RESEARCH ARTICLE OPEN ACCESS

Natural Gas Conditioning and Processing From Marginal Fields Using Modular Technology in Nigeria

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ABSTRACT
Gas flaring in Nigeria is a major pollution concern for the environment and health of Nigerians. Burning of natural gas brings about emitting of carbon monoxide into the environment as well as warm up the environment, thereby contributing to the global warming scourge. The lack of processing this gas has also led to loss of revenue in a sector where there is a likelihood of otherwise generating more revenue in the country. Gas conditioning and processing in Nigeria has brought about certain level of solutions to the flaring of natural gas in the country. This paper discusses a modular technology associated with the conditioning and processing of natural gas that marginal fields can partake-in in Nigeria to monetize natural gas in the country using a typical Nigeria natural gas plant located in Delta State as a cased study. There have been lots of discouragement in the past about investing in associated gas produced during crude oil production, but the study on this particular gas plant in Nigeria shows solutions to most of this problems. The gas plant LPG facility is a modular assembly of process equipment linked with interconnecting pipework for scalability and ease of deployment. The design took into consideration the specific composition of the associated gas produced during production of crude oil. The traditional approach of piping gas from a remotely located oil field to a central processing facility can now be put aside paving the way for a less than orthodox technique of “bringing the plant to the gas” whereby the need for expensive pipeline will be eliminated by situating the facility adjacent to the oil flow station. The gas plant gives a full technology of utilizing natural gas resources to meet the socio-economic needs of mankind while preserving the environment not only for meeting present needs but for the needs of future generations.

I. INTRODUCTION

Natural gas is the cleanest of all fossil fuels and simply the best choice for the environment. Development of the natural gas industry has been very much influenced by the physical characteristics of natural gas. Although oil, being a liquid at ambient temperature, can be contained and transported relatively easily using simple and less-expensive technologies, natural gas is more complex and generally more expensive to process, store and transport because of its physical nature. As a result of this, natural gas is either burnt off, pumped back into the reservoir or wells are abandoned. It may seem expensive at the beginning to go into production of natural gas, but it becomes more lucrative and beneficial in the long run, as regards the present volume of natural gas, impact on the environment, infrastructures and source of energy it will produce. (www.wikipedia.com). Natural gas is the world’s third largest source of primary energy following coal and oil. Since the early 1970s, world reserves of natural gas have been increasing steadily, at the rate of 5% per annum. Similarly the number of countries with known reserves has also increased from around 40 in 1960 to about 102 today. In 2014, Nigeria was recorded to be the 9th country in the world with the largest proven gas reserves, and the largest in Africa. According to the World Fact book, Nigeria has natural gas reserve of about 5.1 trillion cubic meters (tcm). Nigeria as one of the largest gas-flaring country in the world, by not fully harnessing its gas resources, tends to loss an estimated 18.2 million U.S. dollars daily from gas flaring. The numerous challenges associated with the transportation of natural gas to processing plants has led to the high volume of gas still been flared in Nigeria today. The health and environmental challenges associated with gas flaring cannot be overemphasized. There is also a huge economic loss when natural gas is been flared. According to the World Bank report (2008), Nigeria loses up to 30.6 billion US Dollars annually due to gas flaring. Several technologies exist to harness the potential of stranded gas field thereby converting this waste gas to more productive use. Some of these solutions include using the gas to generate power, re-injecting gas to recover more oil, shipping it to markets via pipelines, building of LPG (Liquefied Petroleum Gas) plants, and converting these gases to more useful and cleaner energy source for automobiles, generators etc. This paper is on a practical case study in which a technological solution harnesses the economic potential of a wasting resource as well as mitigating its negative impact on the environment. By utilizing local human and natural resources to synthesize products of commercial value, this case study brings to fore the long-term potential of using today's technology to address the issues of the past. The process described in this paper goes full cycle in utilizing an energy (natural gas) resource to meet the socio-economic needs of mankind while preserving the environment not only for meeting present needs but for the needs of future generations. The case study in question is centered around a gas processing and fractionating facility which takes raw associated input gas stream from an oil flow station located within close proximity to the facility, strips the gas of its liquid content and converts the liquid ends to sellable downstream products while the resulting dry gas is available for power generation or as feedstock to other petrochemical processes. The major aim of this particular gas plant in question is to see that remotely located pocket of stranded gas which are usually abandoned because of the gas volumes, are taken through a process that sets about redefining the landscape of gas as a resource of value in Nigeria's extractive industrial sector. Gas flaring should be abated and the gas converted into useful products in order to protect lives of human beings, animals and plants in the already abused ecosystem in Nigeria. And in doing so, environmental issues due to gas flaring will be addressed, there will be growth in infrastructure and industries, the use of natural gas will reduce our dependence on oil and increase our source of energy, employment will be made available, and more revenue will be generated for the nation's economy.

II. BACKGROUND INFORMATION

Niger Delta region in Nigeria is rated as the most oil-impacted environment and polluted area in the world most especially by environmental experts from the UK, the USA and Nigeria. A major contributor to this is the perennial flaring of associated gas during oil production, which has impacted on the natural and human environment, making these areas a danger to local communities. Flaring which is a means of disposing of the waste gases that are a natural by-product of oil production during the processing of crude oil is highly destructive to the local community and Niger Delta environment, (as recognized by British Trade Commissioner J.S. Sadler in 1963.) The Niger Delta region was found to be the second largest flare site in the world, after Russia, with World Bank report showing that over 150 million cubic meters of natural gas were flared or vented annually in Nigeria. (World Bank 2008, World Bank 2009). That the flaring of gas has undoubtedly continued to impact negatively on the vegetation in the oil-producing community of Niger Delta. Shell BP and Chevron acknowledged that gas flaring was the main ecological problem facing the Niger Delta (Shell and Chevron Staffs, 2010), but since natural gas was produced as a byproduct of oil it was not possible to have one without the other. Gas could not be re-injected into the oil reservoir because of the low technological and industrial base for energy use in Nigeria. The environmental impact has to some extent been established through scientific evidence that shows temperatures at the sites as high as 1,100^{o}C (Emoyan et al 2008), damaging vegetation growth, animal life and the ecological balance. Flare sites, such as Ebubu, Bomu, Elenlewe, and Ibigho north of the eastern Delta, recorded leaf temperatures within 100 to 120 meters (m) of the stacks varying by up to 6 ^{o}C between the upper and lower surfaces of the blades (Augustine & Sandford, 1976). Tests conducted on the soil temperature at a depth of 10 centimeters (cm) further showed it to be about 100oC higher at 15m from the stack, and between 50^{0}C at 50m. This affects the atmospheric conditions necessary for soil fertility and plant growth. Soil temperature over 30^{0}C leads to decreased agricultural yields, with the major impact being desiccation and damage to the micro flora (Bruower 1971 and Sandford 1974). Air quality was also affected, with damage to vegetation, the microclimate surface and groundwater, as a result of the high concentration of volatile oxides, carbon, nitrogen, sulphur oxide and particulates that exceeded the standard set by FEPA (Federal Environmental Protection Agency) in 1991. The pollution in the first oil producing community of Oloibiri and others such as Imiringi , Otuasega, and Anyama of Ogbia Ijaw area have been a consistent health hazards to many local people, including terminal diseases and birth defects (Ashton, 2001; Eweje,2006). Accusations levied against Shell-BP and Chevron Nigeria by the Ijaw included disease and illness, hearing loss, and severe child delivery as a result of gas flaring and oil spills. On several occasions, acidic precipitation was felt in the oil producing areas, through the production of sour gas that produced sulphur-oxide in the air (Aghalino, 2009). Oral evidence has revealed that during the flaring of gas the Ijaw people in that area did not need electricity to see in the dark, that is to say that the "oil industry has banished darkness from the oil bearing enclaves of the Niger Delta" (Aghalino, 2009). The oil companies took steps to reducing the constant flaring of gas in their area of operations, and Shell (Interview with Anonymous Shells Staff 2010) claimed that some of their plants and equipment had been relocated far from the affected villages as a measure to prevent future light pollution. Nevertheless, for five decades the Ijaw communities of Batan, Odidi, Oloibiri, Nembe and Aleibiri were denied bright sunlight during the day and darkness at night. Some will attributes this to lack of compliance with the Gas-reinjection Act of 1979 that mandated permission to flare or reserve it for economic use. Gas flaring continued to light up the sky at night in many village communities in the Niger Delta region (NDDC, 2001). The World Health Organization (WHO) (2002) claimed that flaring of gas contributed on a global scale to about 2.5 million deaths each year, representing 4-5% of the 50-60 million global deaths that occur in a year. The World Bank (2002) reported that gas flaring in the Niger Delta contributed more to greenhouse gases than all other oil producing countries in sub-Saharan Africa. Energy lost through gas flaring was equal to over half of the power generation used in most African thermal power stations. It is very clear that the damage to the soil, climate and vegetation of the local community environment by gas flaring affected livelihoods and brought health hazards to the ordinary people.

III. MODULAR TECHNOLOGY PLANT

Gas conditioning is the pre-treatment of natural gas prior to injecting into a critical process facility. It is the process necessary to transform contaminated natural gas produced from a gas well, crude oil or condensate well into natural gas free of contaminants and ready for use or further processing into other products. Generally, the type of gas conditioning and processing operations recommended for any specific plant depends on the kind of gas under consideration along with the distribution of the hydrocarbons found in the gas. (Campbell John M. 1976).

The construction of the gas processing plant commenced in August 2009, and began operation in December 2010. The plant is located in Kwale Axis, Ndokwa West L.G.A in Delta State Nigeria. The project was conceptualized and scoped to achieve the following primary objectives; completely utilize the associated gas produced from the flow station in the same location, which would eliminate gas flaring and environmental pollution in the region; Generate Electricity to run the plant and supply the neighboring communities; production of Liquefied Petroleum Gas (LPG), Natural Gas Liquids (NGL) and Propane which is a direct input into the domestic consumption pool of these products. Upon take-off, the plant was designed to process up to 25MMSCF/day of gas, with room for expansion in the future. Presently the plant is being upgraded to 80MMSCFD of gas. This has brought about plans for building a power plant that will utilize the bulk volume of methane from processing of its natural feed gas to generate more electricity that will be tired into national power grid. The feed natural gas for the gas plant is gotten from the flow station in the same location. The flow station presently has eight oil wells and produce about 35MMSCFD, though they are working on drilling more wells and developing the field. Associated natural gas from the flow station is piped to the gas plant. The gas from the eight different wells which is channeled from the crude oil separators of the flow station to the gas plant facility has its natural gas composition given below.

Table 1 Feed gas composition analysis

PROPERTY	FEED COMPOSITION 2012	FEED COMPOSITION 2015
Sampling Pressure[Psia]	280	300
Sampling Temperature[^{0}C]	25	25
COMPOSITION		
COMPONENTS	MOLE %	
N_2	0.46	0.27
CO_2	2.04	1.26
C_1	80.89	81.86
C_2	8.92	7.76
C_3	5.97	5.24
i-C_4	0.85	1.26
n-C_4	0.73	1.38
i-C_5	0.09	0.40
n-C_5	0.04	0.25
C_6	0.01	0.16
C_7	0.00	0.11
C_8		0.05
Total	100	100

Plant Processing Facility

The gas plant has two major natural gas processing aspect. The first phase of natural gas processing which the company began with is processing of natural gas into Liquefied Petroleum Gas (LPG). The LPG processing plant is a mechanical refrigeration type of plant. The choice of a mechanical refrigeration plant was made based on the gas composition analysis of the field, specifications of the product and economics of the process. The LPG plant produces LPG as its major product, while propane, methane and NGLs (Condensate) as by-products which also generates revenue.

The gas plant second phase of gas processing which commenced late 2015 in a small scale is getting to sell the methane CH_4 from the LPG processing as Compressed Natural Gas (CNG).

Plant operating Process

Till the late 1990s, it was not economical to install a stand-alone gas-to-liquids (GTL) extraction plant with feed gas rate less than 80 MMSCFD in Nigeria, the gas must be extremely rich in recoverable natural gas liquids (NGL) for a plant to be built. There also must be great assurance of not running out of gas supply for a gas facility to be installed. But with the technology of modular plants installation, installation has been made easy because of maximum portability and minimum installation cost. You have these modules for different stages in gas conditioning and processing operations of natural gas. A modular process skid is a process system contained within a frame that allows the process system to be easily transported. Individual skids can contain complete process systems and multiple process systems or entire portable plant. An example of a modular skid is a separation skid, having a separator as its auxiliary equipment, and valves, pumps and other equipment that makes up the skid. The separation module addresses the separation of NGL in a gas processing facility. The overriding philosophy of this modular plant is to make it simple to dismantle and relocate to other gas sources when existing gas supply is depleted.

The raw natural gas from the flow station contains natural gas liquids that must be separated and impurities removed from the gas to make it suitable for sale. The NGL is separated into its own various components by fractional distillation, and impurities removed by special treatment, thereby making several saleable light hydrocarbons. In addition, the off-gas from the produced sales gas yield is used as utility gas and fuel within the plant. The raw natural gas from the flow station facility is sent to the gas plant where it is compressed to increase the pressure up to 700 psig and at an inlet temperature of 120^0F. The feed Gas is dehydrated by an absorption process using monoethylene glycol. This is necessary to prevent the formation of "hydrates" which may cause plugging of heat exchanger tubes and downstream piping. Following dehydration of the feed gas, the feed stream is further cooled to a very low temperature by exchanging heat with propane in the chiller to at least -29^0C before entering the low temperature separator (LTS).This is to effectively separate sales gas and hydrocarbon liquids (condensate) from the cooled feed gas. The injected ethylene glycol is recovered at the bottom of the LTS, regenerated and recycled back to mix with fresh gas feed entering the unit. The sales gas from the low temperature separator is compressed and injected into a nearby natural gas pipeline or sold directly to an independent power producer. The condensate after exchanging heat with the feed gas is delivered to the De-Ethanizer. The re-boiler at the De-Ethanizer column uses hot oil as heating medium. The De-ethanizer overhead product is a methane-ethane mixture that is yielded as fuel gas for plant energy management. The bottom product from the De-ethanizer is a mixture of propane, butanes and pentanes plus. This is fed to the Depropanizer where propane is taken out as the overhead product, and butanes, pentanes and heavies are passed out as the bottom product. Again the reboiler at the bottom of the De-propanizer uses hot oil as heating agent.

The de-butanizer overhead is a mixed LPG that is yielded to storage while, the stabilized Natural Gasoline product from the De-Butanizer bottoms is yielded to storage after being cooled with an air cooler. The reboiler at the bottom of the debutanizer uses hot oil as well as a heating medium.

LPG Processing with this plant

Associated (wet) gas from the flow station comes into the plant in two separate lines, the low pressure and high pressure lines. The low pressure line gas is piped from the low pressure separator at the flow station while the high pressure line gas is from the high pressure separator. The piped gases from the flow station passes through two phase separators to knock out liquid molecules of crude that is carried over from the oil crude and gas separation at the flow station end by the gas. This is to ensure that the compressors are not fed with liquid in other not to damage them.

LPG extraction or processing from natural gas is pretty much done from the NGL extracted from natural gas processing. First contaminants which include hydrogen sulfide, carbon dioxide, water vapor, helium, and oxygen are being removed from the gas stream. Then methane CH_4 is being separated from the gas using cryogenic processing or absorption method. Cryogenic processing is more effective and majorly use around the globe. Basically, cryogenic processing consists of lowering the temperature of the gas stream to around -120 degrees Fahrenheit. The drop in temperature condenses the hydrocarbons in the gas stream, but methane CH4 remains in its gaseous form. Absorption method, on the other hand, uses a "lean" absorbing oil to separate the methane from the NGLs. The extracted NGLs are sent to a fractionating system where it is separated into a gas product, propane C3's, butane C4's and NGL $C5^+$.

Gas Compression

Gas flows into the high pressure (HP) and low pressure (LP) compressors at different inlet pressures. Inlet gas pressure at the HP compressor is about 280-320psi. The HP compressor has a single stage compression which compresses and discharges the gas at about 950-1000psi. For the LP compressor, suction pressure ranges from 50-75psi. The LP compressor has 3 stage of compression, and since the suction pressure is on the low side, it gradually boosts it up to 950-1000psi. Discharge gas from both compressors at the compressors skid flows through a cooling system at the various compressors before flowing in one line into the plant main process.

IV. RESULTS

Product yield and their economic value

Table 2- economic benefit from the plant

FEED/PRODUCT	QTY (MMSCFD)	QTY (MTD)	UNIT PRICE ($)	UNIT PRICE (₦)	Total value ($)	Total value (Nmillion) @ N200/$1
DAILY DESIGN FEED						
Natural Gas Feed from the flow Station	20	495.32	0.3/MSCF	N60/MSCF	6000	1.2
DAILY PRODUCTS YIELD AND REVENUE						
SALES GAS	19.09	437.84	3.25/MSCF	650/MSCF	62,042.5	12.41
EXCESS PROPANE	0.3699	19.44	300.00/MT	60,000/MT	5832	1.166
MIXED LPG	0.4194	27.03	689.66/MT	137,931/MT	18,641.37	3.728
NATURAL GASOLINE	0.112	10.56	346.75/MT	69,350/MT	3,661.68	0.732
TOTAL					90,177.55	18.036

V. CONCLUSION

The model adopted was basically bringing the plant to the gas and creating a ready market rather than the traditional or more conventional approach of piping the gas to the plant (or market). This gives the required flexibility in accessing stranded gas of relatively small volumes in the neighborhood of 5 – 20MMSCFD and making it economically viable by utilizing modular portable plants that have quick deployment and relocation times. This provides a total consumption solution to associated gas production on the near term while providing a long-term benefit to rid the environment of waste gas.

Investing and developing of natural gas market in Nigeria will go a long way in creating a healthy environment for the people, and huge growth in the nation's economy. Natural gas being the dominant hydrocarbon in volume, with a proven reserve of about 260 trillion cubic feet of natural gas triples the nation's crude oil resources. Therefore, investing in it by building of various types of modular gas plants will bring so much development to the nation.

Generally, small footprint plant that is quick to deploy and easy to relocate like this gas plant offers the most ideal solution for addressing natural gas flared during production of crude oil in the nation. It is expedient for the government and policy-makers in the oil industry make every effort to support and encourage projects such as this for the development of the nation. For increase in the use of natural gas can reduce our dependence on oil and increase our source of energy. Infrastructures and employment will be made available, and generates more revenue for the nation's economy.

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Appendix
Simplified Process Flow Diagram Of Gas Processing Plant

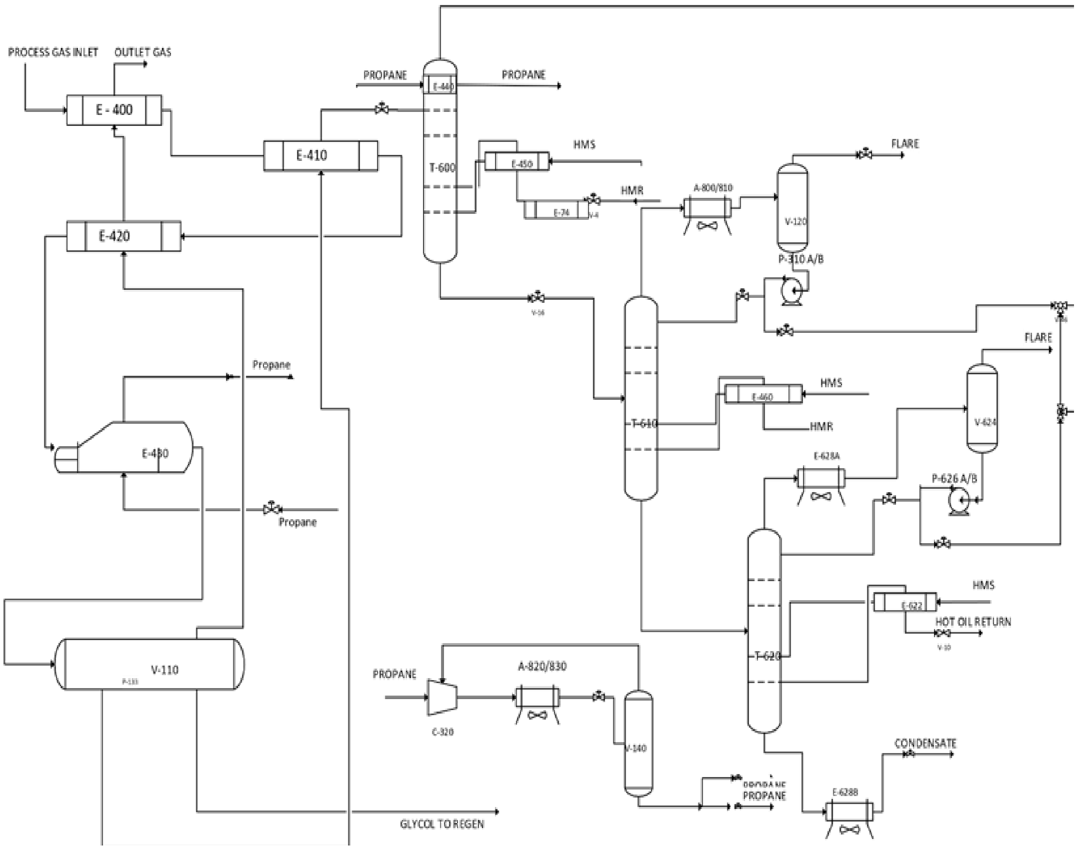
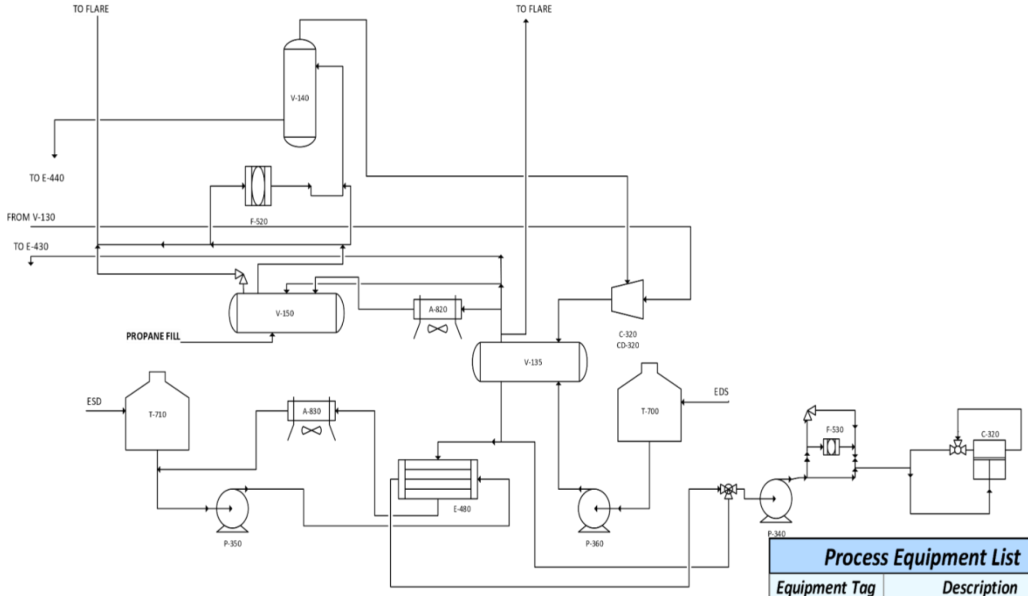


Figure 1 - Main Process diagram for the Gas plant



Process Equipment List

Equipment Tag	Description
A-820	PROPANE CONDENSER
A-830	LUBE OIL COOLER
C-320	PROPANE COMPRESSOR
C-320 CD-320	PROPANE COMPRESSORR DRIVER
E-480	OIL/EG EXCHANGER
F-520	PROPANE DRYER
F-530	MAIN OIL FILTER
P-340	LUBE OIL PUMP
P-350	OIL/EG EXCHANGER OIL
P-360	COMPRESSOR OIL M/U PUMP
T-700	COMPRESSOR OIL STORAGE TANK
T-710	OIL/EG TANK
V-135	GLYCOL/HC FLASH SEPARATOR
V-140	PROPANE ECONOMIZER
V-150	PROPANE ACCUMULATOR

Table 3 Equipment codes/names for figure 1

S/N	EQUIPMENT CODES	EQUIPMENT NAMES
1	A800/810	Overhead Condenser/Product Cooler
2	A-850	De-Butanizer Overhead Condenser
3	A-850A	De-Butanizer Product Cooler
4	E-400	Warm Gas/Gas Heat Exchanger
5	E-410	Gas/Liquid Heat Exchanger
6	E-420	Cold Gas/Gas Heat Exchanger
7	E-430	Chiller
8	E-440	Trim Cooler
9	E-450	De-Ethanizer Reboiler
10	E-460	De-Propanizer Reboiler
11	E-622	De-Butanizer Reboiler
12	P-310A/B	De-Propanizer Reflux Pumps
13	P-626 A/B	De-Butanizer Reflux Pumps
14	T-600	De-Ethanizer Tower
15	T--610	De-Propanizer Tower
16	T-620	De-Butanizer Tower
17	V-110	Low Temperature Separator
18	V-120	De-Propanizer Reflux Drum
19	V-624	De-Butanizer Reflux Drum