Gas to Liquid (GTL) Process Design

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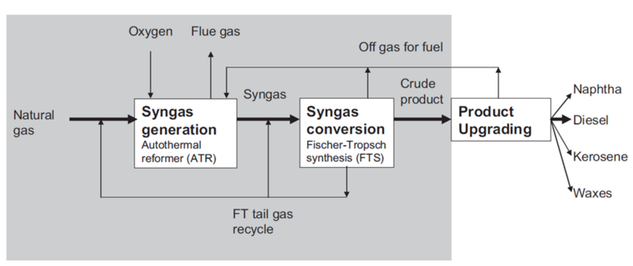
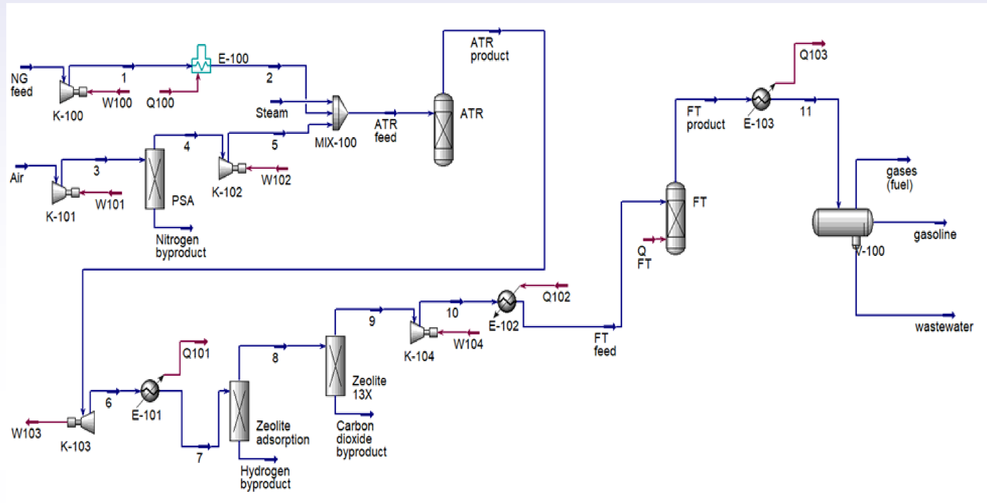
Abstract:

The global consumption of liquid fuels is projected to increase significantly in the coming years, highlighting the need for alternative methods of production. This graduation project aims to design a Gas-to-Liquid (GTL) plant in Saudi Arabia to produce liquid fuels from natural gas. The project entails a thorough literature survey comparing different process alternatives, with Autothermal Reforming of Natural Gas being selected as the most suitable option. The process involves catalytic reactors and cobalt-based catalysts to convert natural gas into syngas and then into various liquid fuel products. Process simulation using Aspen HYSYS software allows for optimization and the production of desired products. The project also considers material and energy balance calculations, environmental impact, and the economics of the GTL process. Lastly, the study identifies the Al-Dahna unconventional natural gas field near Dhahran as the ideal location for the plant due to its modern infrastructure and proximity to the oil industry's main center in Saudi Arabia. Autothermal reforming reactor was designed as fixed bed vertical cylindrical vessel filled with nickel catalyst supported on alumina with 0.45 m diameter and 1.35 m height. The cooler E -103 was designed as U-tube shell and tube heat exchanger with 321 tubes, 25 mm outer diameter, 5 m length, with 0.7 m shell diameter. The capital investment required for the process was estimated as 45176400.72 $. The operating cost was 209550048.2 $/year. The revenue from the product selling was estimated as 514985029.3 $/year. The estimated net present value at the end of life (NPV) is found to be $968.16 million. The high NPV suggests that the GTL process is anticipated to yield substantial returns and create value for the stakeholders involved. Furthermore, the discounted rate of return on investment (ROI) is calculated to be 150.29%. Additionally, the discounted payback period is determined to be 0.2 years after the 2 years of construction. The high economic feasibility of the project was concluded and several recommendations were made.

Process Description

Natural gas is fed to the catalytic reactor (autothermal reactor) with steam and oxygen at 750 k and 21 bar. The catalyst for the autothermal reforming reactor is Ni/Mg-Al2O3 ,The produced syngas is fed to the FT (Fisher-Tropisch) reactor at 255°C on the surface of cobalt-based catalyst .The crude product is upgraded using atmospheric distillation to LPG, naphtha, diesel, kerosene and waxes.





EQUIPMENT DESIGN:

Summary of Cooler design:

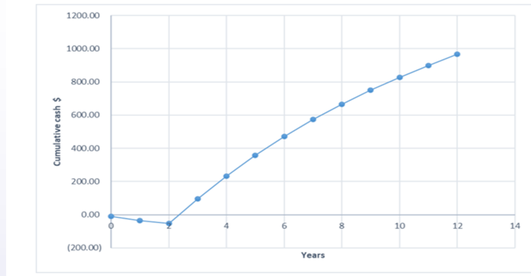
Parameter	Value
Outside diameter	25 mm
Inside diameter	21 mm
Thickness	2 mm
Number of tube	312
Area of one tube	0.39 m^2
Tube Length:	5 m
Shell diameter	0.7 m
Area of shell	20.3 m^2
Heat transfer (hi)	1717.28 W/C m^2
Heat transfer (hs)	10536.2 W/C m^2
Overall coefficient	1208.08 W/C m^2
Baffle spacing	0.28
Baffle cut	25 %

Summary of Autothermal Reforming Reactor design:

Parameter	Value
Type	Packed bed reactor
Catalyst	Ni-γAl2O3
Catalyst mass	115 kg
Configuration and support	vertical vessel on legs
Diameter	0.45 m
Height	1.35 m
Material of construction	Stainless steel 304
Vessel thickness	18 mm
Head and closure	ellipsoidal
Thermal insulation type	mixture of asbestos and diatomeceous earth
Thermal insulation thickness	1.25 inch

Capital Cost:

Equipment Type	Cost in 2024 (million $)
compressor	23.751
Turbine	3.28
Fired Heater	4.23
Heat Exchanger	27.32
Vessels	4.86
Labour	0.8
Raw material	140.85
Waste Treatment	0.0011
Utilities	17.5
Total	222.6



Conclusion:

The project focusing on the design of a Gas-to-Liquid (GTL) plant in Saudi Arabia to produce liquid fuels from natural gas has yielded promising results. The comprehensive literature survey and process comparison have led to the selection of Autothermal Reforming of Natural Gas as the most suitable option. The utilization of catalytic reactors and cobalt-based catalysts to convert natural gas into syngas and further into various liquid fuel products has been successfully simulated using Aspen HYSYS software, enabling process optimization and the production of desired products. The project also encompasses material and energy balance calculations, environmental impact assessment, and economic evaluation, providing a holistic overview of the GTL process. The identification of the Al-Dahna unconventional natural gas field near Dhahran as the ideal location for the plant, supported by detailed reactor and cooler designs, further strengthens the feasibility and practicality of the proposed GTL plant. The estimated capital investment, operating cost, and revenue projections have culminated in a high net present value (NPV) of $968.16 million, a discounted rate of return on investment (ROI) of 150.29%, and a discounted payback period of 0.2 years after the 2 years of construction. These financial metrics underscore the strong economic viability and potential profitability of the GTL project. Several recommendations can be made to enhance the overall success of the GTL project, based on the findings and analysis. Continuous monitoring of market trends and technological advancements should be undertaken to adapt to evolving industry standards and maintain competitiveness. Robust risk management strategies need to be implemented to mitigate potential challenges and uncertainties associated with the GTL process and the energy market. Collaboration with local and international stakeholders should be pursued to leverage expertise, resources, and market access, contributing to the sustained growth and success of the GTL plant. Regular assessment of environmental impact and compliance with regulatory standards is essential to ensure sustainable and responsible operation of the GTL plant. In moving forward, the following areas for future work should be considered to further enhance the GTL project. Exploration of advanced catalyst technologies and process refinements should be undertaken to optimize product yield, quality, and energy efficiency. Investigation of potential diversification of liquid fuel products and exploration of emerging market demands should be conducted to capitalize on evolving consumer needs and preferences. Continued research and development in the field of renewable energy integration and sustainability initiatives should be pursued to align the GTL plant with global energy transition efforts. Evaluation of potential expansion opportunities, including capacity scaling and geographical diversification, should be considered to capitalize on the growing demand for liquid fuels regionally and globally.