = 0

Corresponding yields of the other products from the crude oil distillation are determined the same way. For the catalytic reformer the yield of the Quantity and Quality Constraints for the Refinery Products fuel gas (FGRF) and the reformer gasoline (RFG) are given by the following equations:

158.7 SRNRF - FGRF = 0

0.928 SRNRF - RFG = 0

Now the compiled data of all the units is provided subjected to the volumetric yield and the quality and quantity constraints which are provided as follows:-

For each unit:

For CDU (CRUDE DISTILLATION UNIT):-

CRUDE <= 100,000

- 35.42 CRUDE – FGAD = 0
- .270 CRUDE – SRG = 0
- .237 CRUDE – SRN = 0
- .087 CRUDE – SRDS = 0
- .372 CRUDE – SRFO = 0

For the Reformer:-

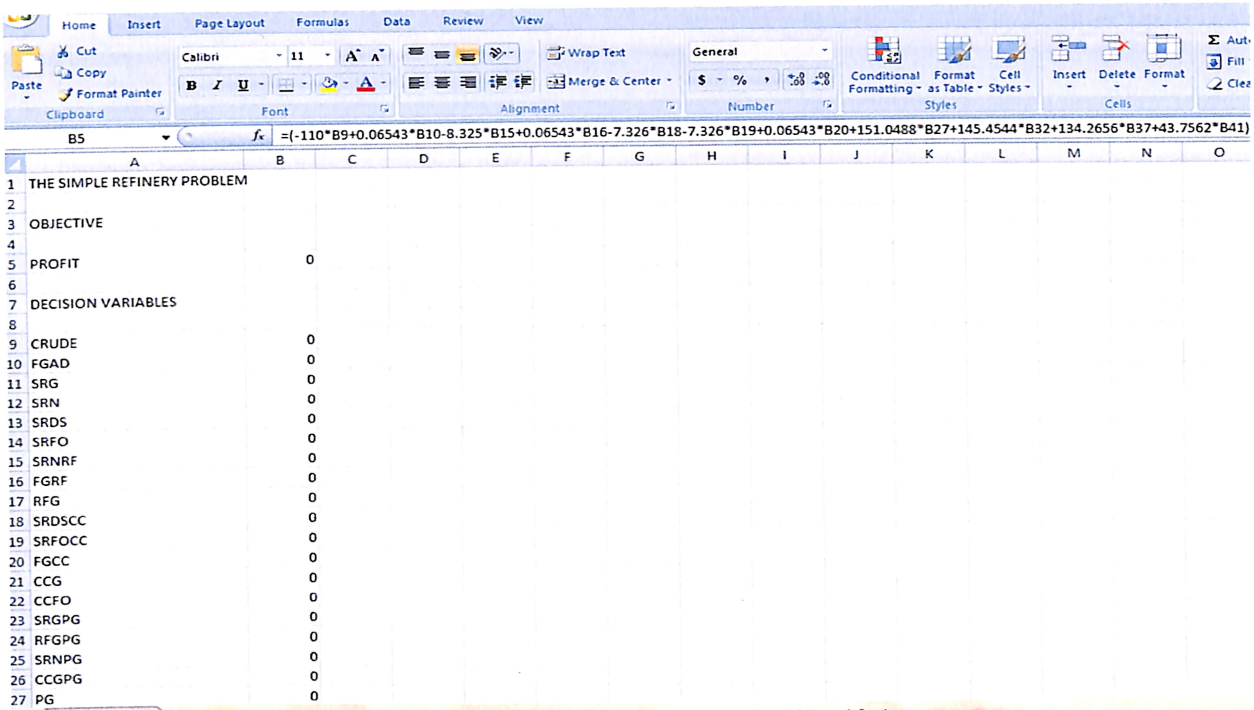
- SRNRF <= 25,000
- 158.7 SRNRF – FGRF = 0
- .928 SRNRF – RFG = 0

For the Catalytic Cracking Unit:-

- SRDSCC + SRFOCC <= 30,000
- 336.9 SRDSCC + 336.8 SRFOCC = FGCC
- .619 SRDSCC + .688 SRFOCC = CCG
- .189 SRDSCC + .220 SRFOCC = CCFO

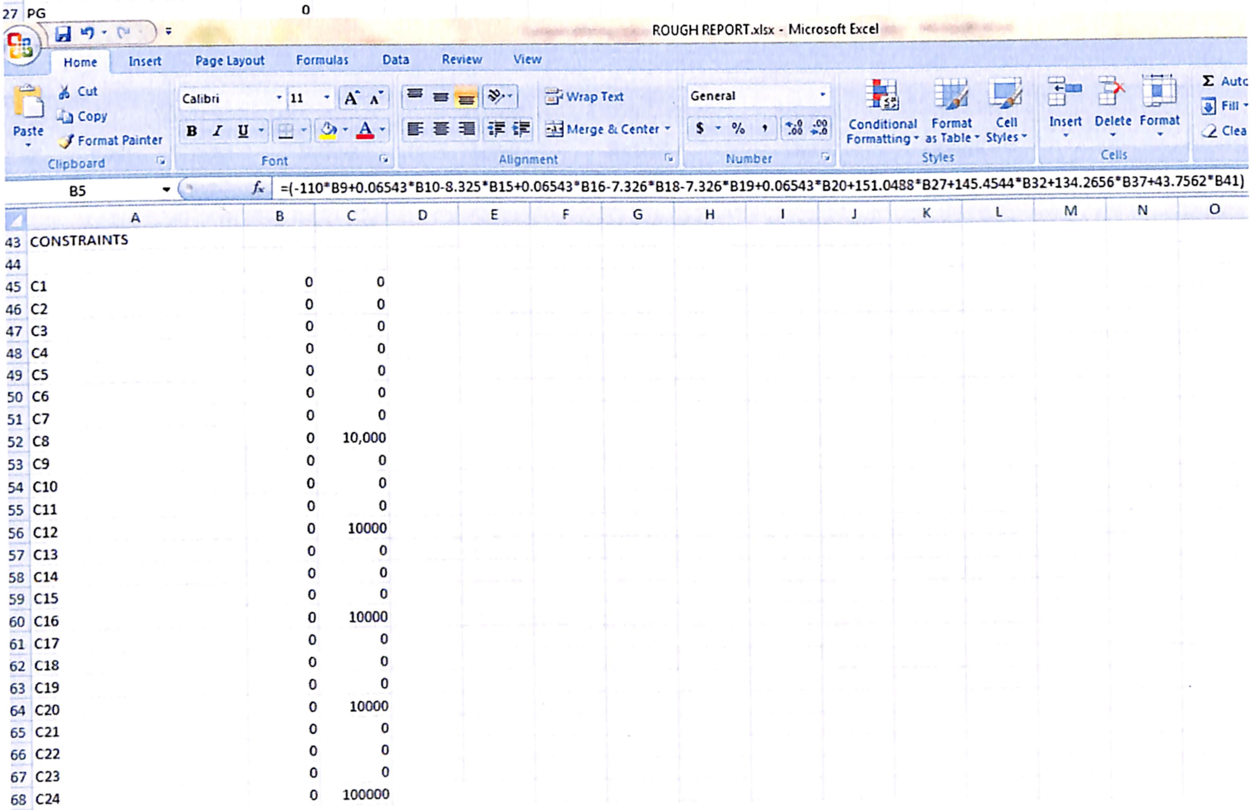
Excel spreadsheet solution for the given profit maximization:-

Entry of data for the different constraints and formulation of the objective equation:-



B5 =(-110*B9+0.06543*B10-8.325*B15+0.06543*B16-7.326*B18-7.326*B19+0.06543*B20+151.0488*B27+145.4544*B32+134.2656*B37+43.7562*B41)

	A	B
1	THE SIMPLE REFINERY PROBLEM	
2		
3	OBJECTIVE	
4		
5	PROFIT	0
6		
7	DECISION VARIABLES	
8		
9	CRUDE	0
10	FGAD	0
11	SRG	0
12	SRN	0
13	SRDS	0
14	SRFO	0
15	SRNRF	0
16	FGRF	0
17	RFG	0
18	SRDSCC	0
19	SRFOCC	0
20	FGCC	0
21	CCG	0
22	CCFO	0
23	SRGPG	0
24	RFGPG	0
25	SRNPG	0
26	CCGPG	0
27	PG	0

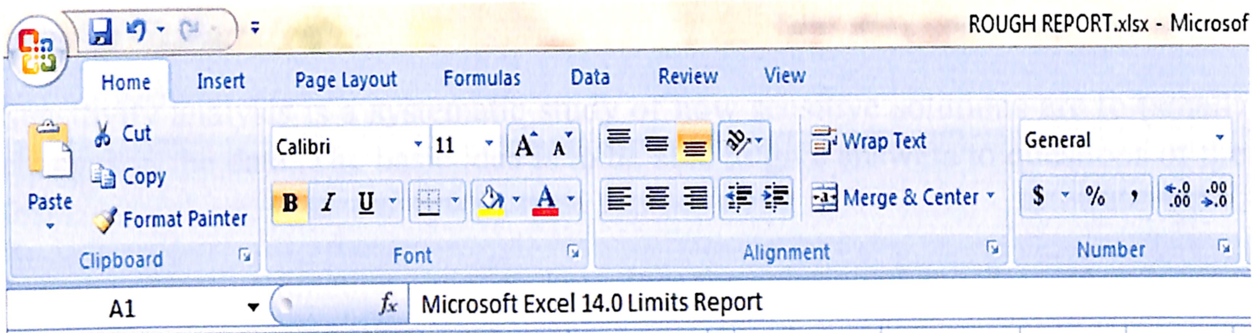


ROUGH REPORT.xlsx - Microsoft Excel

B5 =(-110*B9+0.06543*B10-8.325*B15+0.06543*B16-7.326*B18-7.326*B19+0.06543*B20+151.0488*B27+145.4544*B32+134.2656*B37+43.7562*B41)

	A	B	C
43	CONSTRAINTS		
44			
45	C1	0	0
46	C2	0	0
47	C3	0	0
48	C4	0	0
49	C5	0	0
50	C6	0	0
51	C7	0	0
52	C8	0	10,000
53	C9	0	0
54	C10	0	0
55	C11	0	0
56	C12	0	10000
57	C13	0	0
58	C14	0	0
59	C15	0	0
60	C16	0	10000
61	C17	0	0
62	C18	0	0
63	C19	0	0
64	C20	0	10000
65	C21	0	0
66	C22	0	0
67	C23	0	0
68	C24	0	100000

Next we have formulated constraints and found out the limit report which provides us with the maximum profit which the refinery can generate and also the upper and the lower limit for the different variables in the refinery set up and also their objective results



Microsoft Excel 14.0 Limits Report
Worksheet: [ROUGH REPORT.xlsx]Sheet1
Report Created: 7/17/2013 12:11:00 PM

	Objective	
Cell	Name	Value
$B$5	PROFIT	2229835.536

	Variable		Lower	Objective	Upper	Objective
Cell	Name	Value	Limit	Result	Limit	Result
$B$9	CRUDE	100000	#N/A	#N/A	#N/A	#N/A
$B$10	FGAD	3542000	3542000	2229835.536	3542000	2229835.536
$B$11	SRG	27000	27000	2229835.536	27000	2229835.536
$B$12	SRN	23700	23700	2229835.536	23700	2229835.536
$B$13	SRDS	8700	8700	2229835.536	8700	2229835.536
$B$14	SRFO	37200	37200	2229835.536	37200	2229835.536
$B$15	SRNRF	23700	#N/A	#N/A	#N/A	#N/A
$B$16	FGRF	3761190	3761190	2229835.536	3761190	2229835.536
$B$17	RFG	21993.6	21993.6	2229835.536	21993.6	2229835.536
$B$18	SRDSCC	0	-7.45786E-11	2229835.536	-7.45786E-11	2229835.536
$B$19	SRFOCC	30000	#N/A	#N/A	#N/A	#N/A
$B$20	FGCC	10104000	10104000	2229835.536	10104000	2229835.536
$B$21	CCG	20640	20640	2229835.536	20640	2229835.536
$B$22	CCFO	6600	6600	2229835.536	6600	2229835.536

Sensitivity analysis:-

Sensitivity analysis is a systematic study of how sensitive solutions are to (small) changes in the data. The basic idea is to be able to give answers to questions of the form:

1. If the objective function changes, how does the solution change?
2. If resources available change, how does the solution change?
3. If a constraint is added to the problem, how does the solution change?

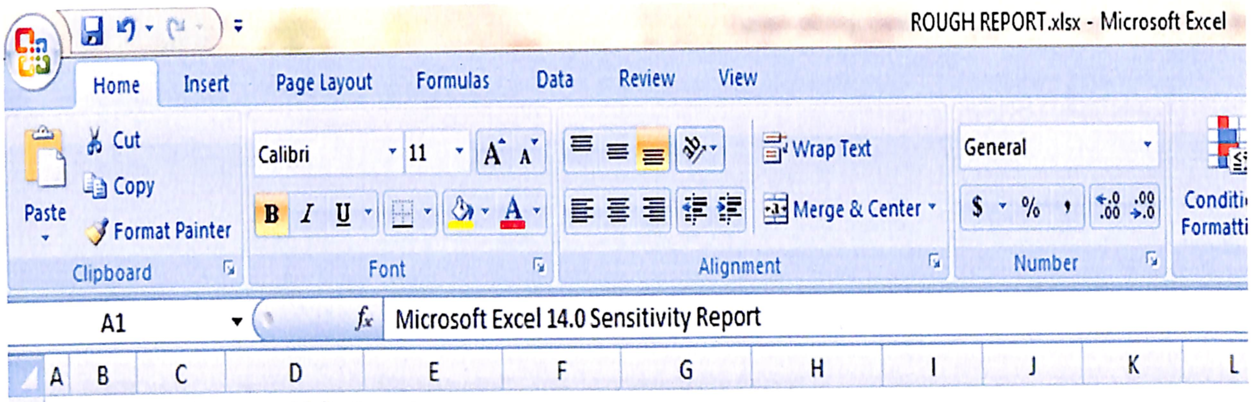
Analysis:-

The non-basic variables are SRDSCC, SRNPG, SRNRG, SRNDA, SRFODF and SRDSFO. The optimal values of these variables is zero is depicted in answer report. We can see that the allowable decrease for the coefficient of these variables in the objective function is 10^{30} which is actually tending to infinity and it can be decreased to any extent without having any effect on the original optimal solution.

But increasing the coefficient of these variables in the objective function to a large extent will change the original optimal solution.

Sensitivity helps us to analyze which variables contribute to a large extent in the objective function which is the maximization of the refinery profit.

Sensitivity Analysis of the above problem by excel spreadsheet solver



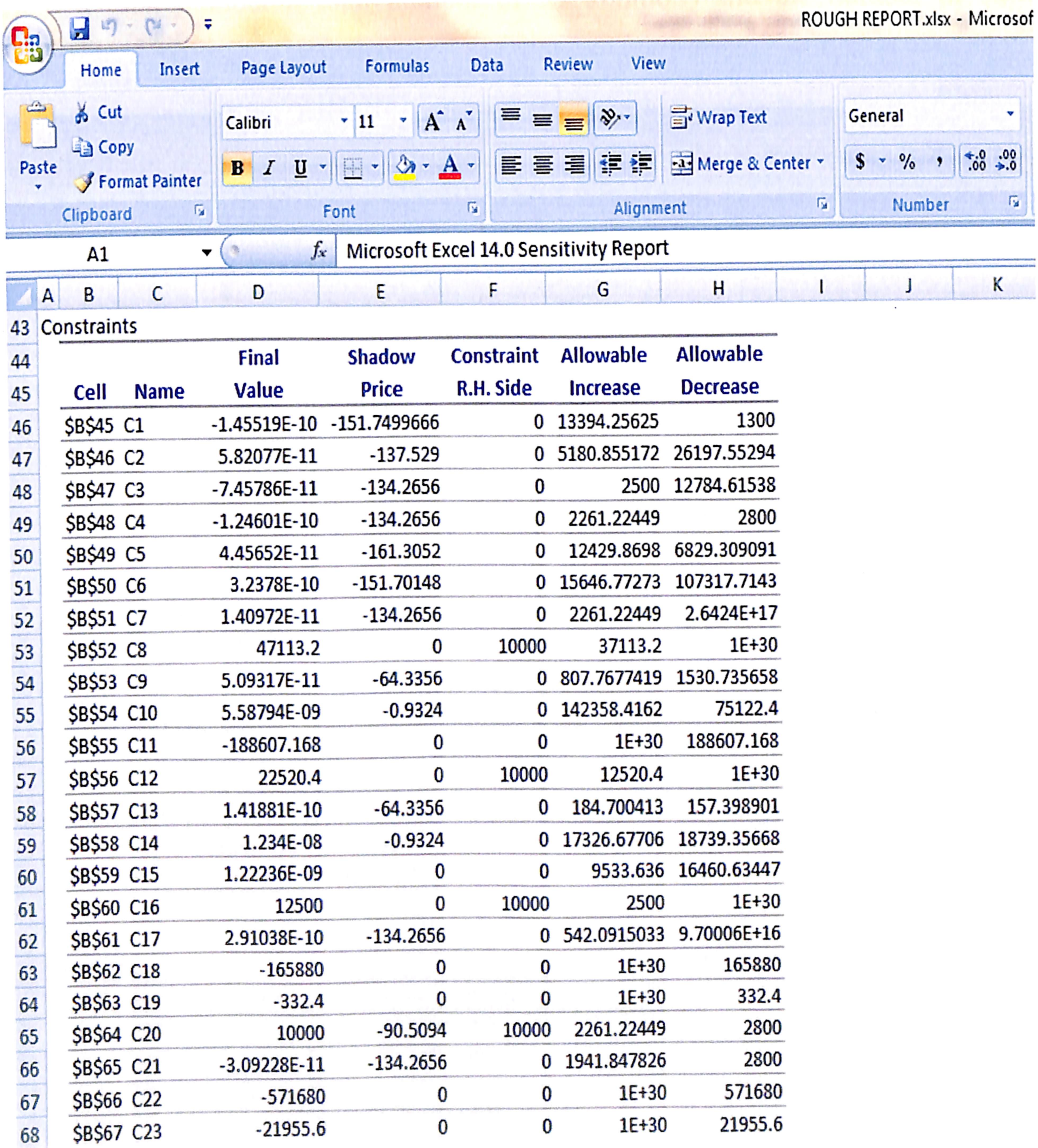
Microsoft Excel 14.0 Sensitivity Report
Worksheet: [ROUGH REPORT.xlsx]Sheet1
Report Created: 7/17/2013 12:10:59 PM

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$B$9	CRUDE	100000	0	-110	1E+30	27.04301308
$B$10	FGAD	3542000	0	0.06543	0	0.76349557
$B$11	SRG	27000	0	0	0	100.1593077
$B$12	SRN	23700	0	0	0	114.1055404
$B$13	SRDS	8700	0	0	6.0467E+15	310.8392309
$B$14	SRFO	37200	0	0	0	72.69627173
$B$15	SRNRF	23700	0	-8.325	0	17.4843666
$B$16	FGRF	3761190	0	0.06543	0	0
$B$17	RFG	21993.6	0	0	0	18.84091228
$B$18	SRDSCC	0	-14.62309272	-7.326	14.62309272	1E+30
$B$19	SRFOCC	30000	0	-7.326	1E+30	14.35427424
$B$20	FGCC	10104000	0	0.06543	0	0
$B$21	CCG	20640	0	0	180.3636364	20.8637707
$B$22	CCFO	6600	0	0	1E+30	65.24670109
$B$23	SRGPG	13852.04675	0	0	0	0
$B$24	RFGPG	17239.98743	0	0	0	0
$B$25	SRNPG	0	-26.8083666	0	26.8083666	1E+30
$B$26	CCGPG	16021.16582	0	0	0	0

Constraints:-

It gives a list of the slack and the surplus variable.



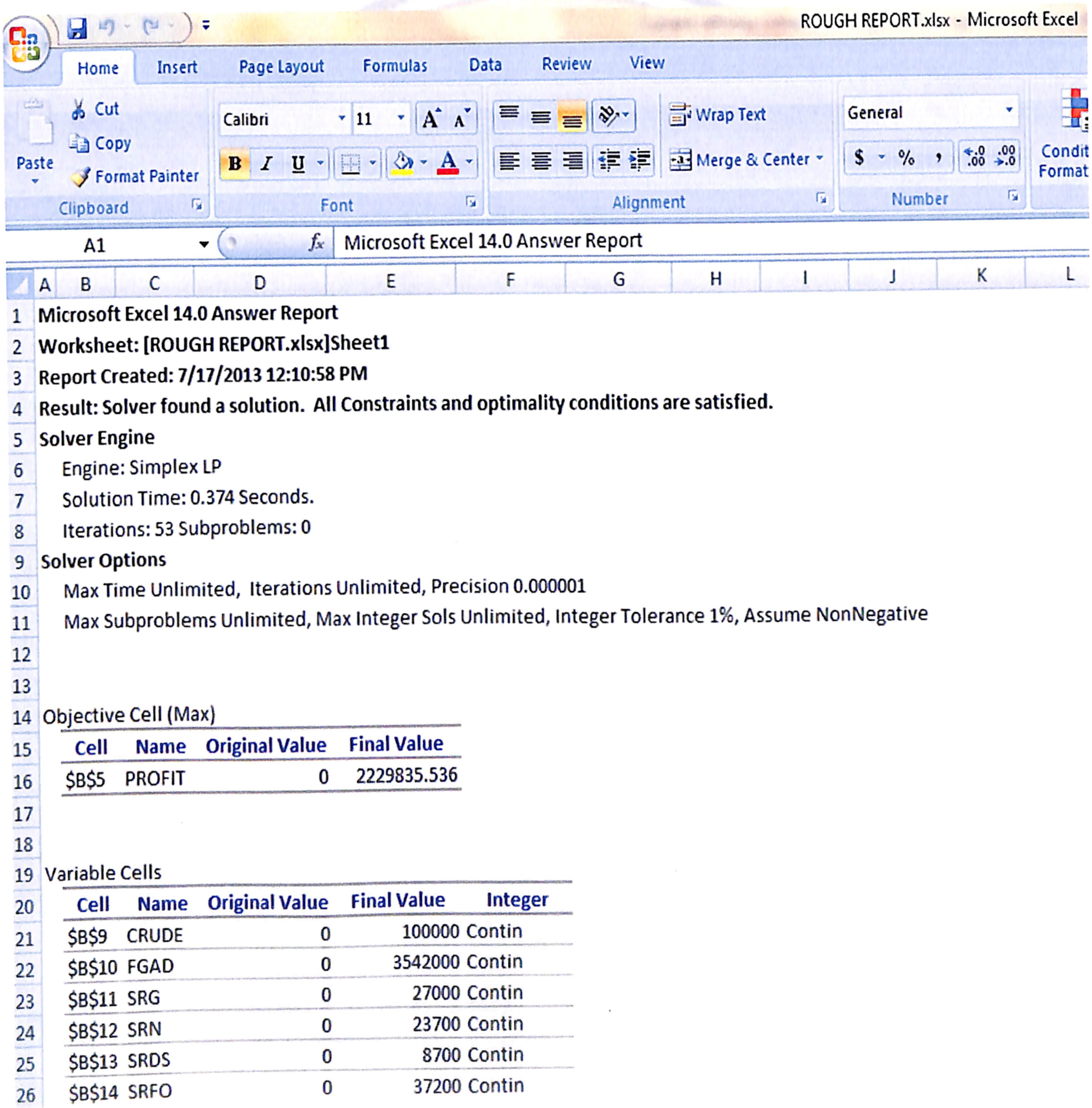
Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$B$45	C1	-1.45519E-10	-151.7499666	0	13394.25625	1300
$B$46	C2	5.82077E-11	-137.529	0	5180.855172	26197.55294
$B$47	C3	-7.45786E-11	-134.2656	0	2500	12784.61538
$B$48	C4	-1.24601E-10	-134.2656	0	2261.22449	2800
$B$49	C5	4.45652E-11	-161.3052	0	12429.8698	6829.309091
$B$50	C6	3.2378E-10	-151.70148	0	15646.77273	107317.7143
$B$51	C7	1.40972E-11	-134.2656	0	2261.22449	2.6424E+17
$B$52	C8	47113.2	0	10000	37113.2	1E+30
$B$53	C9	5.09317E-11	-64.3356	0	807.7677419	1530.735658
$B$54	C10	5.58794E-09	-0.9324	0	142358.4162	75122.4
$B$55	C11	-188607.168	0	0	1E+30	188607.168
$B$56	C12	22520.4	0	10000	12520.4	1E+30
$B$57	C13	1.41881E-10	-64.3356	0	184.700413	157.398901
$B$58	C14	1.234E-08	-0.9324	0	17326.67706	18739.35668
$B$59	C15	1.22236E-09	0	0	9533.636	16460.63447
$B$60	C16	12500	0	10000	2500	1E+30
$B$61	C17	2.91038E-10	-134.2656	0	542.0915033	9.70006E+16
$B$62	C18	-165880	0	0	1E+30	165880
$B$63	C19	-332.4	0	0	1E+30	332.4
$B$64	C20	10000	-90.5094	10000	2261.22449	2800
$B$65	C21	-3.09228E-11	-134.2656	0	1941.847826	2800
$B$66	C22	-571680	0	0	1E+30	571680
$B$67	C23	-21955.6	0	0	1E+30	21955.6

Final answer report:-

In this optimization, the most optimum or the maximized solution for the refinery profit margin is $2229835.536.

Here a total number a total number of 53 iterations and the number of sub-problems is zero.



Microsoft Excel 14.0 Answer Report
Worksheet: [ROUGH REPORT.xlsx]Sheet1
Report Created: 7/17/2013 12:10:58 PM
Result: Solver found a solution. All Constraints and optimality conditions are satisfied.
Solver Engine
Engine: Simplex LP
Solution Time: 0.374 Seconds.
Iterations: 53 Subproblems: 0
Solver Options
Max Time Unlimited, Iterations Unlimited, Precision 0.000001
Max Subproblems Unlimited, Max Integer Sols Unlimited, Integer Tolerance 1%, Assume NonNegative

Objective Cell (Max)

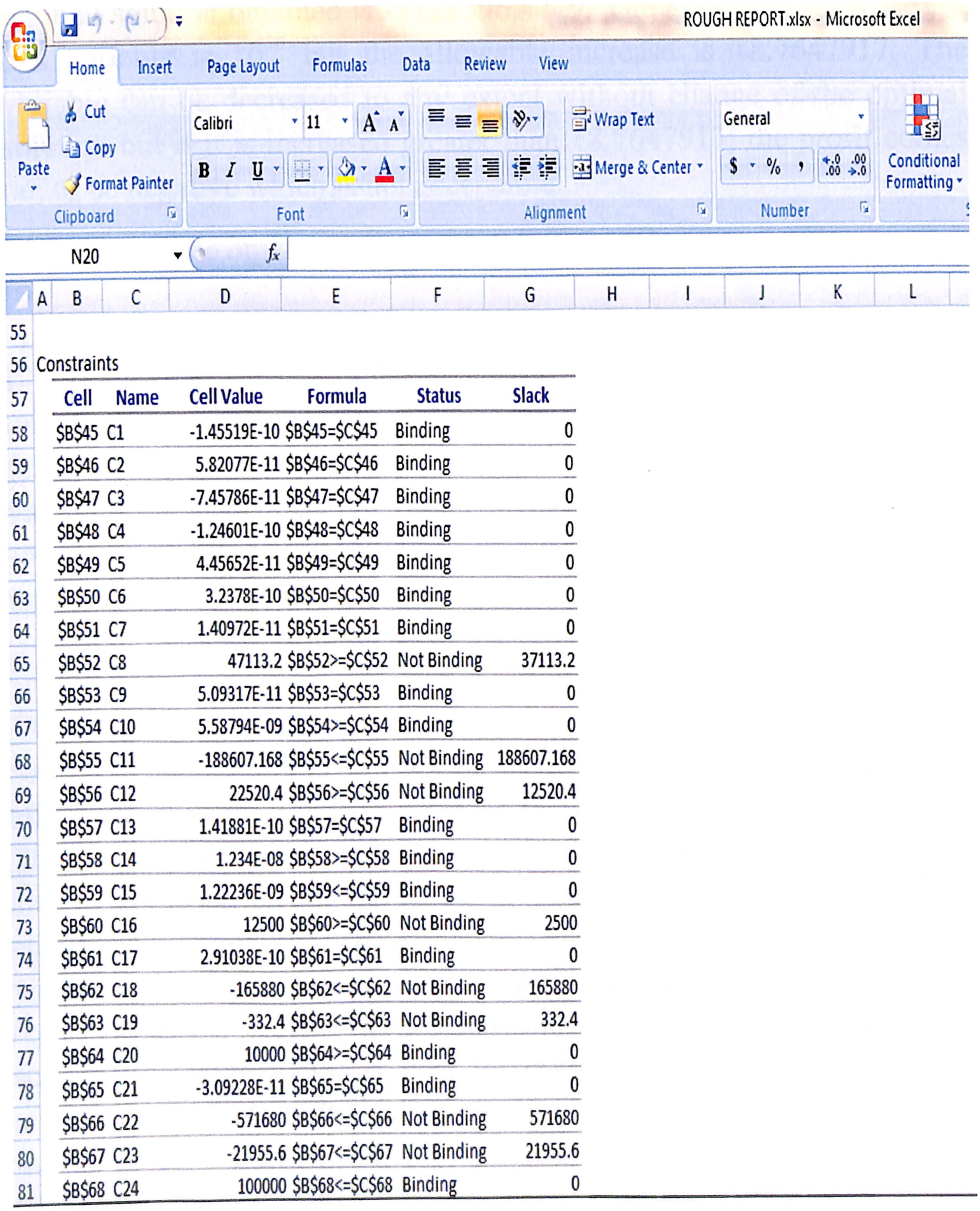
Cell	Name	Original Value	Final Value
$B$5	PROFIT	0	2229835.536

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$B$9	CRUDE	0	100000	Contin
$B$10	FGAD	0	3542000	Contin
$B$11	SRG	0	27000	Contin
$B$12	SRN	0	23700	Contin
$B$13	SRDS	0	8700	Contin
$B$14	SRFO	0	37200	Contin

Constraints:-

It gives a list of the slack and the surplus variable.



Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$B$45	C1	-1.45519E-10	$B$45=$C$45	Binding	0
$B$46	C2	5.82077E-11	$B$46=$C$46	Binding	0
$B$47	C3	-7.45786E-11	$B$47=$C$47	Binding	0
$B$48	C4	-1.24601E-10	$B$48=$C$48	Binding	0
$B$49	C5	4.45652E-11	$B$49=$C$49	Binding	0
$B$50	C6	3.2378E-10	$B$50=$C$50	Binding	0
$B$51	C7	1.40972E-11	$B$51=$C$51	Binding	0
$B$52	C8	47113.2	$B$52>=$C$52	Not Binding	37113.2
$B$53	C9	5.09317E-11	$B$53=$C$53	Binding	0
$B$54	C10	5.58794E-09	$B$54>=$C$54	Binding	0
$B$55	C11	-188607.168	$B$55<=$C$55	Not Binding	188607.168
$B$56	C12	22520.4	$B$56>=$C$56	Not Binding	12520.4
$B$57	C13	1.41881E-10	$B$57=$C$57	Binding	0
$B$58	C14	1.234E-08	$B$58>=$C$58	Binding	0
$B$59	C15	1.22236E-09	$B$59<=$C$59	Binding	0
$B$60	C16	12500	$B$60>=$C$60	Not Binding	2500
$B$61	C17	2.91038E-10	$B$61=$C$61	Binding	0
$B$62	C18	-165880	$B$62<=$C$62	Not Binding	165880
$B$63	C19	-332.4	$B$63<=$C$63	Not Binding	332.4
$B$64	C20	10000	$B$64>=$C$64	Binding	0
$B$65	C21	-3.09228E-11	$B$65=$C$65	Binding	0
$B$66	C22	-571680	$B$66<=$C$66	Not Binding	571680
$B$67	C23	-21955.6	$B$67<=$C$67	Not Binding	21955.6
$B$68	C24	100000	$B$68<=$C$68	Binding	0

Analysis of the answer report:-

If we change of SRNRF in the objective function from -8.325 to -90, the optimal solution obtained is -$122596.4719. The allowable decrease for this variable is 10^{30} but the allowable increase is 18.7647917. The variable can be decreased to any extent without change of the optimal solution but if it is increased greater than 18.7647917; the profit comes out to be negative which is not acceptable.

The terms in the objective function

If we change of SRNRF in the objective function from -8.325 to -90, the optimal solution obtained is -$122596.4719. The allowable decrease for this variable is 10^{30} but the allowable increase is 18.7647917. The variable can be decreased to any extent without change of the optimal solution but if it is increased greater than 18.7647917; the profit comes out to be negative which is not acceptable.

The non basic variables are SRDSCC, SRNPG, SRNRG, SRNDF, SRFODF and SRDSFO. As we can see from the sensitivity report the allowable decrease for each of them is 10^{30} which is actually infinity. This implies the co-efficient of these variables can be increased up to any extent without any effect on the optimal solution which is the maximized profit but the allowable increase for these non-basic variables is finite value. In the objective function we have two components i.e. (-7.326*SRDSCC) and (-8.325*SRNRF). These are actually the total operating cost for catalytic cracking and reforming unit. From the sensitivity report we can see that the allowable increase for the co-efficient of SRNRF is 0 and the allowable decrease is 17.48

which are both finite values. This implies that for maximum profit to worker the operating cost for both the units cannot be increased and it can be decreased only up to a certain limit.

The sensitivity analysis report actually tells us which components in the objective function have a greater contribution towards maximizing profit for fuel oil i.e. FO. The allowable decrease is 10^{30} and allowable increase is 90.50. Within this range the optimal solution will not change.

In case of SRFOFO the allowable increase and decrease are both '0'. This variable does not contribute anything in the objective function. As we can see from the objective function there is no SRFOFO term. Similarly, we can see for CCFOFO, CCFODF, CCGRG, SRGRG and CCGPG the allowable increase and decrease is '0'. For the variable 'CRUDE', the allowable increase is 10^{30} which is infinity and the allowable decrease is 27.04.

If we consider the constraint C8, the right hand side represents the minimum market demand for premium gasoline. The allowable decrease for this demand is 10^{30} and the allowable increase is 37113.20. In order to get the optimum profit, i.e. the maximum profit the minimummarket demand should be between these two values. If we consider the constraint C12 which represents the minimum demand for regular gasoline, we can see that the minimum market demand should be between 12520.40 and 10^{30} for maximum profit. We can see from the C24 constraint which represents the maximum capacity for crude distillation unit that increasing this maximum capacity for about 5485.2320 barrels per day and decreasing this capacity by about 5446.62 barrels per day yield maximum profit.

For constraint C30 which represents the maximum capacity to the reformer unit we can see that the allowable increase is 10^{30} and the allowable decrease is 1300. The capacity cannot be decreased beyond the factor of 1300. Otherwise, we will get less profit and increasing the capacity of the reformer unit will give maximum profit. For the constraint C33 which represents the maximum capacity of Catalytic Cracking unit, the allowable increase is 2899.005 but the allowable decrease is 2800. The capacity of this unit should be within the range in order to get maximum profit.

The limits report depicts the lower and upper limit of each variable within which we will get maximum profit.

Naphtha Hydro treating Unit:-

Heavy Naphtha cut from the atmospheric crude distillation column in a refinery is sent to a 'Naphtha Hydrotreater Unit'. After the hydrotreater unit, naphtha is sent to an isomerisation unit or a catalytic reformer unit, which often use reforming catalysts. Most reforming catalysts contain platinum as the active material. Sulfur and nitrogen compounds present in naphtha from atmospheric distillation column can deactivate the catalyst and must be removed prior to catalytic reforming.

Purpose of the naphtha hydrotrater unit is to remove sulphur and nitrogen compounds. The Naphtha hydrotreating unit uses a cobalt-molybdenum catalyst to remove sulfur by converting it to hydrogen sulfide that is removed along with unreacted hydrogen. Some of the hydrogen sulphide-hydrogen mixture is recycled back to the reactor to utilize the unreacted hydrogen, using a compressor.

Reactor conditions for Naphtha hydrotreater unit are around 400-500°F (205-260°C) and pressure of 350-650 psi (25-45 bars). As coke deposits on the catalyst, reactor temperature must be raised. Once the reactor temperature reaches ~750°F (400°C), the unit is scheduled for shutdown and catalyst replacement.

If required, the boiling range of the catalytic reforming charge stock can be changed by redistilling in the naphtha hydrotreater in a stripper. Often light naphtha containing pentanes, hexanes and light naphtha are stripped off and sent directly to gasoline blending or pretreated in an isomerization unit prior to gasoline blending. The heavy naphtha from the bottom of the stripper column goes back to the catalytic reformer unit before blending with gasoline.

Equations for Naphtha Hydro-treater:-

Objective function: Minimization of sulphur content in product which is equal to 0.1*P7.

Material Balance:-

P7-P4-P5=45

(We have assumed the flow rate of hydrogen and of gas constant.)

(557*P4)+(557*P5)-(0.1*P7)=24.30

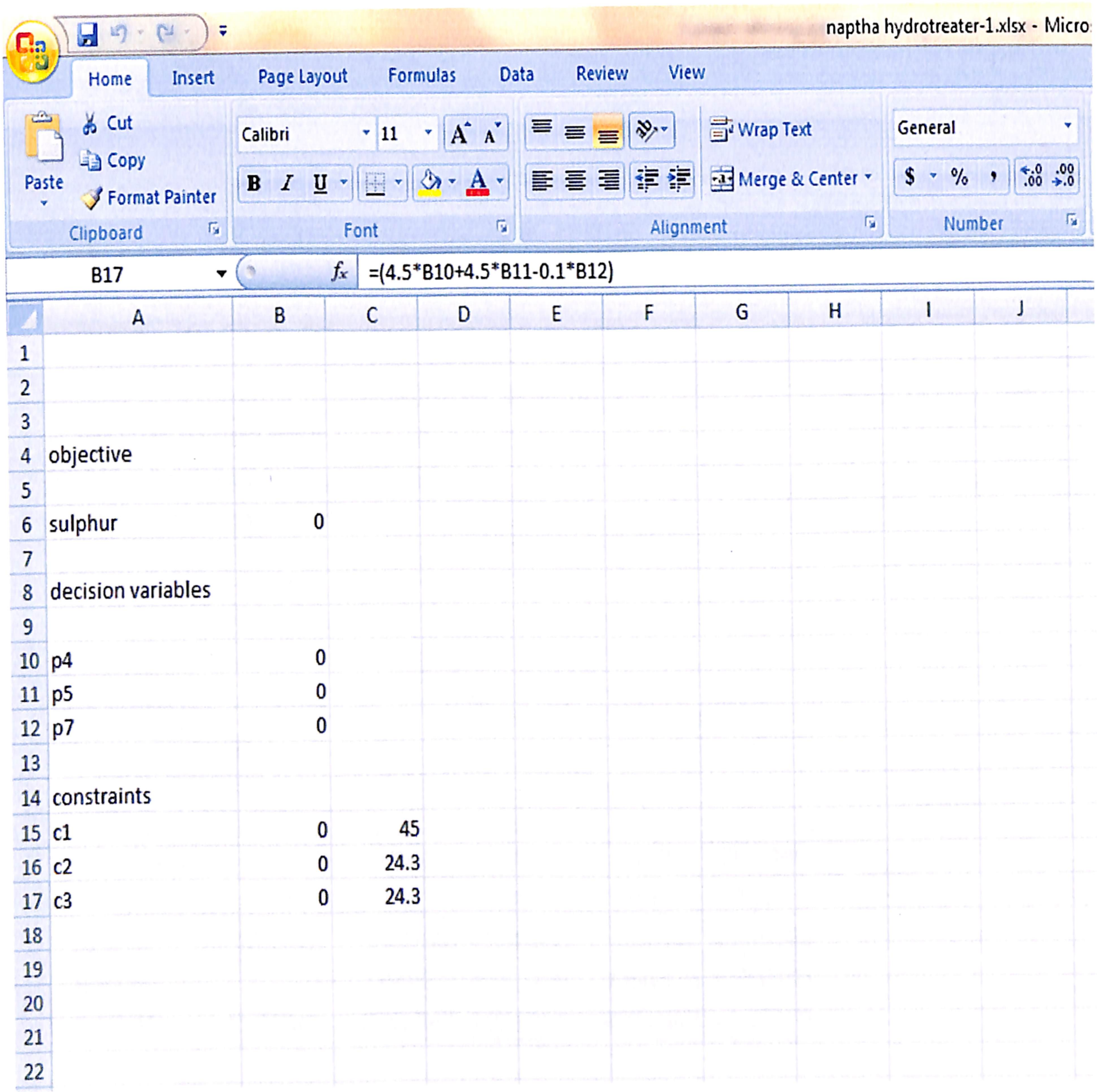
(Sulphur Balance)

Nitrogen Constraint:-

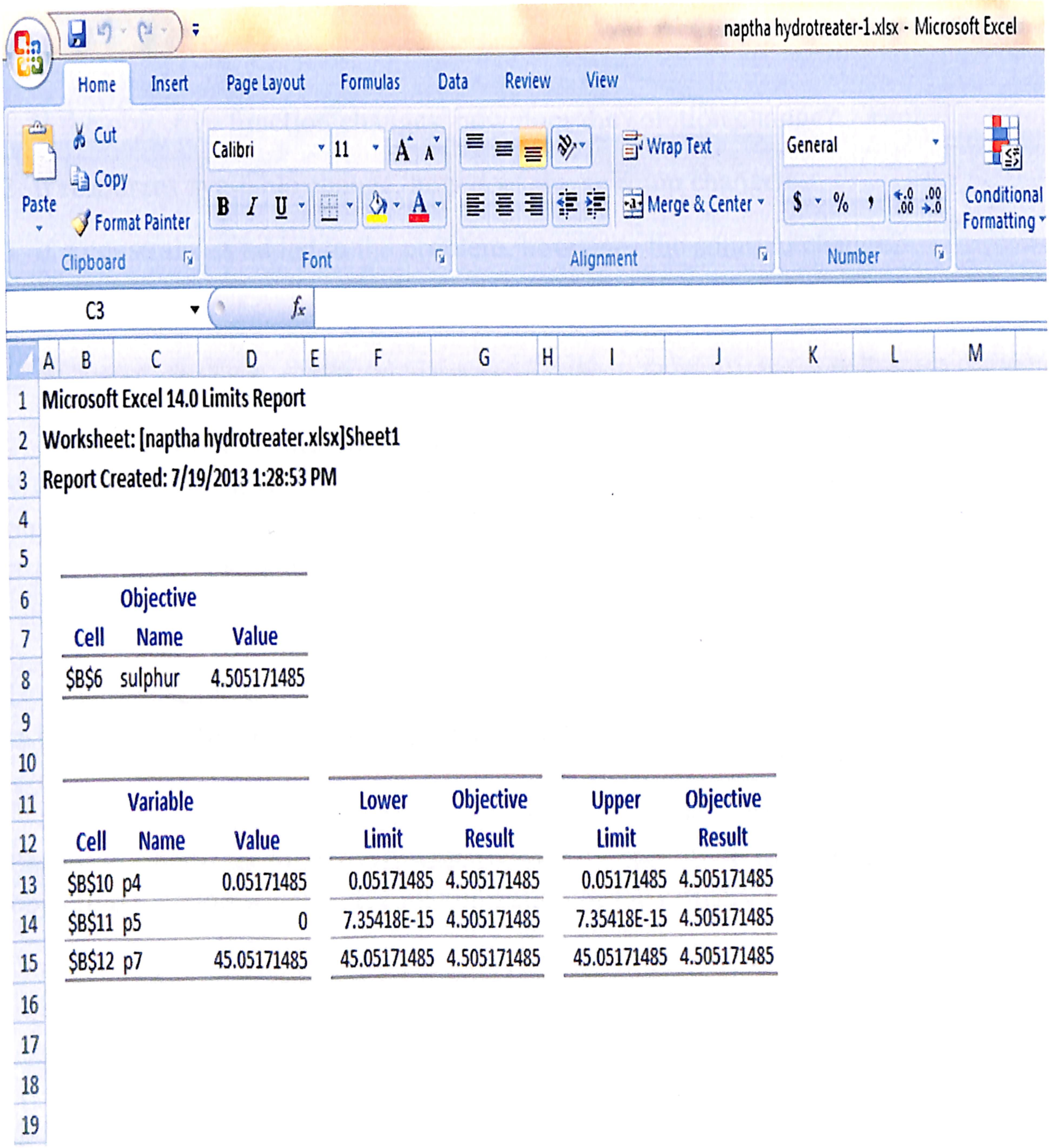
(4.50*P4)+(4.5*P5)-(0.1*P7)<24.30

Excel spreadsheet solution for the given sulphur minimization:-

Entry of data for the different constraints and formulation of the objective equation:-



Next we have formulated constraints and found out the limit report which provides us with the minimum amount of sulphur which the refinery can generate and also the upper and the lower limit for the different variables in the refinery set up and also their objective results



Microsoft Excel 14.0 Limits Report
Worksheet: [naptha hydrotreater.xlsx]Sheet1
Report Created: 7/19/2013 1:28:53 PM

Objective		
Cell	Name	Value
$B$6	sulphur	4.505171485

Variable			Lower	Objective	Upper	Objective
Cell	Name	Value	Limit	Result	Limit	Result
$B$10	p4	0.05171485	0.05171485	4.505171485	0.05171485	4.505171485
$B$11	p5	0	7.35418E-15	4.505171485	7.35418E-15	4.505171485
$B$12	p7	45.05171485	45.05171485	4.505171485	45.05171485	4.505171485

Sensitivity analysis:-

Sensitivity analysis is a systematic study of how sensitive solutions are to (small) changes in the data. The basic idea is to be able to give answers to questions of the form:

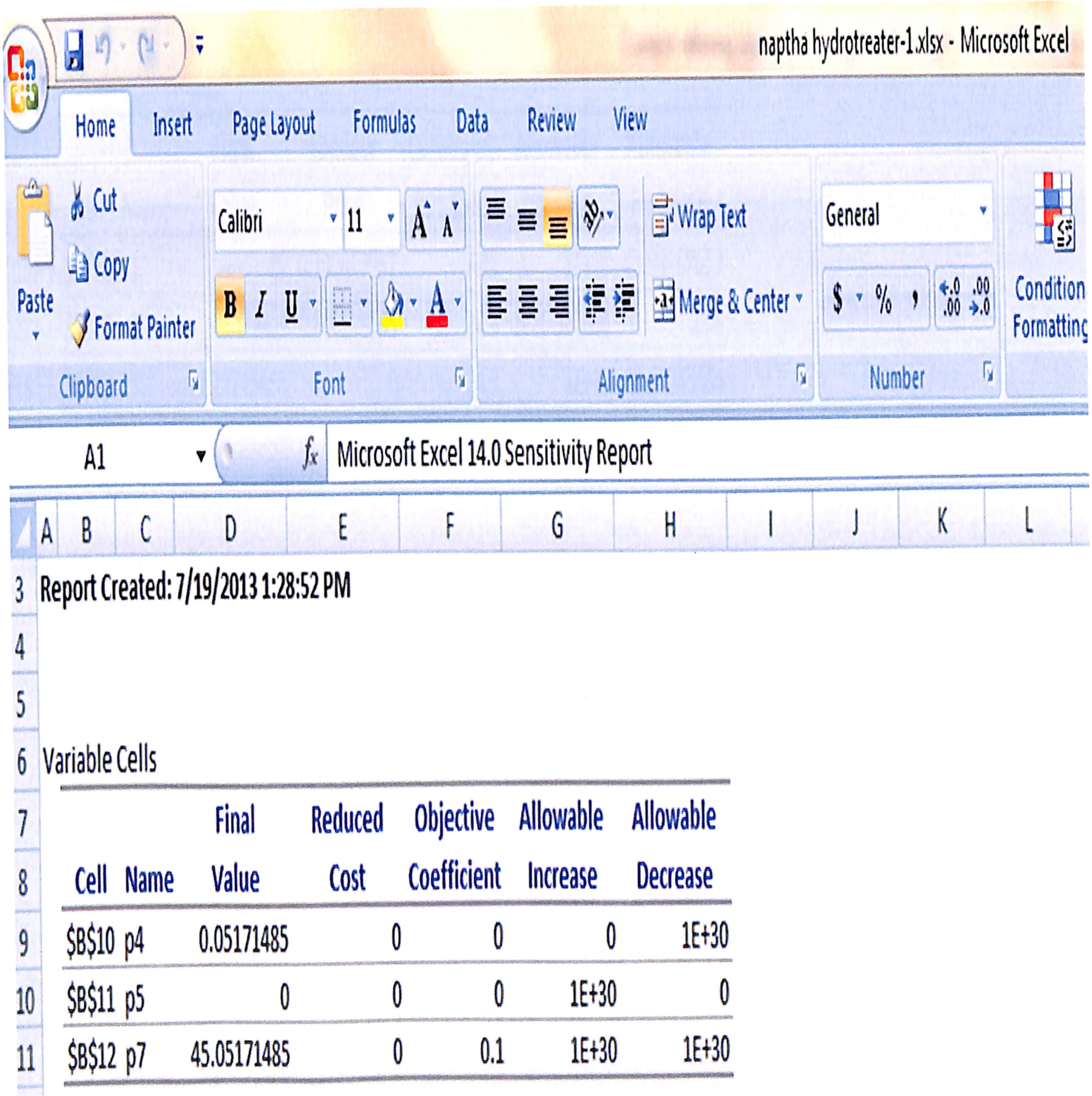
1. If the objective function changes, how does the solution change?
2. If resources available change, how does the solution change?
3. If a constraint is added to the problem, how does the solution change?

The optimal value of the non-basic variables is zero is depicted in answer report. We can see that the allowable decrease for the coefficient of these variables in the objective function is actually tending to infinity and it can be decreased to any extent without having any effect on the original optimal solution.

But increasing the coefficient of these variables in the objective function to a large extent will change the original optimal solution.

Sensitivity helps us to analyze which variables contribute to a large extent in the objective function which is the maximization of the refinery profit.

Sensitivity Analysis of the above problem by excel spreadsheet solver



Report Created: 7/19/2013 1:28:52 PM

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$B$10	p4	0.05171485	0	0	0	1E+30
$B$11	p5	0	0	0	1E+30	0
$B$12	p7	45.05171485	0	0.1	1E+30	1E+30

Constraints:-

It gives a list of the slack and the surplus variable.

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$B$15	c1	45	0.100017957	45	1E+30	45.04362657
$B$16	c2	24.3	0.000179565	24.3	3616.363636	28.8
$B$17	c3	-4.27245466	0	24.3	1E+30	28.57245466

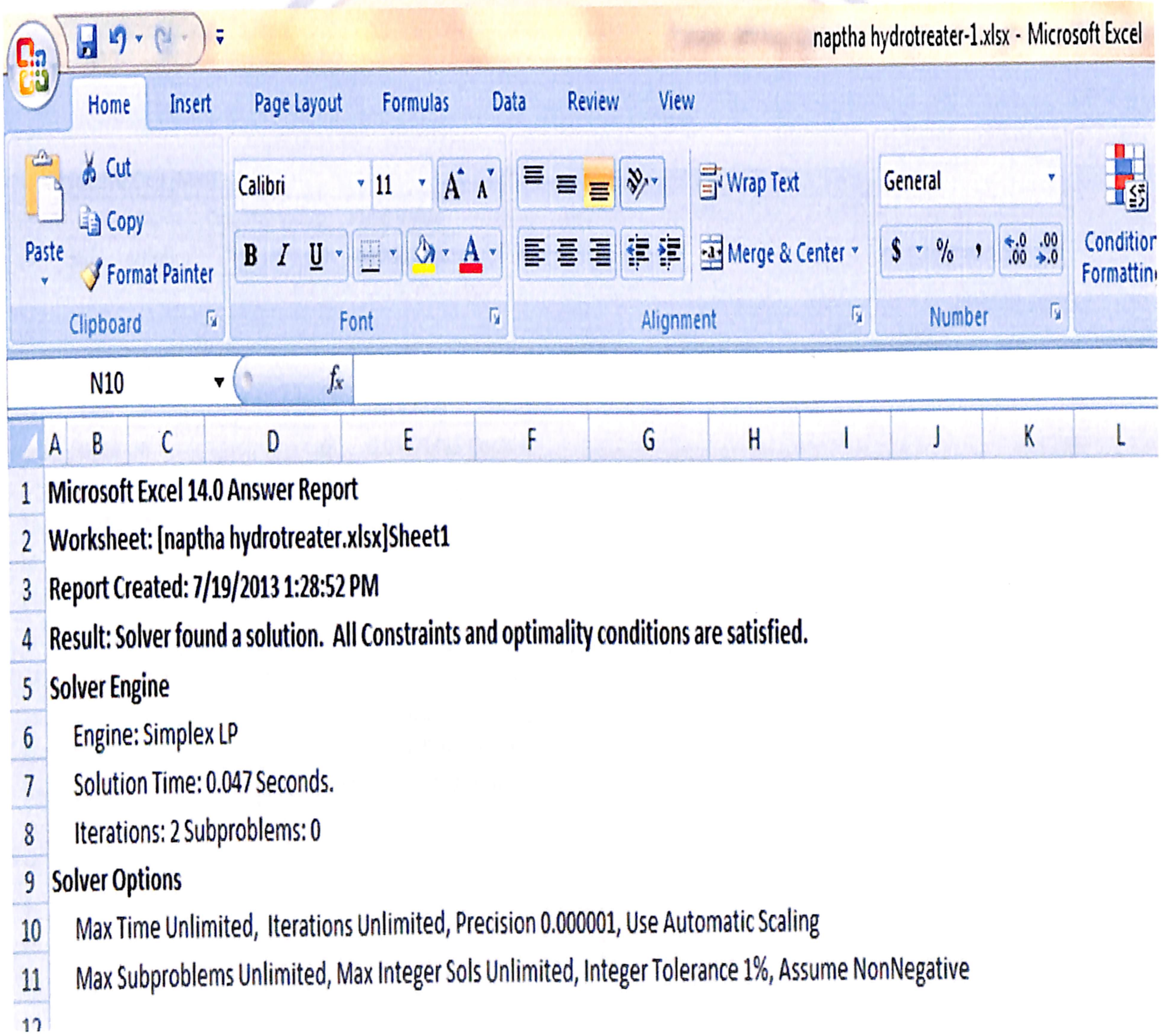
Answer Report 1 | Sensitivity Report 1 | Limits Report 1 | Sheet1 | Sheet2 | Sheet3

Ready

Final answer report:-

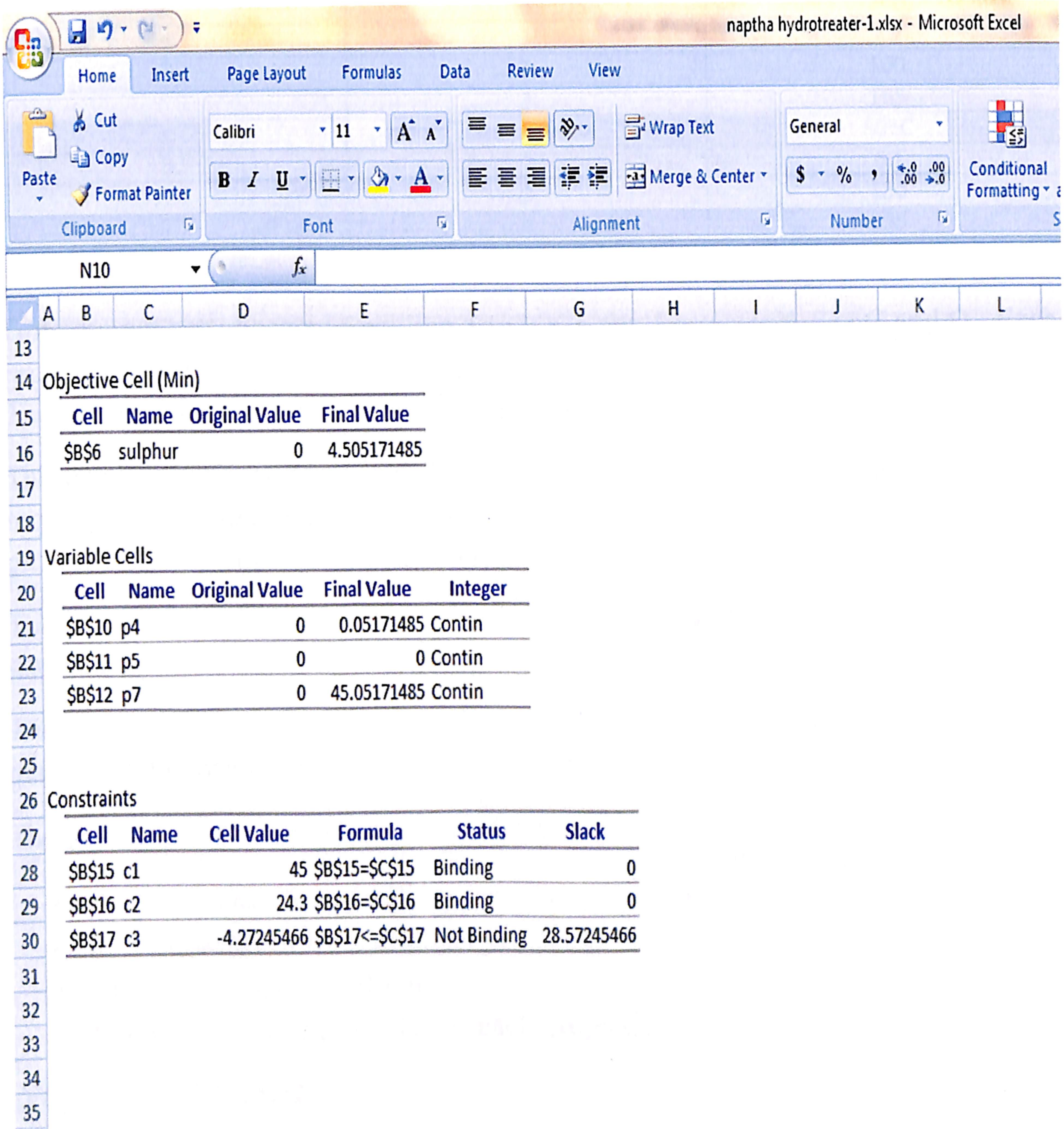
In this optimization, the most optimum or the minimized solution for the refinery sulphur margin is 4.505171 ppm.

Here a total number a total number of 2 iterations and the number of sub-problems is zero.



Constraints:-

It gives a list of the slack and the surplus variable.



Objective Cell (Min)

Cell	Name	Original Value	Final Value
$B$6	sulphur	0	4.505171485

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$B$10	p4	0	0.05171485	Contin
$B$11	p5	0	0	Contin
$B$12	p7	0	45.05171485	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$B$15	c1	45	$B$15=$C$15	Binding	0
$B$16	c2	24.3	$B$16=$C$16	Binding	0
$B$17	c3	-4.27245466	$B$17<=$C$17	Not Binding	28.57245466

PROBLEM STATEMENT GIVEN BY MENTOR

TABLE 22: MONEY ALLOCATION TO PROFITABLE PROJECTS

PROJECTS	COST IN MILLION $	PROFIT POTENTIAL OF EACH OPTION
A	4	200
B	1	25
	2	100
	3	165
C	c	50*C
D	2	50
	3	130
	4	195

Government has allocated 5 million $ to IOCL for 4 projects A, B , C and D . Each project in charge has to submit proposals costing from 1 million $ to 5 million $. The proposal must state the profit potential that it would create.

The head of projects has asked the four project managers to submit one or more requests for funding in agreement with government guidelines along with profit the project expects to generate under each funding option.

The table above illustrates the cost of each project and the profit that would be generated.

The government would like to allocate the funds to the projects in order to maximize the overall profit from the projects.

The government wants to achieve the following:

- Allocate funds to the four projects.
- Maximize profit from all the 4 projects
- Limit funding to 5 million $.
- Fund at most one proposal of each project.

NOTATIONS USED

D_{j} = money allocated (in million $) to project j where j is

1- Project A

2- Project B
3- Project C
4- Project D

$R_j(D_j)$= the profit generated by funding pojectjth with D_j million$. $R_j(D_J)$is not linearly related to amount D_j.

ASSUMPTIONS

All the four projects represent a team and the objective is to maximize profit from the the 4 projects

Model for the prolem :

MAX $R_1(D_1) + R_2(D_2) + R_3(D_3) + R_4(D_4)$

CONSTRAINTS:

$D_1 + D_2 + D_3 + D_4 <= 5$

$D_1, D_2, D_3, D_4 >= 0$

BOUNDARY CONDITIONS:

TABLE 23: MONEY ALLOCATIONS TO PROJECT D:

AVAILABLE FUNDING (X_4)	OPTIMAL FUNDING (D_4)	MAX PROFIT $F_4(X_4)$
0	0	0
1	0	0
2	2	50
3	3	130
4	4	195
5	4	195

These are the boundary conditions for the problem.

Stage 3:

At this stage funding for projects C & D is considered . The third project can be funded by any amount from 0 to 5 million $. Suppose an amount of X_3 MILLION

$ is allocated for project C , then D. if D_3 million $ is allocated to Project C then the money allocated to project D is X_3-D_3 million $.

Available funding for projects C & D	Possible allocated amount for project C (D_3)	For project D (X_3-D_3)	MAX PROFIT	Optimal Value $F_3(X_3)$ And optimal D_3
0	0	0	0+0 =0*	$F_3(0)$ =0 D_3 = 0
1	0	1	0 + 0 = 0	$F_3(1)$ =50
	1	0	50 + 0 = 50*	D_3 =1
2	0	2	0 + 50 =50	$F_3(2)$ = 100
	1	1	50 + 0 =50	D_3 = 2
	2	0	100 + 0 = 100*	
3	0	3	0 + 130 =130	$F_3(3)$ = 150
	1	2	50 +50 =100	D_3 = 3
	2	1	100 + 0 = 100	
	3	0	150 + 0 = 150*	
4	0	4	0 + 195 = 195	$F_3(4)$ = 200
	1	3	50 +130 = 180	D_3 = 4
	2	2	100 +50 =150	
	3	1	150 + 0 = 150	
	4	0	200 + 0 = 200*	
5	0	5	0 + 195 = 195	$F_3(5)$ = 50
	1	4	50 + 195 = 245	D_3 = 5
	2	3	100 + 130 = 230	
	3	2	150 + 50 = 200	
	4	1	200 + 0 = 200	
	5	0	250 + 0 = 250*	

Funding for projects B to D (X_2)	Funding for project B (D_2)	Funds to be allocated for projects C & D	Maximum profit	Optimal Value $F_2(X_2)$ And optimal value D_2
0	0	0	0 + 0 = 0*	$F_2(0) = 0$ $D_2 = 0$
1	0	1	0 + 50 = 50*	$F_2(0) = 50$
	1	0	25 + 0 = 25	$D_2 = 0$
2	0	2	0 + 100 = 100*	$F_2(2) = 100$
	1	1	25 + 50 = 75	$D_2 = 2$
	2	0	100 + 0 = 100*	
3	0	3	0 + 150 = 150	$F_2(3) = 165$
	1	2	25 + 100 = 125	$D_2 = 3$
	2	1	100 + 50 = 150	
	3	0	165 + 0 = 165*	
4	0	4	0 + 200 = 200	$F_2(3) = 215$
	1	3	25 + 150 = 175	$D_2 = 3$
	2	2	100 + 100 = 200	
	3	1	165 + 50 = 215*	
5	0	5	0 + 250 = 250	$F_2(3) = 265$
	1	4	25 + 200 = 225	$D_2 = 3$
	2	3	100 + 150 = 250	
	3	2	165 + 100 = 265*	

FOR PROJECT A

Funding for projects A to D (X_1)	Funding for project A (D_1)	Funding for projects B to D (X_1-D_1)	Maximum Profit	Optimal Solution $F_1(X_1)$ and optimal solution D_1
5	0	4	0 + 215 = 215*	$F_1(0) = 215$
	4	0	200 + 0 = 200	$D_1 = 0$

Project A should be allocated 0 million $. So projects B , C , D should be allocated 5 million $. For 5 million $ for B,C,D the optimal solution is 3 million $ for the project B. Therefore money left to allocated for projects C & D is 5-0-3 = 2 million $.

For 2 million $ for projects C & D the optimal solution is 2 for Project C as can be seen from the above tables.

So money allocated to

Project A = 0 Million $

Project B = 3 Million $

Project C = 2 Million $

Project D = 0 Million $

7. CONCLUSION

Linear Programming models and Dynamic Programming approach are useful tools for Planning for uncertainities for a complex refinery where the variables involved are numerous and the there are several objectives conflicting with each other. In case of the prototype of the simple refinery problem, sensitivity analysis of the problem tells what are the limits for all the variables which give maximum profit. We can see from the problem that for the variables which are non- basic the allowable increase is limited but the allowable decrease tends to infinity. The variables can be decreased upto any extent giving the same maximum profit. In case of operating cost which have a contribution in the objective function the allowable increase is limited as increasing the operating cost will not giving the maximum profit under the given conditions. Thus under the giving constraints of market demand, capacity of the various units and the quality construe raints LP modeling gives the maximum profit by use of EXCEL Solver . But in reality the properties of the feed do not linearly blend into products .Some properties blend non-linearly . In reality a number of variables other than flow rate of the streams are involved which affect the yield of the process units.

In case of the Problem statement 2 we were given 4 projects and the money that would be allotted to all 4 projects was given. The projects had different profit potential for different funding schemes . By use of Dynamic Programming we came to a conclusion that the the money allotted the projects should be :

So money allocated to

Project A = 0 Million $

Project B = 3 Million $

Project C = 2 Million $

Project D = 0 Million $

This funding scheme would give the maximum profit.

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APPENDICES:

ORGANISATION STRUCTURE:-

The organizational structure of IOCL Koyali Refinery is highly complex. At the top of the hierarchical structure is the ED or Executive Director. Under the Executive Director we have

- GM (T) or GM (Technical)
- GM (TS) or GM (Technical Services)
- GM (F) or GM (Finance)
- GM (P&U) or GM (Power and Utilities)
- GM (HSE) or GM (Health ,Safety and Environment)
- GM (M&C) or GM (Material and Contracts)
- GM (PJ) (ACP- JV)

Under GM (T) we have:

- DGM (MN) or DGM (Maintenance)
- DGM (PN) or DGM (Production)
- DGM (INST) or DGM (Instrumentation)

Under DGM (MN) we have:

11. Various chief managers and Deputy Managers

Under DGM(PN) we have a Chief production manager.

Under DGM (INST) we have a chief instrumentation manager. Under GM (TS) we have

- DGM (ES &EI)
- DGM (TS)
- DGM (INSP)

Under DGM (ES & EI) we have CESM (chief manager). Under DGM (TS) we have chief manager technical services. Under GM Finance we have DGM (finance) under whom we have chief finance manager.

Under GM (power and utilities) we have various chief managers (power and utilities).

The hierarchical structure ensures that there is effective co-ordination between various departments and work flow is smooth between the various departments.

ORGANISATIONAL STRUCTURE:-

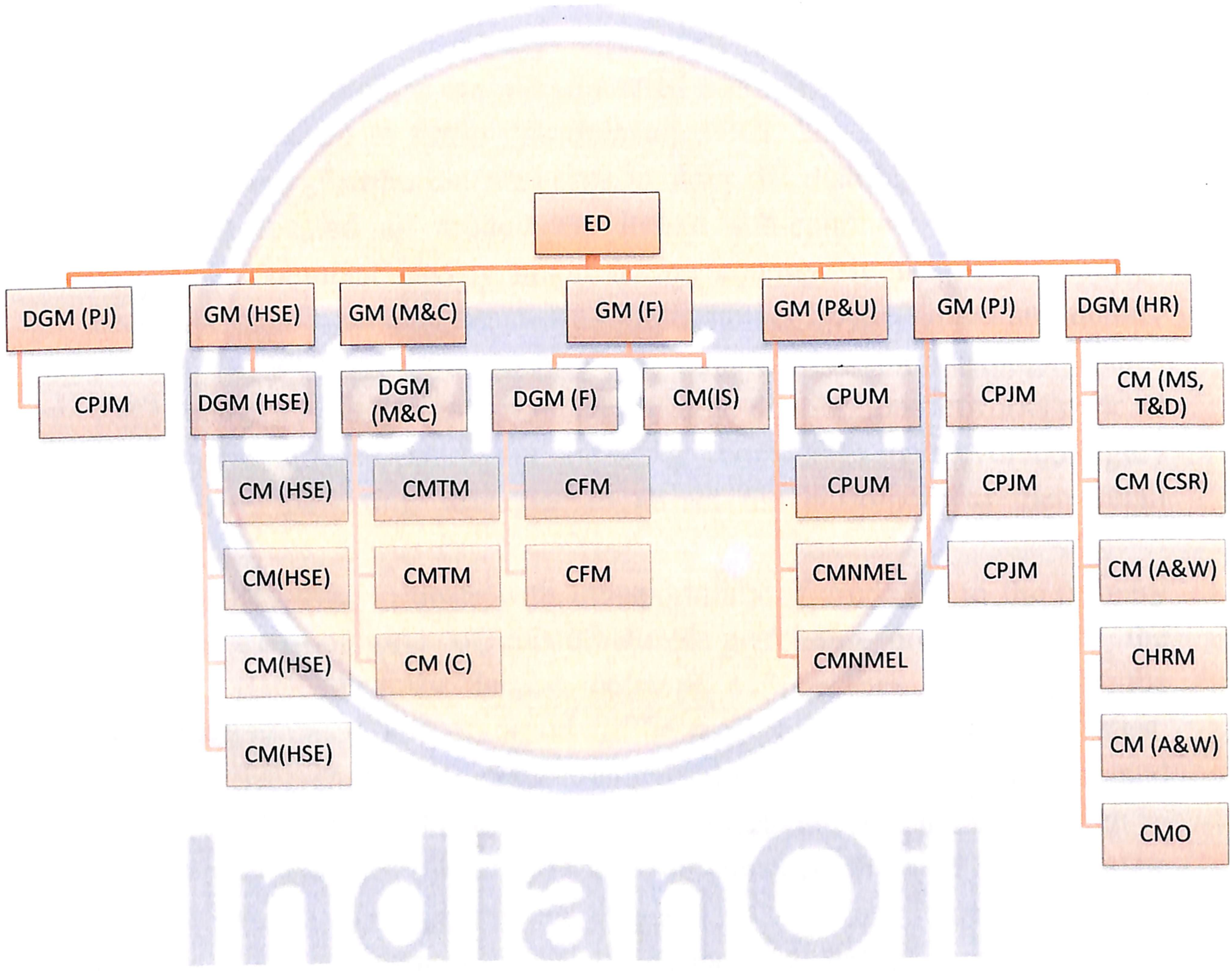

Fig.1.4: Organizational Structure

DEPARTMENTS:-

IOCL Koyali Refinery consists of the following departments:

- Marketing
- Pipeline
- Refinery
- The marketing department of IOCL handles the selling of the products to the end customers. The marketing department does not have any storage facilities so the products are manufactured according to their current market demand: sufficient to fulfill this demand. IOCL has the largest petroleum marketing and distribution networks in Asia. Its distribution networks are ubiquitous located all around the Indian sub-continent. Indian oil has become a dominant energy brand in the country. It has its distribution centers located such that they assure the customer uninterrupted and quality products as well as service at any time as and when the customer wants. IOCL being a PSU has an advantage of large distribution networks over its private competitors even though the private companies have evolved highly competitive marketing strategies to attract the customers to their retail outlets.
- The pipeline division deals with transportation of crude oil to the refinery and the transportation of manufactured petroleum products from the refinery. IOCL has the largest network of pipelines to transport the petroleum products and crude oil to the markets. Pipelines are the safest, cost-effective, energy efficient mode of transportation of crude oil and petroleum products. IOCL pipelines connect the refineries to high – consumption centers. IOCL has also implemented the a 217 km pipeline from Koyali-Sanganer pipeline at Viramgam to existing scrapper station at Churwa along with use of a 14 km long existing pipeline from Churwa to Kandla.
- The refinery deals with production of products according to the actual current market demand. It has both primary and secondary units for conversion of crude oil to refined petroleum products which are according to quality specifications of customers and which satisfy the current market demand.