MONETIZING CO_2 IN A GTL PLANT WITH THE MIDREX® REFORMER

By: Rob Cheeley
Sales Manager

Midrex Technologies, Inc.
2725 Water Ridge Parkway, Suite 100
Charlotte, NC 28217
U.S.A

Phone: 704-378-3343
Fax: 704-373-1611

email: rcheeley@midrex.com

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INTRODUCTION

GTL Plants are being considered for numerous locations around the world. One thing all of these potential sites have in common is a low cost, stranded natural gas for feeding the plant. Another common issue for many of these sites is the presence of high levels of CO_2 in the natural gas. The CO_2 is an undesired constituent that may require special handling to prevent it from adversely affecting the plant economics.

In addition, conventional reforming technologies are net generators of CO_2, as are the Fischer-Tropsch reactors, especially those using iron catalysts. Since the goal of a GTL Plant is to economically convert natural gas into liquid hydrocarbons, the generated CO_2 represents wasted natural gas. One way of improving the plant economics is to minimize the net CO_2 emissions into the atmosphere by converting the CO_2 into CO, which is a required feedstock into the F-T reactor.

This paper will discuss how the MIDREX Reformer can be utilized by a GTL Plant to effectively "monetize" available CO_2 by readily converting it into a high quality syngas, thus improving the overall plant economics.

I. CO_2 AND GTL PLANTS

Large volumes of CO_2 are available in GTL plants from a variety of sources. The primary CO_2 sources are: (1) the natural gas supply (2) the reformer (3) the F-T reactor and (4) nearby industrial complexes, such as LNG plants. Unfortunately, the CO_2 is an inert in the F-T reactor and is therefore an undesired compound.

High CO_2 Natural Gas

Many stranded natural gas fields contain fairly high levels of CO_2. Natural gas fields containing more than 10% CO_2 include the Alaska North Slope, the Gorgon Field in NW Australia, and numerous locations in Indonesia. Using a natural gas with more than 10% CO_2 causes problems within the GTL plant. First, it becomes challenging to generate the desired 2:1 H_2/CO ratio in the reformer. Second the high quantity of inert CO_2 in the syngas adversely affects the FT reactor performance and hence the overall plant economics.

Carbon Conversion Efficiency and Reformer CO_2 Generation

A key measure of a GTL Plant's operating economics is its carbon conversion efficiency. This value provides a gauge of how much natural gas is required to produce a specific quantity of liquid hydrocarbon products. The carbon conversion efficiency is typically measured as:

Σ C in liquid products out of the FT reactor / Σ C in natural gas to the reformer

Obviously, the higher the carbon conversion efficiency, the less natural gas that is required to generate the desired liquid products. The issue of carbon conversion efficiency was addressed by Sasol at a recent conference. They estimated that their current GTL process has a 75% carbon conversion efficiency. They also presented data indicating the approximate breakdown of carbon losses in their GTL process.[1] Per the Sasol data, CO_2 generated in the reformer constitutes 39% of the carbon losses, and is the largest source of lost carbon. This implies that for a modern, state-of-the-art GTL plant about 10% of the natural gas feed into the plant is lost as CO_2 generated in the reformer. This carbon loss is unavoidable when using the traditional natural gas reforming methods (ATR, POX, SMR) which are all net CO_2 generators.

Iron Catalyst

FT reactors utilizing iron catalysts produce significant quantities of CO_2 as a reaction byproduct. This byproduct CO_2 represents a major loss of carbon in the overall GTL plant. Using conventional reforming technologies it is not possible to recover this lost carbon.

II. THE MIDREX™ SYNGAS SYSTEM

A solution to the CO_2 issues is the MIDREX Syngas System. The main component of the MIDREX Syngas System is the MIDREX Reformer, a proprietary, tubular style reformer. It is specifically designed to reform natural gas with both CO_2 and H_2O to generate a synthesis gas with a H_2/CO ratio as low as 1.5:1 in a single pass. It generates H_2 and CO via the following two reactions:

$$CH_4 + CO_2 \rightarrow 2\,CO + 2\,H_2$$

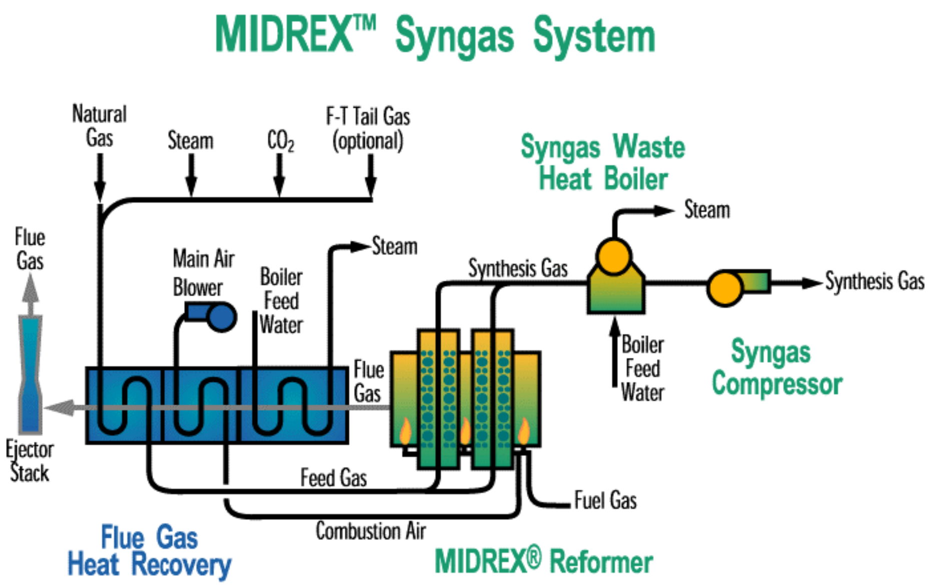
$$CH_4 + H_2O \rightarrow CO + 3\,H_2$$

The MIDREX Reformer has a long commercial history, having been utilized for over 30 years in the direct reduced iron (DRI) segment of the steel industry to produce a high quality synthesis gas. A total of 52 MIDREX Reformers have been built in 16 countries, with individual units having syngas capacities of up to 200 MMSCFD (220,000 Nm^3/h). Current plant designs are for units having syngas capacities as high as 270 MMSCFD (300,000 Nm^3/h). Since 1969, the operating MIDREX Reformers have produced approximately 13.2 TCF of syngas, enough to make about 440 million barrels of FT liquids.

In addition to the MIDREX Reformer, the other primary components of the MIDREX Syngas System are the reformer Flue Gas Heat Recovery System, the Syngas Waste Heat Boiler, and the Syngas Compressor. These ancillary units are used to minimize the net reformer fuel gas requirement, generate high pressure steam, and raise the syngas pressure up to the desired level for downstream processing. The high pressure steam is used to drive the Syngas Compressor and the other rotating equipment in the MIDREX

Syngas System. Depending on the specific flowsheet utilized, the MIDREX Syngas System may also include equipment for separating H_2 and CO from the FT Reactor tail gas and a pre-reformer for converting olefins and heavy hydrocarbons (C_5+) into CH_4.

A simplified process flowsheet for the MIDREX Syngas System is shown below:



The following tables describe the predicted syngas data at 360 psig (25 barg) and the typical operating inputs required to produce the syngas.

TABLE 1
Predicted Syngas Data

Component	Syngas Content
H_2	62.5 %
CO	31.5 %
H_2O	0.5 %
CO_2	3.5 %
CH_4	2.0 %
Pressure	360 psig

note: assumes no N_2 in feed gas

TABLE 2
Typical Operating Inputs

Input	Units	Quantity per 1 MMSCF syngas
Feed Gas		
Natural Gas	MMBtu	235
Steam	T (short)	6.5
CO_2	T (short)	6.1
Fuel Gas	MMBtu	125
Make-up H_2O	gallons	4200
Make-up BFW	gallons	1400

note: all steam is generated internal to the MIDREX Syngas System

If the natural gas is 100% methane, then the approximate feed gas composition on a volumetric basis is 43% steam, 40% methane, and 17% CO_2.

The required CO_2 can be a constituent of the natural gas, part of the FT tail gas, imported from a nearby plant, such as an LNG facility, or obtained from the reformer flue gas. A natural gas containing 30% CO_2 would not require the supply of CO_2 from any other source.

The MIDREX Reformer is also highly tolerant of variations in the natural gas composition. These reformers have successfully operated with natural gases containing up to 15% C_2H_6, 4% C_3H_8, and 2% C_4H_{10} without the need for any natural gas pre-treatment.

MIDREX Reformers in Al Jubail, Saudi Arabia

III. MONETIZING CO_2 IN A GTL PLANT

By properly applying the MIDREX Syngas System, the CO_2 that is normally a wasteful byproduct in the GTL process can be converted into a valuable raw material. Thus, "monetizing" the CO_2. The primary benefits from monetizing CO_2 are described below.

Reduced Natural Gas Consumption:

Our calculations indicate that about 30,000 SCF of syngas produced in the MIDREX Syngas System is required to produce one barrel of FT liquids. This should be fairly comparable to conventional reforming technologies. The main difference is that by partially substituting CO_2 for natural gas in the reformer feed gas, the amount of required natural gas per barrel of FT liquids can be decreased by as much as 20% when using the MIDREX Syngas System. The critical issue is how much fuel gas is available for use by the MIDREX Reformer. It is assumed that most of the required fuel gas can be supplied by the FT reactor tail gas.

Reformer Operational Flexibility:

In general, ATR / POX / SMR reformers tend to have minimized carbon deposition problems the higher the steam/carbon ratio. Therefore, it would be ideal to run with a higher steam/carbon ratio than is required to produce a 2:1 H_2/CO ratio syngas.

Operating MIDREX Reformers in the steel industry routinely run with H_2/CO ratios in the 1.5:1 range. Thus, by blending a mixture of a low H_2/CO ratio syngas from the MIDREX Reformer with a higher H_2/CO ratio syngas generated by the primary GTL reformer, the desired 2:1 H_2/CO ratio can still be achieved. This can help enhance the performance of the primary reformer.

LNG/GTL Combination Synergies:

Many LNG plants are located in regions where the local natural gas contains significant quantities of CO_2 (Indonesia, NW Australia, etc.). This CO_2 must be removed and flared prior to compressing the natural gas. Thus, very large quantities of "free" CO_2 could be available for use in an adjacent GTL plant.

For example, the PT Badak LNG facility in East Kalimantan, Indonesia produces about 12,500 T/D of CO_2 byproduct.[2] Using all of this CO_2 in the MIDREX Reformer feed gas would enable the MIDREX Syngas System to generate enough syngas for the manufacture of 75,000 bpd of liquid hydrocarbons in a GTL plant.

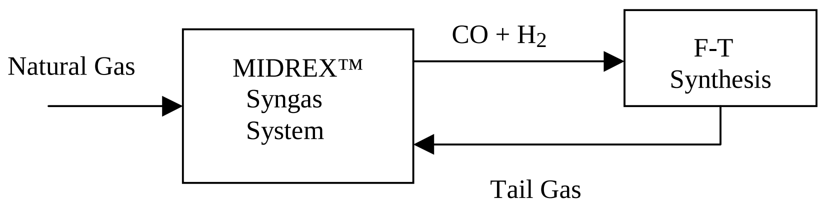
Developing High CO_2 Natural Gas Fields:

Historically, the costs and difficulties associated with using high CO_2 natural gas fields for supplying GTL and LNG facilities have prevented their development. By effectively monetizing the previously undesired CO_2 with the MIDREX Syngas System, development of these natural gas fields may become economically justified.

IV. FLOWSHEET OPTIONS

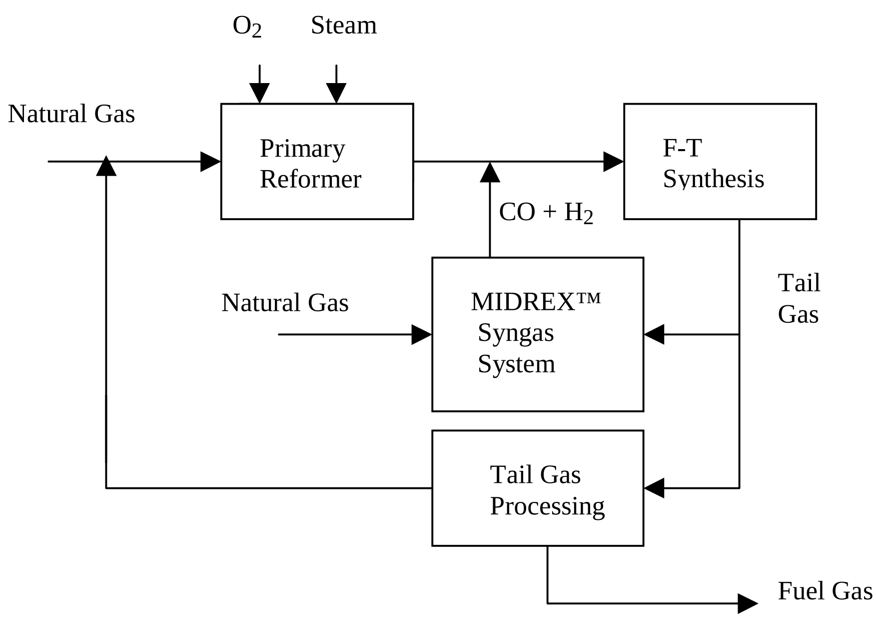
The strategy of monetizing CO_2 can be implemented via one of several options, which are more fully described below. The first option uses the MIDREX Reformer as the only reformer utilized. For the other three options the MIDREX Reformer is used as a complement to the primary reformer. In two of these options the MIDREX Reformer uses the FT tail gas as its major CO_2 source and in the third the CO_2 is received from an external supply source.

Option 1 – MIDREX™ Syngas System is only syngas source



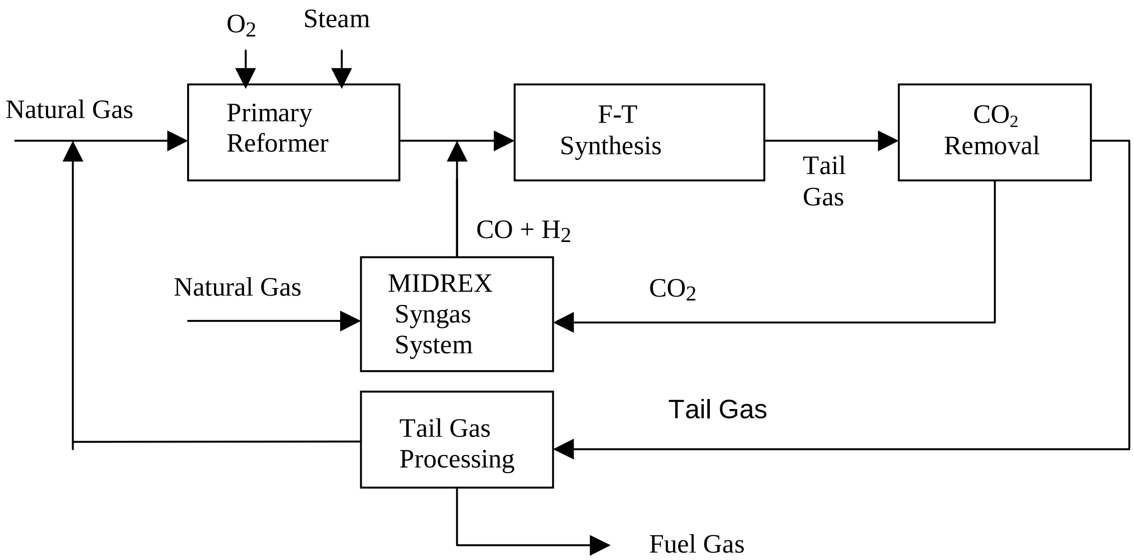
In this option, the MIDREX Syngas System is the only syngas source for the F-T Reactor. This option is most applicable for GTL plants in which the FT Reactor uses an iron catalyst or when the natural gas contains a significant amount of CO_2. In this option, the MIDREX Syngas System utilizes a PSA or membrane system to separate the CO and H_2 out of the tail gas and a pre-reformer to convert the olefins and heavy hydrocarbons (C_5+) into methane. Some of the tail gas H_2 and CO is recycled back to the F-T reactor and some is used as burner fuel.

Option 2 – Primary Reformer + MIDREX Syngas System



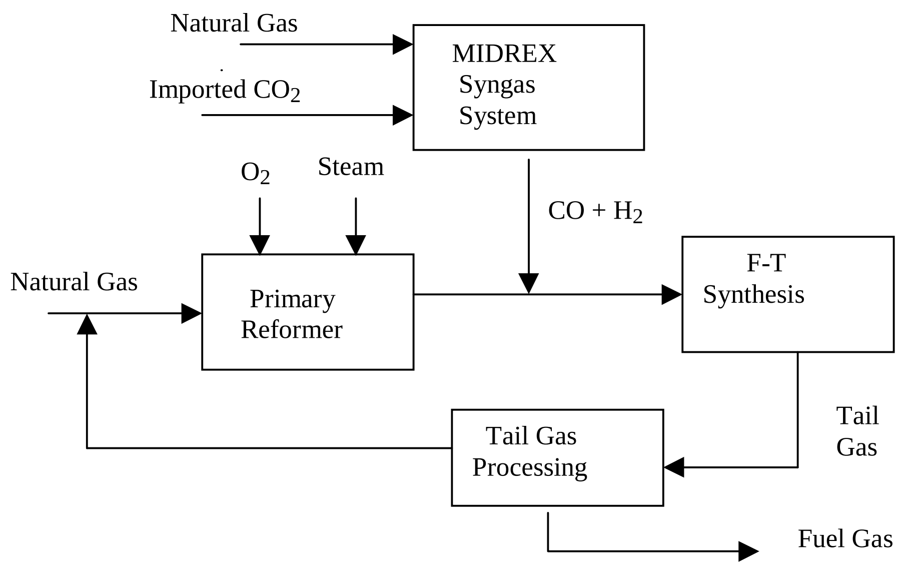
In this option, the MIDREX Syngas System uses the FT reactor tail gas as its supply source. A PSA or membrane unit would be used to separate the H_2 and CO from the rest of the tail gas entering the MIDREX Syngas System and a pre-reformer would be utilized to convert the olefins and heavy hydrocarbons (C_5+) into CH_4. The primary reformer can be either an ATR, POX, or SMR type unit and the MIDREX Syngas System is used as a supplement to the primary reformer.

Option 3 – Primary Reformer + MIDREX Syngas System
CO_2 removal system on FT Tail Gas



In this option, the CO_2 is removed from the FT reactor tail gas. None of the non-CO_2 constituents are sent to the MIDREX Syngas System. This represents the simplest flowsheet for monetizing CO_2 generated by the primary reformer.

Option 4 – Primary Reformer + MIDREX Syngas System
Imported CO_2 from external source



This option represents combining an LNG plant or petrochemical plant which separate out large volumes of CO_2 with a GTL plant. All of the FT reactor tail gas is handled by the primary reformer and none is sent to the MIDREX Syngas System. It is possible for this flowsheet to also include sending some of the tail gas to the MIDREX Syngas System if additional CO_2 is required as feed gas to the MIDREX Reformer.

CONCLUSION:

The MIDREX Reformer is a technically viable and commercially proven method for reforming CO_2 into CO. Using the MIDREX Syngas System, of which the MIDREX Reformer is the major component, a GTL plant can effectively "montetize" the available CO_2 by converting it into CO. There are many different flowsheet options for utilizing the MIDREX Syngas System, thus enabling it to be a good fit in almost any GTL project.

REFERENCES:

1. Steynberg, A.P., Vogel A.P., Price J.G., Nel H.G., "Technology Targets for Gas to Liquids Applications", AIChE Spring National Meeting, Houston, Texas, U.S.A., April 2001.
2. Sutope and Zudiharto, "Increase the Reliability of the CO_2 Removal Unit by Improving the Upstream Facilities", AIChE Spring National Meeting, Houston, Texas, U.S.A., April 2001