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Plant # 457

SYNGAS (HyCO) PLANT - 18,500 Nm3/hr

Capacity: 18,500 Nm3/hr (653,000 SCFH)

Raw Materials: Natural Gas

Process Information: This plant was designed to use landfill gas and/or natural gas to produce synthesis gas, which is then converted into paraffinic naphtha, diesel and wax by Fischer-Tropsch process.

Major Equipment

- Reformers #1 & #2
- Feed Heater
- Feed Superheater
- Hydrodesulfurizer
- Flue Gas Steam Generator
- Reformer Effluent Steam Generator
- Dirty Steam Drum
- Clean Steam Drum
- Combustion Air Preheater
- Dearator

Brief Plant Description

Used 18,500 Nm3/hr (653,000 SCFH) Hydro-Chem (Now Linde) designed Syngas Reforming (Hydrogen and Carbon Monoxide) Plant built in 2016, skid mounted. Almost like new, immediately available for purchase. Operated for only a few months. This plant was designed to use landfill gas and/or natural gas to produce synthesis gas, which is then converted into paraffinic naphtha, diesel and wax by Fischer-Tropsch process. The syngas output flow rate is at 500 °F and 175 psig. The syngas has the following composition (mol %): Hydrogen 43.01, Carbon Monoxide 16.37, Carbon Dioxide 8.34, Nitrogen 3.90, Methane 1.42, Argon 0.16, Water 26.79. Capacity may be varied from the control panel from 100% of design to 40% of design. The syngas can also be further processed depending on the desired final products such as ammonia and methanol. Plant is currently dismantled and stored. Immediately available for shipment.

Products

Syngas, hydrogen, carbon monoxide

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1. Executive Summary

- This syngas unit was designed by Hydro-Chem (now Linde) to use landfill gas and / or natural gas to produce synthesis gas, which is then converted into paraffinic naphtha, diesel and wax by Fischer-Tropsch process.

- Major Equipment of this unit includes Reformers #1 & #2, Feed Heater, Feed Superheater, Hydrodesulfurizer, Flue Gas Steam Generator, Reformer Effluent Steam Generator, Dirty & Clean Steam Drums and Blowdown Drum.

- The syngas output flow rate is 15.7 MMSCFD (or 18,500 Nm^3/hr) at 500 °F and 175 psig. The syngas has the following composition (mol %):

  - Hydrogen 43.01
  - Carbon Monoxide 16.37
  - Carbon Dioxide 8.34
  - Nitrogen 3.90
  - Methane 1.42
  - Argon 0.16
  - Water 26.79

  H2 + CO content, 59 vol %, (9.3 MMSCFD or 11,000 Nm^3/hr)

- Capacity may be varied from the control panel from 100% of design to 40% of design.

- The syngas can also be further processed depending on the desired final products such as ammonia and methanol. Some examples include:

  - Ammonia plant primarily comprises a syngas unit, a nitrogen unit and an ammonia synthesis unit.
    https://www.linde-engineering.com/en/process_plants/hydrogen_and_synthesis_gas_plants/gas_products/ammonia/index.html)

  - Integrated methanol and acetic acid plants using carbon monoxide.
    https://www.linde-engineering.com/en/process_plants/hydrogen_and_synthesis_gas_plants/gas_products/methanol/index.html

- This unit was commissioned around 2016, and operated for a few months.

- Feedstock can be landfill gas and/or natural gas.

  - Typical composition of landfill gas (vol %)
    Methane 53.54
    Hydrogen 0.11
    Carbon Monoxide 0.22

Carbon Dioxide	33.57
Oxygen	0.21
Nitrogen	11.83
Argon	0.52
LHV, btu/SCF	487.9
HHV, but/SCF	541.4
Total sulfur (as COS)	150 (ppbv design)
Temperature	43 °F
Pressure	259 psig

- Typical composition of natural gas (vol %)

Methane	91.5
Ethane	5.0
Carbon Dioxide	0.5
Propane	0.5
Nitrogen	2.5
LHV, btu/SCF	924.6
HHV, but/SCF	1024.0
Total sulfur	5 (ppmv design)
Temperature	70 °F
Pressure	415 psig

- Complete documentation available.

2. Process Description

2.1 Feed Treatment

Natural gas for feed and fuel enter the plant and separates into two streams: one flowing to the reformer burner manifold, and one flowing as feed gas to the process. The feed natural gas is mixed with FT offgas and purified landfill gas and heated to 650 °F in the Feed Heater using process heat downstream of the Reformer Effluent Steam Generator.

2.2 Desulfurization & Deoxidation

The landfill gas and natural feed stocks contains sulfur compounds which are poisons to the reformer catalyst and should be removed prior to reforming. The heated feed gas is passed up through the hydrodesulfurizer which contains two catalyst beds. The bottom bed contains a Co-Mo hydrotreating catalyst, which converts organic sulfur compounds to hydrogen sulfide and converts oxygen to water. In addition, any olefins present are converted to saturated hydrocarbon. The hydrotreated feed is then passed through the desulfurizer bed containing the zine oxide, which adsorbs the hydrogen sulfide. The desulfurizer bed is designed for a minimum catalyst life of 2 years (based on a total sulfur level of 3 ppmv in the combined feed stream).

2.3 Reforming

The desulfurized feed is mixed with steam that is heated in the Feed Superheater. Next, the mixed feed is passed to the catalyst tubes in an upfired, upflow, cylindrical reformers. Each reformer tube is packed with nickel catalyst. Reforming reaction and shift conversion occur. Both reactions are equilibrium limited based on the outlet temperature and pressure. The reformer exit conditions are 1600 °F. The overall reaction is endothermic, requiring heat supplied by the burner. The rest is supplied by natural gas. The flue gas leaving the furnace is used to superheat process feed, in the Feed Superheater, to generate steam in the Flue Gas Steam Generator and to preheat combustion air in the Combustion Air Preheater before being sent to the atmosphere.

2.4 Process Gas Cooling

The syngas product is cooler to 500 °F by the Feed Heater before being sent to the battery limit.

2.5 Waste Heat Recovery

The waste heat in the process gas and the reformer flue gas is used to generate steam at 250 psig in the Flue Gas Steam Generator and 410 psig in the Reformer Effluent Steam Generator. The process water is mixed with demineralized make-up water and degassed in the top section of the Deaerator using steam. The deaerated boiler feed water is pumped by the BFW Pumps to the Flue Gas Steam Generator. The makeup water for the Reformer Effluent Steam Generator is boiler feed water from the battery limit. Most of the steam from the Flue Gas Steam Generator is used as process steam; the rest is sent to the deaerator. Most of the clean steam from the Reformer Effluent Steam Generator is sent to the battery limit as export steam; the rest is used as makeup process steam.

3. Consumption Data

Below are the consumption of raw materials and utilities for the production of 15.7 MMSCFD syngas:

Landfill Gas Feed, SCFH	119,710
FT Offgas Feed, SCFH	47,440
Natural Gas Feed, SCFH	30,300
Fuel Gas, SCFH	174,550
Natural Gas Fuel, SCFH	17,900
Export Steam, lb/hr	13,000
Clean Boiler Feed Water Makeup, lb/hr	15,000
Process Water, lb/hr	11,500
Demin Water Makeup, lb/hr	11,500
Import H2, SCFH	1,300
Import H2, SCFH (note 3)	100
Nitrogen, SCFH (note 1)	40,000
Nitrogen, SCFH (note 4)	5,000
Instrument Air, SCFM	50
Power, KW (note 2)	175

Notes:

1. Nitrogen is required only for 4 – 8 hours during startup and shutdown for purging the equipment.

2. Power for heat tracing is not included.
3. Hydrogen is required only for 4 – 8 hours during catalyst reduction of the ultrapurification catalyst.
4. Nitrogen is required only for 4 – 8 hours during catalyst reduction of the ultrapurification catalyst.

4. Major Equipment

A. Reformer #1 (PK-200-R-1A)

Duty	16.2 MM BTU/hr
Size	144" OD
Tube Rating	225 psig @ 1783 °F
Tube Material	25 – 35 + Nb
Tubes	20 tubes of 5.563" OD X 50'
Number of Burners	1
Tube Weight	825 Lbs each
Reformer Weight	55,100 Lbs (without legs)
Shipping Weight	100,000 Lbs
Shipping Dimensions	12' 10.375" W X 13' 7" H X 64' 9" OAL

B. Reformer #2 (PK-200-R-1B)

Duty	16.2 MM BTU/hr
Size	144" OD
Tube Rating	225 psig @ 1783 °F
Tube Material	25 – 35 + Nb
Tubes	20 tubes of 5.563" OD X 50'
Number of Burners	1
Tube Weight	825 Lbs each
Reformer Weight	55,100 Lbs (without legs)
Shipping Weight	100,000 Lbs
Shipping Dimensions	12' 10.375" W X 13' 7" H X 64' 9" OAL

C. Feed Heater (PK-200-E-1)

Size	331 Sq. Ft.
Type	Hairpin
Material	CS / 304 SS
Shell Rating	260 psig @ 800 °F
Tube Rating	220 psig @ 790 °F
Configuration	Horizontal

D. Feed Superheater (PK-200-E-2)

Size	739 Sq. Ft.
Type	Hairpin
Material	304 SS / Incoloy 601
Shell Rating	260 psig @ 800 °F
Tube Rating	220 psig @ 790 °F
Configuration	Horizontal

E. Hydrodesulfurizer (PK-200-V-1)

Size	58” ID X 10’ S/S
Material	CS
Shell Rating	260 psig @ 800 °F
Configuration	Vertical
Heads	Dished
Support	Skirt
Internals	Packed Bed

F. Flue Gas Steam Generator (PK-200-B-1)

Duty	12.2 MM BTU/hr
Size	3775 Sq. Ft.
Material	CS
Shell Rating	280 psig @ 424 °F
Configuration	Horizontal

G. Reformer Effluent Steam Generator (PK-200-B-2)

Duty	4.9 MM BTU/hr
Size	445 Sq. Ft.
Material	CS
Shell Rating	460 psig @ 472 °F
Tube Rating	220 psig @ 620 °F
Configuration	Horizontal

H. Dirty Steam Drum (PK-200-V-2)

Size	41” X 10’
Material	CS
Rating	180 psig @ 424 °F
Configuration	Horizontal
Heads	Dished

I. Clean Steam Drum (PK-200-V-3)

Size	48” X 10’
Material	CS
Configuration	Horizontal
Heads	Dished

J. Combustion Air Preheater (PK-200-E-3)

Duty	6.2 MM BTU/hr
Size	9452 Sq. Ft.
Material	CS

K. Dearator (PK-200-V-5)

Vessel Size	42” X 8’
Dome Size	24” X 6’
Material	CS
Rating	50 psig @ 300 °F
Configuration	Vertical / Horizontal
Heads	Dished

Most of the equipment is mounted on skids.

Skid #1A&B

PK-200-B-1	Flue Gas Steam Generator
PK-200-V-2	Dirty Steam Drum
PK-200-E-2	Feed Superheater

Skid #2A&B

PK-200-B-2	Reformer Effluent Steam Generator
PK-200-V-3	Clean Steam Drum
PK-200-V-4	Blowdown Drum

Skid #3A&B

PK-200-E-1	Feed Heater
PK-200-V-5	Deaerator
PK-200-V-1	Hydrodesulfurizer
PK-200-P-1A	BFW Pump A
PK-200-P-1B	BFW Pump B

Skid #4

No process equipment on this skid.

Skid #5

Pipe Rack

Skid #6

Pipe Rack

Skid #7

PK-200-E-3	Combustion Air Preheater
PK-200-BL-1	ID Fan
PK-200-STK-1	Flue Gas Stack

Skid #8

PK-200-BL-2	FD Fan

Off-Skid Equipment

PK-200-R-1A	Reformer A
PK-200-R-1B	Reformer B
PK-200-X-1	Sulfur Dosing System

5. Process Flow Diagram

See attachment.

6. Reformer Specifications

See attachment.

Item No.		**PK-200-R-1 A&B**	
Type		Vertical,cylindrical,upflow,upfired	
Service		Steam-hydrocarbon reforming	
Absorbed Duty Total, MM Btu/hr		32.32	
Absorbed Duty per Cell, MM Btu/hr		16.16	
Radiant Section Heat Loss, % Abs'd duty		5.0	
Process Conditions		Inlet	Exit
Temperature, °F		1050	1600
Pressure, psig		213	193
Tube Design			
Material			Modified HP 50 or equal
Average Heat Flux (ID), Btu/hr ft2			13,856
Design Tubewall Temperature, °F			1,783
Design Pressure, psig			225
Design Stress to rupture in 100,000 hrs, psi min			1,739
Number of Tubes per Cell			20
Fired Length, ft			46.270
Total Length, ft			50.0
Tube OD, inches (as cast)			5.563
Tube ID, inches (as cast)			4.689
Tube ID, inches (as bored)			4.814
Catalyst Volume per Tube, cft			6.0
Catalyst Weight per Tube, lbs			507.9
Unsound Wall Allowance, inches (as cast)			
Outside			1/32
Inside			1/16
Calculated Minimum Soundwall thickness, inches			0.338
Design Minimum Sound Wall Thickness, inches			0.343
Tube Bored			YES
Tube RMS			125
Furnace Layout			
Tube Spacing, CL to CL, inches (arc length)		Note 5	15.03
CL to wall, inches			11.00
Tube Circle diameter, inches min			105.25
Shell thickness, inches			3/8
Shell OD, inches			144.00
Burner Layout			
Number of Burner(s) per Cell			1
Burner Bolt Circle Diameter, inches estimated			By Burner Vendor
Burner Circle Diameter, inches estimated			By Burner Vendor
Flame Diameter, inches			By Burner Vendor
Refractory (Floor, wall, and roof)		Type	Thickness, in.
Floor (towards flame)	Note 2	Superwool HT 8pcf	3
Floor (remaining layers)	Note 2	Superwool Plus 10pcf	5
Wall (towards flame)	Note 2	Superwool HT 8pcf	3
Wall (remaining layers)	Note 2	Superwool Plus 10pcf	5
Roof (towards flame)	Note 2	Superwool HT 8pcf	3
Roof (remaining layers)	Note 2	Superwool Plus 10pcf	5
Ducting		Firebox Stack	Firebox Ducting
Shell thickness, inches		3/8	3/8
Shell OD, inches		72	72
Open ID, inches		55.25	55.25
Insulation (hot face), Type		Superwool HT 8pcf	Superwool HT 8pcf
Thickness (hot face), inches	Note 6	3	4
Insulation (remaining layers - cold face), Type		Superwool Plus 10pcf	Superwool HT 8pcf
Thickness (remaining layers - cold face), inches		5	4

Item No.			PK-200-R-1 A&B	
Type			Vertical,cylindrical,upflow,upfired	
Service			Steam-hydrocarbon reforming	
Piping		Size, in	Schedule	Material
Inlet				
Header		4	40	304H SS
Trombones		1	80	304H SS
Bottom Stub End		N/A	—	Note 4
External Insulation		—	—	Superwool Plus
Flanges	Note 4	1	600 lb.	316H SS
Outlet				
Pigtails		1 1/2	160	Incoloy 800 HT
Internal Insulation		—	—	Superwool HT
Projected Tube Flange		4	300 lb.	Carbon Steel
Blind Flange		4	300 lb.	Carbon Steel
Header	Note 3	4	160	Incoloy 800 HT
Downcomer	Note 3	6	160	Incoloy 800 HT
Site Conditions				
Design Atmospheric Pressure, psia				14.11
Minimum Design Metal Temperature, °F				minus 20
Maximum Wind Velocity, mph				90
ASCE 7-10 Seismic Values				
S_s				0.317
S_1				0.073
Soil Bearing Load for Foundation Design, psf				3,000

Notes

1. The outlet header and pigtail wall thicknesses are designed based on 1614 F (879 C) and 220 psig (15.2 barg) design conditions.
2. The first layer (nearest flame) of insulating blanket is designed for temperatures up to 2100 F (1149 C).
3. Engineering to verify the thickness.
4. The reformer tubes shall not have tube size flanges at the inlet. Instead the tubes shall have a cone reducer that connects to a 1" flange that connects to the trombones.
5. Tube circle to have enough room for 2 extra tubes (22 total).
6. Insulation thickness to be checked for fluegas temperature of 1900 F (1038 C).

Item No.		**PK-200-R-1 A&B**	
Type		Vertical,cylindrical,upflow,upfired	
Service		Steam-hydrocarbon reforming	
Absorbed Duty Total, GJ/hr		34.10	
Absorbed Duty per Cell, GJ/hr		17.05	
Radiant Section Heat Loss, % Abs'd duty		5.0	
Process Conditions		Inlet	Exit
Temperature, °C		566	871
Pressure, barg		14.7	13.3
Tube Design			
Material			Modified HP 50 or equal
Average Heat Flux (ID), kJ/hr m2			157,355
Design Tubewall Temperature, °C			973
Design Pressure, barg			15.5
Design Stress to rupture in 100,000 hrs, bar min			119.9
Number of Tubes per Cell			20
Fired Length, m			14.1
Total Length, m			15.2
Tube OD, mm (as cast)			141.3
Tube ID, mm (as cast)			119.1
Tube ID, mm (as bored)			122.276
Catalyst Volume per Tube, m3			0.17
Catalyst Weight per Tube, kgs			230.3
Unsound Wall Allowance, mm (as cast)			
Outside			0.8
Inside			1.6
Calculated Minimum Soundwall thickness, mm			8.59
Design Minimum Sound Wall Thickness, mm			8.72
Tube Bored			YES
Tube RMS			125
Furnace Layout			
Tube Spacing, CL to CL, mm (arc length)		Note 5	381.8
CL to wall, mm			279.4
Tube Circle diameter, mm min			2,673.4
Shell thickness, mm			9.5
Shell OD, mm			3,657.6
Burner Layout			
Number of Burner(s) per Cell			1
Burner Bolt Circle Diameter, mm estimated			By Burner Vendor
Burner Circle Diameter, mm estimated			By Burner Vendor
Flame Diameter, mm			By Burner Vendor
Refractory (Floor, wall, and roof)		Type	Thickness, mm
Floor (towards flame)	Note 2	Superwool HT 8pcf	76.2
Floor (remaining layers)	Note 2	Superwool Plus 10pcf	127.0
Wall (towards flame)	Note 2	Superwool HT 8pcf	76.2
Wall (remaining layers)	Note 2	Superwool Plus 10pcf	127.0
Roof (towards flame)	Note 2	Superwool HT 8pcf	76.2
Roof (remaining layers)	Note 2	Superwool Plus 10pcf	127.0
Ducting		Firebox Stack	Firebox Ducting
Shell thickness, mm		9.5	9.5
Shell OD, mm		1,828.8	1,828.8
Open ID, mm		1,403.4	1,403.4
Insulation (hot face), Type		Superwool HT 8pcf	Superwool HT 8pcf
Thickness (hot face), inches	Note 6	76.2	101.6
Insulation (remaining layers - cold face), Type		Superwool Plus 10pcf	Superwool HT 8pcf
Thickness (remaining layers - cold face), inches		127.0	101.6

Item No.			PK-200-R-1 A&B	
Type			Vertical,cylindrical,upflow,upfired	
Service			Steam-hydrocarbon reforming	
Piping		Size, in	Schedule	Material
Inlet				
Header		4	40	304H SS
Trombones		1	80	304H SS
Bottom Stub End		N/A	—	Note 4
External Insulation		—	—	Superwool Plus
Flanges	Note 4	1	600 lb.	316H SS
Outlet				
Pigtails		1 1/2	160	Incoloy 800 HT
Internal Insulation		—	—	Superwool HT
Projected Tube Flange		4	300 lb.	Carbon Steel
Blind Flange		4	300 lb.	Carbon Steel
Header	Note 3	4	160	Incoloy 800 HT
Downcomer	Note 3	6	160	Incoloy 800 HT
Site Conditions				
Design Atmospheric Pressure, bara				0.97
Minimum Design Metal Temperature, °C				minus 29
Maximum Wind Velocity, km/h				145
ASCE 7-10 Seismic Values				
S_s				0.317
S_1				0.073
Soil Bearing Load for Foundation Design, kg/m2				14,644

Notes

1. The outlet header and pigtail wall thicknesses are designed based on 1614 F (879 C) and 220 psig (15.2 barg) design conditions.
2. The first layer (nearest flame) of insulating blanket is designed for temperatures up to 2100 F (1149 C).
3. Engineering to verify the thickness.
4. The reformer tubes shall not have tube size flanges at the inlet. Instead the tubes shall have a cone reducer that connects to a 1" flange that connects to the trombones.
5. Tube circle to have enough room for 2 extra tubes (22 total).
6. Insulation thickness to be checked for fluegas temperature of 1900 F (1038 C).