4.4 REFORMED GAS COMPRESSION

4.4.1 General

In order to economically synthesize methanol, the proper conditions must exist. The methanol synthesis section is designed to operate at a pressure of 800 - 840 psig. Since the reforming reaction takes place at 200 - 240 psig, and since there is some pressure drop associated with the equipment used for cooling the Reformed Gas, compression of the Reformed Gas is required to bring it to the pressure necessary for the Methanol Synthesis reactions to take place.

There are three compressors associated with compressing the Reformed Gas up to the pressure required for Methanol Synthesis, the Booster Compressor, C-327, the Make Up Gas Compressor (M.U.G.), C-328, and the Recycle Compressor, C-329.

The Booster Compressor, C-327, is used to raise the pressure of the Reformed Gas from the Selas Reformer (105 psig) to the same pressure as the Reformed Gas from the Powergas Reformer (213 psig). The Reformed Gas streams from the two Reformers then combine and enter the suction of the

Make Up Gas Compressor, C-328, which has two stages. The Reformed Gas is compressed to 488 psig in the first stage of C-328. Heat of compression is removed by preheating Boiler feedwater, then by cooling water until the Gas is cooled to 104°F. After passing through a Knock Out Drum to remove condensed water, the gas enters the second stage of C-328 where it is compressed to 800 psig.

The gas from C-328 then enters the suction of the Recycle Compressor, C-329, which functions primarily as a circulator, compressing the gas only from 800 psig to 840 psig.

4.4.2 Selas Reformer Gas Compression

A. C-327 Booster Compressor

Reformed Gas is delivered to the Booster Compressor, C-327, at 104°F and 105 psig after being cooled in the waste heat recovery section of the Selas Reformer. C-327 is a barrel type centrifugal compressor designed to compress the Reformed Gas from the Selas Reformer at 105 psig to the same pressure as the Reformed Gas from the Powergas Reformer (213 psig). Its speed is controlled by a pressure

controller (PAC-204) which operates off the suction pressure to C-327 and adjusts the governor on the compressor driver, Pt-1220, to maintain a constant suction pressure to the compressor. This allows the compressor to automatically adjust rpm to compensate for small to moderate changes in Selas Reformed Gas Flow and still maintain constant back pressure on the Selas Reformer.

For a compressor operating at a certain pressure real and speed, there is a gas flowrate below which the compressor will exhibit a phenomenon known as "surging". A compressor in a surging condition can vibrate so badly that it can destroy or severly damage its internals within a matter of minutes, in some cases even seconds. In order to prevent this phenomenon from accurring, a certain minimum flow must be supplied to a machine operating within a certain set of conditions. This is accomplished by a flow controlled bypass from the discharge of C-327 back to its suction. Reformed Gas leaving

the compressor has its heat of compression removed and condensed steam removed by equipment to be discussed in more detail later. The anti-surge loop, or bypass, takes reformed Gas from the discharge of the Compressor & returns it upstream of the cooling equip. on the suction of the compressor. The compressor, in this manner, pumps enough gas to stay out of the combination of conditions that would allow it to go into a surge condition.

The anti-surge control loop is basicly a pressure differential recorder controller (PDRC-203) that is reset by a total flow transmitter (FT-202). For each flowrate there is a corresponding pressure differential at which point the compressor will go into surge. PD C-203 is calibrated to be 5-10% above the pressure differential corresponding to the surge point for a given flow. As flow through the compressor drops, FT-202 resets PDRC-203 so that the set point for the pressure differential always corresponds to the actual flowrate. If the flowrate drops far enough,

the PDRC-202 set point cannot be satisfied and the anti surge valve opens until the flow to the compressor increases enough to satisfy the PDRC-203 set point, thus keeping the machine out of the surge condition. A similar anti-surge control is employed on the Make Up Gas Compressor, C-328.

By taking the anti-surge gas flow from the main flow down stream of the gas cooling equipment, the anti-surge loop can be used without restraint on startups without the danger of the recycled gas heating up over a period of time from the heat of compression.

The operating conditions for the Booster Compressor are as follows:

a) Compressor

Manufacturer-------	Clark
Model--------------	2 BAC 8
Fluid--------------	Selas Reformed Gas
Fluid rate---------	1897 M SCFH
Suction pressure---	105 psig
Discharge pressure-	224 psig
Suction Temp.------	104^{o}F
Discharge Temp.----	275^{o}F
Speed--------------	9386 rpm

b) Driver (PT-1220)

Manufacturer	Worthington
Fluid	Steam
Fluid Rate	17.7 M lb/hr
Speed	9386 rpm
Horsepower	2587 hp
Pressure inlet	600 psig
outlet	55 psig

B. HE-1542 Boiler Feedwater Preheater

The Boiler Feedwater Preheater is a 750 square foot shell and tube heat exchanger, the purpose of which is to remove part of the heat of compression, generated by C-327. This is necessary so that the Reformed Gas can be more economically compressed to pressures required for methanol synthesis. It should be noted that the Boiler Feedwater being preheated in HE-1542 is not used in the Powergas Reformer or Synthesis Loop steam generation system. Part of the preheated Boiler Feedwater is used in the Selas Reformer and Gas Turbine steam generation system, the remainder of the water being recycled back to the #1 Boiler Plant. The operating conditions for HE-1542 are as follows.

a) Shell Side

Fluid---------- Boiler Feedwater
Fluid rate--------- 82.1 M lb/hr
Temp. inlet-------- 228°F
outlet--------
Pressure inlet----- 760 psig
outlet-----

b) Tube Side

Fluid---------- Selas Reformed Gas
Fluid rate--------- 1897 M SCFM
(46.9 M lb/hr)
Temp. inlet-------- 275°F
outlet--------
Pressure inlet----- 224 psig
outlet-----

C. HE-1551 Selas Reformed Gas Air Cooler

After being initially cooled by preheating boiler feedwater, the Selas Reformed Gas is further cooled in HE-1551, a 1280 square foot fin fan heat exchanger. Operating conditions for HE-1551 are as follows.

a) Fin Side

Fluid---------- Ambient Air
Fluid rate---------
Temp. inlet--------
Temp. outlet-------
Pressure drop------

b) Tube Side

Fluid----------
Fluid Rate---------
Temp. inlet--------
Temp. outlet-------
Pressure inlet-----
Pressure outlet----

D. HE-1554 Selas Reformed Gas Final Cooler

HE-1554 is a 1220 square foot shell and tube heat exchanger which is the last heat exchanger used to remove the heat of compression of C-327 from the Selas Reformed Gas. The operating conditions for HE-1554 are as follows:

a) Shell Side

Fluid---------- Cooling Water
Fluid Rate---------
Temp. inlet-------- 90°F
outlet--------
Pressure inlet-----
outlet-----

b) Tube Side - Selas Reformed Gas

Fluid---------- 1897 M SCFH
(46.9 M lb/hr)
Fluid rate---------
Temp. inlet--------
outlet--------
Pressure inlet-----
outlet-----

E. V-1451 Selas Reformed Gas Knock Out Drum

As the Selas Reformed Gas is cooled by the heat exchangers, steam condenses. The purpose of V-1451 is to remove the droplets of water that are formed when the steam condenses. The operating conditions for V-1451 are as follows:

Total flow in------	1,897 M SCFH 46.9 M lb/hr
Flow out:	
Dry Gas (top)----	46.1 M lb/hr
Steam (top)------	402 lb/hr
Condensate (botm)	401 lb/hr
Temperature--------	104°F
Pressure----------	213 psig
Separation Effi.---	

4.4.3 Make Up Gas Compression

A. C-328, The Make Up Gas Compressor, is so named because it supplies the fresh reformed gas, or make up gas, to the Synthesis Loop. It consists of two stages, both of which are barrel type centrifugal compressors.

The first stage of C-328 was purchased new for the Methanol Expansion. The second stage is the second stage case from the make up gas compressor that was in service prior to the Methanol Expansion, but with new internals. The compressor train is equipped with interstage cooling and water removal equipment which will be discussed in more detail later in this section of the manual.

C-328 is designed to compress the total reformed gas flow from both the Selas and Powergas Reformers from 213 psig to 488 psig with the

first stage, then from 487 psig to 800 psig with the second stage.

C-328 is driven by a 19,550 hp. Gas Turbine, PT-937. This turbine was in service as the driver for the Make Up Gas Compressor train in use prior to the M. S. Expansion.

The speed of the Gas Turbine is controlled by the suction pressure to the first stage of C-328. PRC-214 is connected to the governor circuit of PT-937 and makes small changes in turbine speed to maintain a constant suction pressure to C-328. The instrument is set very slow to avoid a cycling effect.

The M U G train is equipped with an antisurge control system similar to that used for the Booster Compressor, C-327. Compressed gas from the discharge of the second stage of C-328 is recycled back to the inlet of HE-2545, the Reformed Gas Air cooler. This allows the hot recycled gas to be cooled so the second stage heat of compression can be removed, and thereby prevent a continual heat

buildup when the anti-surge valve is open for long periods of time, i.e.: for startups, etc.

The pressure differential across the first stage is monitored by PDAC-216 since the first stage operates closer to its surge point than the second stage does.

Since for any flow through a compressor, there exists a corresponding pressure differential at which the machine will surge, PDRC is calibrated to maintain a set point 5-10% above the differential corresponding to the surge point. This set point is reset by FT-215, which measures the flow through the compressor, so that the differential pressure set point being used by PDRC-216 corresponds to the actual flow through the compressor.

In actual operation, as the flow through the machine changes, FT-215 resets the PDRC so it uses a new set point. If the flow drops sufficiently so that the new set point cannot be satisfied, PDRC-216 opens

the valve in the anti-surge line a sufficient amount to allow the flow to increase enough to satisfy the set point. In this manner the compressor is automatically kept out of a surge condition with no special Operator attention required to initiate the control system.

Operating conditions for the M U G Compressor, C-328, are as follows.:

a) C-328

	First Stage	Second Stage
Manufacturer	Clark	Clark
Model	553 B →	2 BC - 9 - 5
Fluid	Reformed Gas	Reformed Gas
Fluid rate	6.841 M SCFH (173.0 M lb/hr)	6.824 M SCFH
Suction pressure	213 psig	487 psig
Discharge pressure	488 psig	800 psig
Suction temperature	104°F	104°F
Discharge temperature	278°F	212°F
Horsepower required flowsheet	9294	5801
Max. design	11,140	7096
Speed: minimum (RPM)	7680	7680
Operating (flowsheet)	9952	9952
Max. design	10,348	10,348

b) PT-937

Manufacturer	General Electric
Model	M 5191
Firing fuel	Natural Gas
Horsepower:	
Operating	15,095
Max. design	19,550
Speed: Minimum	3888
Operating (flowsheet)	4569
Max. design	4860

B. Make Up Gas Compressor Interstage Heat Removal

The temperature of a gas that is to be compressed greatly affects the horsepower required for compression. It is for this reason that cooling equipment is used to remove the heat of compression in the reformed gas from the first stage compression before the gas is compressed in the second stage.

The interstage cooling equipment consists of HE-2551, a 2747 square foot shell and tube heat exchanger that preheats boiler feedwater, followed by HE-2552, a 5050 square foot shell and tube heat exchanger that uses cooling water. Steam condensed in the two heat exchangers is removed by V-2356 before the reformed gas enters the second stage of C-328.

The operating conditions for HE-2551, HE-2552, and V-2356 are as follows:

a) HE-2551 Interstage Boiler Feedwater Preheater

	Shell Side	Tube Side
Fluid	Boiler Feedwater	Reformed Gas
Fluid rate	202.0 M lb/hr	6,841 M SCFH (173.0 M lb/hr)
Temperature inlet	228°F	278°F
Temperature outlet	253°F	240°F
Pressure inlet	760 psig	488 psig
Pressure outlet	755 psig	487 psig

b) HE-2552 Interstage Trim Cooler

	Shell Side	Tube Side
Fluid	Cooling Water	Reformed Gas
Fluid Rate	1,059 M lb/hr (1926 GPM)	6,841 M SCFH (173.0 M lb/hr)
Temperature inlet	90°F	240°F
Temperature outlet	110°F	104°F
Pressure inlet	50 psig	487 psig
Pressure outlet	39.2 psig	487 psig

c) V-2356, C-328 Interstage Knock Out Drum

Total Flow In	6,824 M SCFH 172.2 M lb/hr
Flow out: Dry Gas (top)	171.5 M lb/hr
Steam (top)	693 lb/hr
Condensate (bottom)	797 lb/hr
Temperature	104°F
Pressure	487 psig
Separation efficiency	