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Case Report

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An Innovative & New Concept of a New Co-Generation Plant in a Refinery (A Proposed Idea – A Beautiful Case Study) (Co-Existence Of Gtg Brayton Cycle + Stg Steam Rankine Cycle + Organic Rankine Cycle) (Would Be 1st Time in Our Nrl Refinery)

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Abstract

• This 1st paper highlights the case study of Power & Steam generation in an innovative way from the available energy sources in a Refinery taking an example of the Existing & Upcoming Post expansion of our NRL.
• It illustrates the beautiful concept & idea of the "Co-existence of the GTG Brayton Cycle + STG Steam Rankine Cycle + Organic Rankine Cycle" (1st of it's kind of a case study in Our NRL Refinery)
• Numaligarh Refinery Limited (NRL) was established as a Company on 22nd April 1993.
• It's present capacity is 3 MMTPA.
• NRL intends to expand its refining capacity to additional 6 MMTPA due to:
• Projected demand growth of petroleum products in the country
• Retain its profitability and competitiveness in the long run
• This mega project would also increase the power & steam demands to manifolds
• In view of this, an innovative idea and novel concept was devised to generate power & steam from the available sources of the existing & the upcoming new units in
• the post NRL expansion scenario.
• Now, the problem is …. how it would be possible ……. ???
• How the above scheme would be accomplished ……. ???

Let's see that beautiful idea and the new innovative scheme with beautiful illustrations of the scheme which would be the first of its kind in our NRL ……..

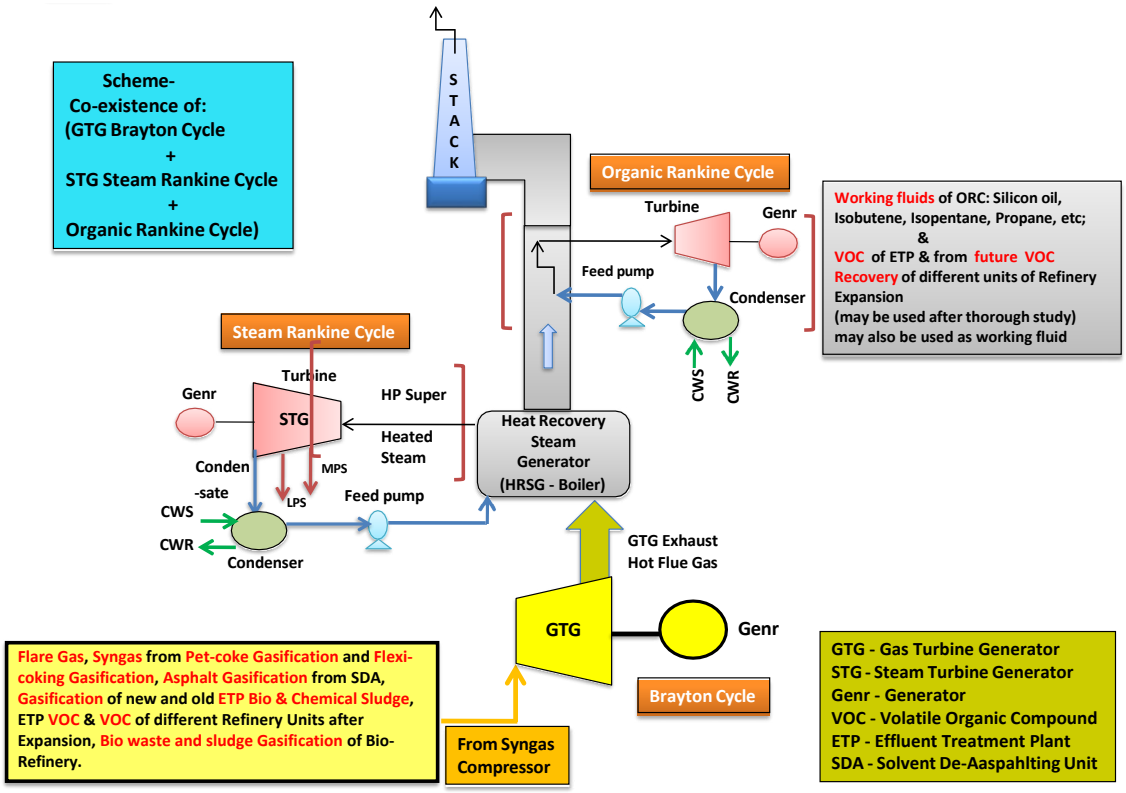


Figure1: An Innovative Concept of – A Co-Generation Plant in Post Refinery Expansion

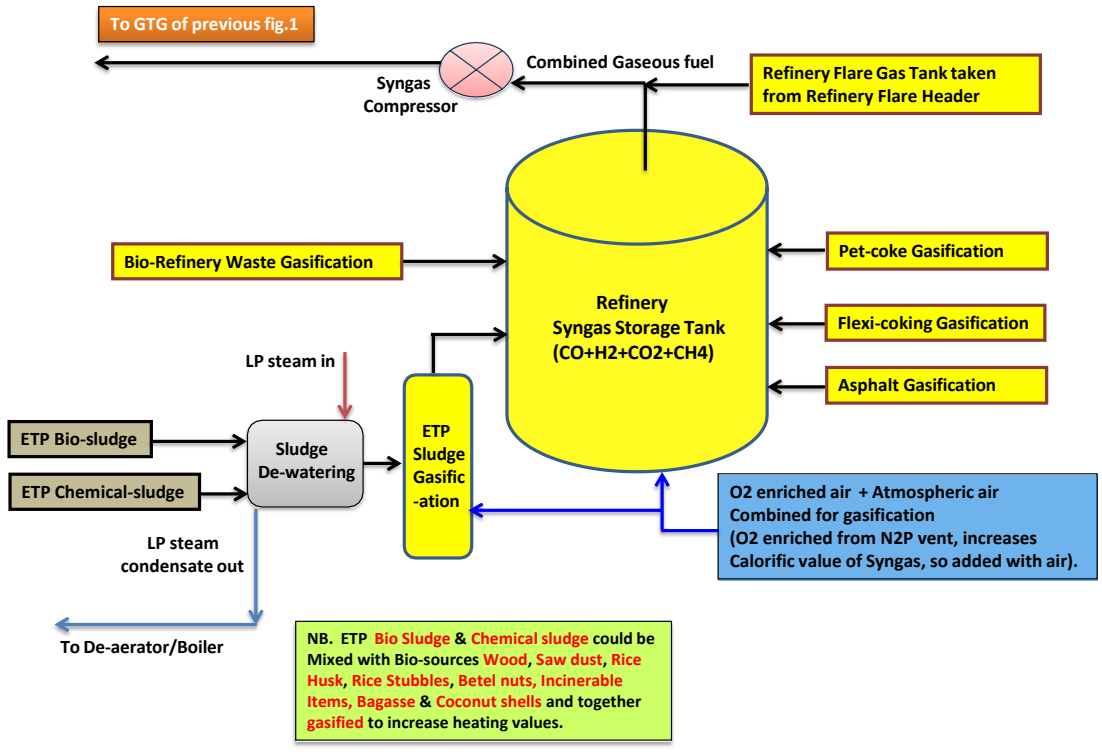


Figure 2: Generation of Syngas from various potential sources in Post Refinery Expansion

1. Co-existence of Brayton Cycle + Steam Rankine Cycle + Organic Rankine Cycle

1.1 Brief Concept of Idea

• Setting up of a combination of GTG Brayton Cycle, STG Steam Rankine Cycle and Organic Rankine Cycle
• Generation of Electricity from all these 3 Thermodynamic cycles.
• Generation of High Pressure (HP) steam from Boiler.
• Generation of superheated Medium Pressure (MP) & Low Pressure (LP) steam from the STG.

1.2 Sources of Fuels

Following re-sources would be integrated into a Combination of Fuels in the Post Expansion of Refinery to generate useful outputs (Power & Steam):

(i) Syngas (Gaseous Fuel)

From Pet-coke Gasification, Asphalt Gasification and Flexi-coking Gasification (Syngas is a mixture of Hydrogen+CO+CO2, & hence is a good source of Fuel).

(ii) Flare Gas (Gaseous Fuel)

In Post Expansion, the mass flow of the flare gas would be much more than the existing Refinery. So, there is a very good potential of it's recovery and use it as a source of combustion.

(iii) VOC of ETP (Gaseous Fuel)

As the Effluent Treatment Plant (ETP) capacity would increase, hence it's potential of recovery of Volatile Organic Compound (VOC) would also increase. As VOC is recovered from the surface of the Oil surface of ETP, hence it would contain hydrocarbons in it. So, VOC could also be used as a probable source of Fuel for combustion. Also, VOC could be recovered from other units of the Refinery and combined with this ETP VOC. This would give an extra VOC mass flow.

(iv) ETP Bio and Chemical Sludge (Semi & Solid Fuel)

• Increase in ETP capacity, so the production of bio and chemical sludge.
• These sludge after removal of moisture could be used as a source of combustion.
• These sludge is gasified to produce Syngas.
• To increase the heating values of these sludge, they may be mixed with the other

(v) Bio-Refinery wastes and Sludge (Semi & Solid Fuel)

• The wastes generated from our upcoming Bio-Refinery Plant would be utilized as a source of combustion as they contain good amount of heating values through Gasification to produce another Syngas from Bio-source.

NB. (O2 enriched air + Atmospheric air) are Combined for gasification (O2 enriched of Nitrogen Plant (N2P) vent, increases the Heating Value or Calorific value of Syngas, so, it is added with air).

Electricity would be produced through three nos. of Thermodynamic cycles: GTG Brayton Cycle, STG Normal Steam Rankine Cycle and Organic Rankine Cycle, which are explained as below:

(a) Power Generation by the Gas Turbine Generator (GTG) through Brayton Cycle

• All the Syngas collected from the Refinery Syngas Tank generated from the various sources of the Refinery and the upcoming Bio waste/sludge of the Bio-Refinery and the Flare Gas recovered from the Flare Header together would be used as a combined Fuel source for the GTG.
• All the above combined Fuel sources would be compressed in a compressor to increase Fuel pressure up-to the required pressure at GTG combustion inlet (10 to 12 kg/cm2).
• The combined fuel before entering the GTG would be heated to maintain the Fuel temperature at approx. 40 to 45 deg C.
• After combustion, the Hot & Compressed Flue Gas produced would be expanded in the Gas Turbine would drive the Generator to produce useful Electrical Power through the Thermodynamic Cycle called Brayton Cycle.
• Then the GTG Hot Flue Gas Exhaust will be diverted to a HRSG unit (Heat Recovery Steam Generator).
• In HRSG, Heat Energy from the GTG Hot Flue Gas Exhaust will be recovered to
• generate HP steam at 40 kg/cm2 (or ksc) & 450 deg C.

(b) Power & Steam Generation through Steam Rankine Cycle

• The Normal Steam Rankine Cycle will use superheated HP steam as working fluid. produced by the above-mentioned Heat Recovery Steam Generator (HRSG).
• HRSG would be kept with a provision of Supplementary Burners to increase the steam generation if and when required and also for the Operation flexibility.
• The Flue gas produced on combustion will generate Super Heated High-Pressure Steam
• (HP Steam : 40 ksc/450 deg C)
• This HP steam will drive the Condensing-cum-Extraction Steam Turbine Generator (STG)
• This will generate Electrical Power in the Generator.
• The Turbine will also generate MP superheated steam (14 ksc/250 deg C) and LP superheated steam (4 ksc/180 deg C).
• MP & LP steam are supplied to the Refinery steam headers.
• Some portions of the LP steam would be used to heat and remove the moisture from the ETP Bio and Chemical Sludge. Finally, it is converted into condensate and reused in Boiler or De-aerator (so, again Energy saved in the process).
• The final Turbine exhaust steam is then condensed in a surface condenser.
• The steam condensate is again sent back to the boiler.
• The cycle is repeated.
• Thus here, Steam & Power is produced through Thermodynamic cycle of Steam Rankine Cycle.

(c) Power generation by an Organic Rankine Cycle

• Further the heat of the flue gas is recovered at the downstream of the boiler.
• This recovered heat is used to drive an expansion Turbine to

produce Electrical Power output through an Organic Rankine Cycle (ORC).

• Here the organic compound with high molecular mass and lower boiling point

• than water will be used to recover heat from this recovered flue gas at stack inlet.

• The working fluid is vaporized and then expanded in a vapor expansion turbine, that drives a generator, producing electricity.

• The Flue gas is then finally goes into the atmosphere through the stack.

• Here, the working fluid may be silicon oil, iso-pentane, propane, etc.

• The Volatile Organic Compound (VOC) of ETP may also be used as a source of this fluid

• after further feasibility study of the composition and properties of the compound.

• We may recover VOC from other units of our Refinery which will act as a source of working fluid for this cycle.

• Also, these VOCs can be used as a source of gaseous fuel for the GTG and HRSG along with the other available sources after further feasibility study of the composition and properties of the compound.

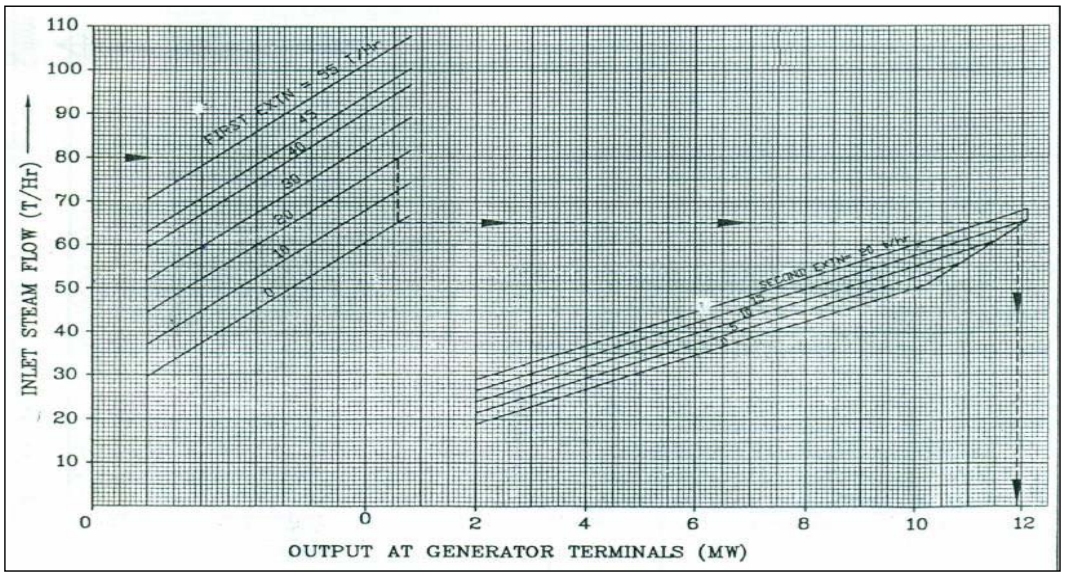
Calculation Details:

Refinery Flare Gas (HHV)		
Components	mol%	
CH4	43.6	
H2	5.54	
CO	0.186	
HHV	1806.576	
HHV	18.06	MJ/m3

Syngas (HHV)		
Components	mol%	
CH4	21.51	
H2	13.42	
CO	21	
HHV	1291.707	
HHV	12.92	MJ/m3

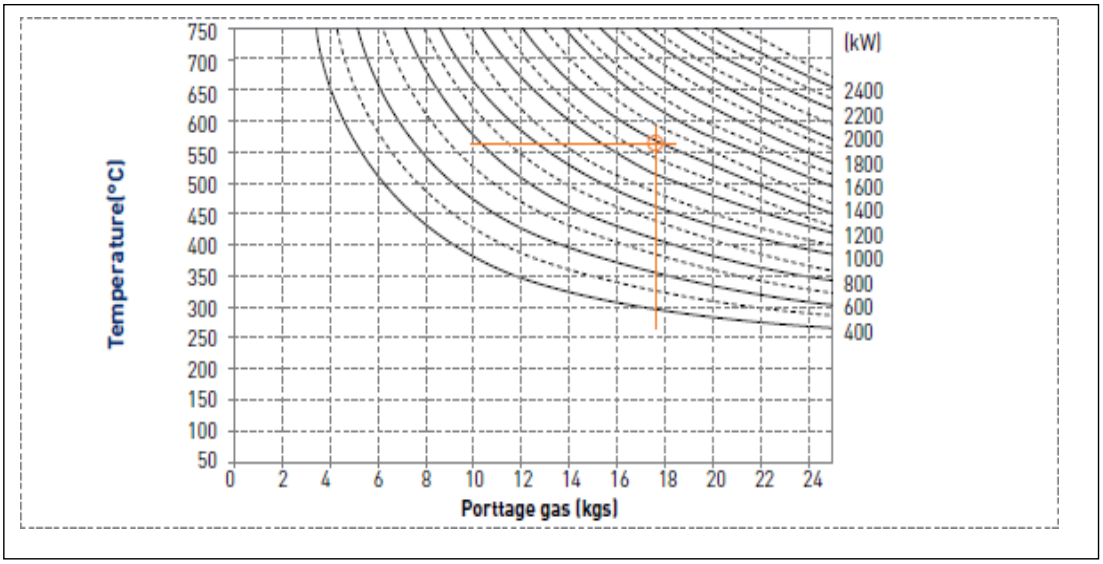
NRL Expansion Scenario							
Type	Source	Figure	Unit	MTPA	MTPD	m3PD	HHV (MJ/day)
Syngas	Petcoke	0.364	MMTPA	364000	997.260274	1049747.657	13562739.73
Syngas	Asphalt (SDA)	0.755	MMTPA	755000	2068.493151	2177361.211	28131506.85
Flare Gas	Flare Gas	5	TPH		120	141176.4706	2549647.06
Syngas	ETP (Bio+Chemical sludge)	1070	TPY		2.931506849	3085.796683	39868.49
Syngas	VOC (ETP)	3000	NM3/Hr		72000	72000	36000.00
	Density of Flare Gas	0.85	kg/m3			Total Energy Available	44319762.13
	Density of Syngas	0.95	kg/m3				
	NB: VOC ETP HHV = 0.5 MJ/m3 (assumption)						

Calculation of Power Produced		
Taking GTG at CPP as reference for calculation		
Energy required to generate 1 MW (taking NG as fuel)	24710739.27	kcal
Available Heat Energy from all the Fuels	10592423148.43	kCal/day
Available Heat Energy from all the Fuels	441350964.52	kCal/Hr
Power generated by the available energy in GTG	17.86	MWHr
Power generated in 1 day	428.66	MW/Day
Savings per day	1148799.87	rupees/day
Savings per year from GTG Power Generation	419311952.26	rupees/year
Expected HP steam generation in Boiler from GTG Flue Gas Exhaust	36.00	TPH (approx)
Now, STG HP steam consumption at FSNL	7.00	TPH
STG HP steam concumption per MW	4.50	TPH
So, HP steam left for Power generation after FSNL	29.00	TPH
Power generated by 36 TPH HP steam	6.44	MWHr
Power generated in 1 day	154.67	MW/Day
Savings per day	414506.67	rupees/day
Savings per year	151294933.33	rupees/year
Finally total Power generated by GTG & STG	24.31	MWHr
Finally total Power generated by GTG & STG	583.32	MW/day
Finally, Total savings from GTG & STG Power generation	570606885.59	rupees/year



Graph-1

• The above graph-1 shows the HP steam consumption versus MWHr generation in the
Condensing-cum-Extraction STG along-with MP & LP steam extractions.
• We could extract 5 to 10 TPH of superheated LP Steam in our case.
• More LP steam & also MP steam would be generated once Bio-Refinery Wastes, existing ETP Bio & Chemical wastes & nearby areas Bio-wastes could be utilized which is kept as future scope.
• Supplementary firing option is also kept as future scope to fire increase MP & LP steam generations.



Graph-2

• The above graph-2 shows an Estimating potential of power generation using ORC.
• Thus, by back calculating, we approx. get around 50 to 55 kWHr of Power from our ORC which would further increase once Bio-Refinery Wastes, existing ETP Bio & Chemical wastes & nearby areas Bio-wastes could be utilized which is kept as future scope.
• So, per day Electrical Power generation of ORC = 1320 kW/day or 1.32 MW/day
• Finally, total power generated per day:
= GTG Brayton Cycle + STG Rankine Cycle + ORC
= 426.66 + 154.67 + 1.32 = 584.65 MW/day = 24.36 MWHr

2. Advantages of the Schemes

• Huge potential of Power generation along with steam is discovered.

Power	Unit	Savings	Unit
24.36	MWHr	65.2848	Rupees/Hr
584.64	MW/Day	1566835.2	Rupees/Day
213393.6	MW/Year	571894848	Rupees/Year

• Discovery & use of the available resources as fuels for combustion like – Syngas, Flare Gas Loss, VOC, Bio-Refinery sludge and wastes.
• Both upcoming ETP & existing old ETP Bio & Chemical sludges & wastes, VOC products would
• also be utilized as fuel.
• Recovery and use of VOC of both old and new ETP & reduce health hazards from VOC. Brings into new angles of VOC recovery from other units of the Refinery – Future scopes.
• Better way of waste management at ETP.
• Thus, ETP a new look – "Future Power-House Hub of our Refinery " along with the present
• Process Waste Treatment plant of the Refinery.
• Some sources of earning and livelihood for the nearby residing people due to
• Use of nearby areas wastes as fuel sources - Wood, Saw dust, Rice Husk, Rice Stubbles,
• Betel nuts, Incinerable Items, sugarcane bagasse, Coconut shells (if used as additional bio source).
• Helps to supply some amount of MP & LP steam required in the post Expansion Refinery units.
• Schemes Reduce Specific Energy Consumption of the Refinery & Lower Refinery's Energy cost.
• Combination of Three Thermodynamic cycles 1st time in our NRL Refinery: GTG Brayton Cycle,
• STG Steam Rankine Cycle and Organic Rankine Cycle to produce both Useful Power and Steam.
• Could be replicated in other Refineries also for Power Generations after detailed feasibility study.

Thus ……. "What is now proved was once only imagined."– William Blake……. is rightly proved herewith.

This Innovative & Novel concept of Co-Generation Plant would indeed be a Game Changer in the Power sector of our future post NRL expansion configuration. It could be replicated in other Refineries also for Power Generations after detailed feasibility study.