Manipal University Jaipur

Department of Chemical Engineering

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PROJECT

TRIETHYLENE GLYCOL BASED DEHYDRATION OF NATURAL GAS USING ASPEN HYSYS SIMULATION

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ABSTRACT

The project titled '**Triethylene glycol-based dehydration of natural gas using Aspen Hysys simulation'** was conducted in order to develop a model depicting the dehydration of moist natural gas using TEG. Several test models were developed through the course of this study and after a comparative data analysis (based on the purity and the net recovery of the regenerated TEG stream, relative cost estimation of the plant including capital and utility cost, and available energy saving) the most feasible setup was selected and thoroughly studied. The data sets obtained by using the selected dehydration setup have been included in the appendix of this report.

Regeneration of TEG to enhance the economic feasibility of the process has also been included. By using the arrangement of unit operations shown in the process flow sheet of this report, triethylene glycol with 99.9% purity was obtained as the regenerated stream. Furthermore, a net recovery of 99.4% TEG was obtained through out the process while 98.42% of the inlet natural gas was successfully dehydrated. The estimated utility and capital cost of the selected plant setup were 80,645$/Year and 38,55,730$/Year respectively. After several optimization test runs, the net available energy saving was reduced to a minimum of 0% hence further boosting the feasibility of the simulated dehydration setup.

INTRODUCTION

Natural gas from reservoirs usually contains water vapor, the presence of this vapor causes flow assurance issues hence the need to dehydrate the gas and optimize the process. This article illustrates the role of glycol dehydrator unit in the field of natural gas pipelines. In the operation of natural gas pipelines, a blockage or leak can cause expensive production losses, damaged equipment, and safety hazards.

When water is present, for instance, gas hydrates can form creating an icy plug in natural gas mixtures, especially when at low temperatures and high pressures. With water, carbon dioxide and hydrogen sulphide present, acid gases form and cause corrosion in pipelines which can lead to damaged downstream equipment. In order to create safer and more reliable operations, organizations need to remove free water from the natural gas. Many governments or agencies regulating shared pipelines maintain restrictions on the water content of sales gas or fungible product.

While there are many options to remove excess water, dehydration by a glycol is most commonly used by gas processing facilities with more than 36,000 glycol dehydration units in the United States. Triethylene glycol (TEG) is most frequently used, but other glycols including diethylene glycol (DEG) and monoethylene glycol (MEG) are also utilized.

There are however, still some issues with the dehydrator units as they are often overdesigned, resulting in high capital or operating costs. According to a USEPA report, TEG is recirculated two or more times higher than necessary. In order to ensure design options, meet the necessary requirements of saving capital, solvent, or energy costs, thermodynamic modelling and a holistic view of operations is needed [1].

SIMULATION

The process of simulation has been further subdivided into the following sections

.

ACQUIRING A BASIC UNDERSTANDING OF THE PROCESS

In order to understand the procedure utilized in order to dehydrate the given feed of natural gas, a basic understanding of the procedure is of utmost important. The following diagram represents the block flow diagram of a typical industrial dehydration setup in its essence:

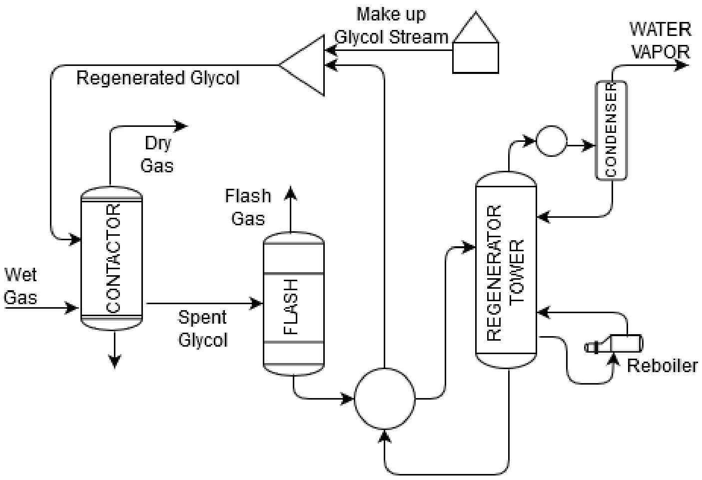

FIG. 1.1: BLOCK FLOW DIAGRAM OF DEHYDRATION OF NATURAL GAS USING TEG

The block flow diagram above may be divided into two sections (a). dehydration and (b). regeneration. In dehydration, wet gas is first channelled into a scrubber to remove any free water of the gas. Natural gas stream is then introduced into an absorber where the water content is removed from it. The pure glycol is fed into from the top of the absorber and is allowed to flow counter-current to the wet gas absorbing water from the gas. Then the water - rich glycol leaves the bottom of the absorber. The rich glycol is used as a condenser cooling medium for the regenerator gas before it enters the flash tank. Acidic gases and light hydrocarbons in the rich glycol stream evaporate at the flash tank and are used as a fuel [2]. For the regeneration part, the rich glycol stream from the flash tank enters the regenerator, which separates the TEG and water. The glycol is preheated through a heat exchanger by the lean glycol from the reboiler before it enters the regenerator. A stripping gas such as methane and nitrogen can then be injected into the reboiler to help reduce the water contents and reboiler duty. Finally, the regenerated glycol from bottom of the regenerator recycles into the contactor [2]. The flash gas which evaporated from flash tank can be used as fuel for the reboiler or as stripping gas. Since the hydrocarbon liquid can cause several problems such as reducing the efficiency of reboiler, if the hydrocarbon liquid exists at the condition, three-phase separation flash drum is needed. Glycol circulation rate determine the water contents in the dry gas and amount and volatile organic components (VOCs) emission from regenerator as well. The higher glycol rate, the lower the water contents and higher the venting emission. Therefore, it is important to optimize the circulation rate of glycol to compensate between two [2].

MODELLING OBJECTIVES

There are 3 priority tasks throughout the modelling of this process. These are:

- Maximum dehydration of natural gas feed.
- Maximum recovery of the TEG with a minimum purity of 99%
- Minimization of cost incurred in operation and capitalization of the plant, along with minimal waste of energy.

There are number of process conditions that can affect gas dehydration performance and significantly change results- i.e. TEG recirculation and stripping gas flow rate, temperature, pressure and number of equilibrium states. With all these changing variables, organizations need to have a holistic view of operations to better understand the process and help guide decisions to reduce costs and prevent damage to equipment. One way to do this is by utilizing advanced process simulation tools.

DESCRIPTION OF MODELLED PLANT

Just as described in the above BFD, the process of simulation has been divided into the following parts:

- Phase Separation of natural gas feed stream.
- Absorption of the water from natural gas feed using triethylene glycol in an absorption tower.
- Recovery of dissolved hydrocarbons from the bottom stream of the absorber.
- Regeneration of spent TEG (and recycle stream to the inlet (TEG) of the absorber).

The initial step to simulating the dehydration process was to compose the feed stream and the TEG stream. After doing so, the fluid package was appropriately chosen to accurately represent the TEG circulation rates, purities of lean TEG, dew points and the water content of the gas stream used.

There was a wide variety of fluid packages that could be used to perform this simulation. A few of these include Peng-Robinson FP, NRTL, UNIQUAC, SRK-FP, Lee Kessler Plöcker, but regardless of this, Glycol fluid package was chosen. This is so since the glycol fluid package has been specifically designed to accurately predict the thermodynamic properties of TEG, C1-C8 based natural gas components and water at pressures and temperatures encountered in industrial TEG based Dehydration plants, it was selected for this purpose. The glycol package utilizes the

The modelled plant for the dehydration process in Aspen Hysys v9 is shown below:

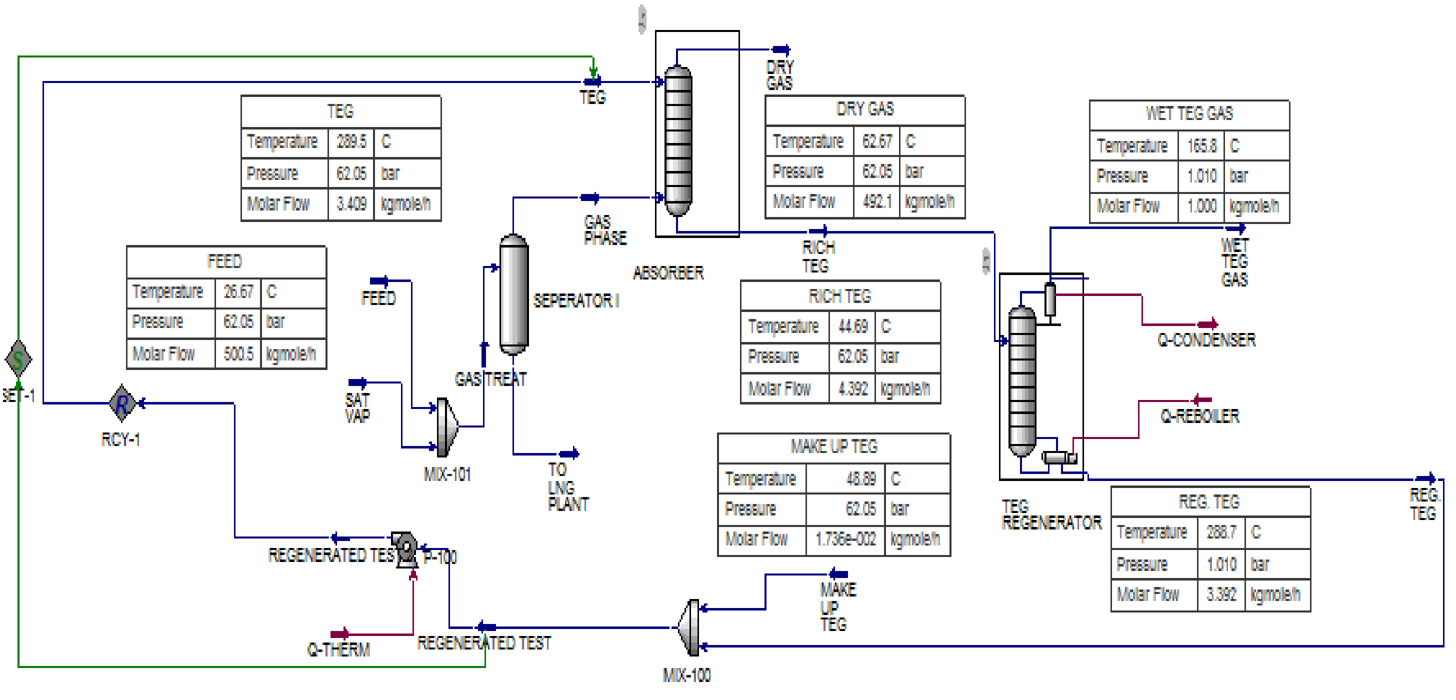

FIG 1.2: PROCESS FLOWSHEET OF TEG BASED DEHYFRATION

The inlet natural gas stream “FEED” is composed of the following:

COMPOSITIONS (MASS FRACTION)	
Nitrogen	0.106
Carbon dioxide	0.112
Hydrogen Sulphide	0.00004
Methane	0.684
Ethane	0.037
Propane	0.021
iso-butane	0.006
n-butane	0.009
iso-pentane	0.005
n-pentane	0.005
Hexane	0.007
Heptane	0.007
Triethylene glycol	0
Water	0.002

PROCESS/ STREAMDESCRIPTION

The “FEED” stream is first mixed with a stream of water titled “SAT VAP” at the same stream conditions as the FEED stream. This is done in order to saturate the FEED stream in order to increase the mass transfer coefficient between the moist natural gas and TEG in the absorber column. A case study was conducted in order to determine the amount of water needed to saturate the FEED stream and it was found that on an hourly basis, 800 Kg-moles of water need to be supplied. The two initial streams are mixed in a mixer to attain a uniform stream composition names “GAS TREAT”. GAS TREAT is a two-phase stream containing an aqueous phase as well as a gas phase. Hence to maximize the efficiency of the absorber, GAS TREAT is separated into a gas stream names “GAS PHASE” and a liquid stream named “TO LNG PLANT”. The TO LNG PLANT stream can later be refined in a LNG production plant. This permits for a (unaccounted) decrement in the net utility cost of the plant. The GAS PHASE stream which is saturated natural gas is fed into the contact towers named “ABSORBER” from the bottom. Simultaneously, a stream of TEglycol named “TEG” of 99.9% purity is introduced from the top of the plant. The absorber column has 14 trays with 50% efficiency (except for the top and bottom stream which operate at 100% efficiency). As a result of the absorption, the gas which emerges from the top of the ABSORBER named “DRY GAS” contains less than 0.01 mole% water and is sent off to the point of consumption. It should be noted that DRY GAS should be maintained at a high pressure in order to avoid transportation costs. In order to regenerate TEG, the bottom outlet of the ABSORBER named “RICH TEG” is sent to a 3-phase distillation column named “TEG EGENERATOR”. It consists of 1 tray and operates at a 170°C condenser temperature and 250°C Reboiler temperature with a reflux ration of 0.5 and a vapor flowrate of 0.2Kg-mole/hr. This allowed only the water from the RICH TEG stream to escape as water vapor in the “WET GAS TEG” stream whereas the “REG TEG” stream containing the pure TEglycol was recycled back into the initial TEG stream in order to increase the feasibility of the plant. This was done by adding the amount of TEglycol which was lost in the plant as the “MAKE UP TEG” stream. Both these streams were thoroughly mixed in a mixer and the outlet of the mixer was name “REGENERATED TEST”. The pressure with which this stream was discharged in the initial TEG stream as recycle was also altered using a pump. The stream emerging from the pump titled “REGENERATED TEST 2” was first equalized with the initial TEG stream using a “SET” block, and then it was recycled using the recycle block “RCY-I”

RESULTS OBATINED AND VALIDATION

The modelled plant can be used in order to obtain triethylene glycol with 99.9% purity as the regenerated stream. Furthermore, a net recovery of 99.4% TEG can be obtained through out the process while 98.42% of the inlet natural gas was successfully dehydrated. The estimated utility and capital cost of the selected plant setup were 80,645$/Year and 38,55,730$/Year respectively. After several optimization test runs, the net available energy saving was reduced to a minimum of 0% hence further boosting the feasibility of the simulated dehydration setup.

COMPONENT AND ENERGY BALANCES

The following material balances were conducted across the 4 major equipment in the flowsheet namely:

- Contactor/Absorber Column
- TEglycol Regenerator
- MIXER (MX-100)
- Recycle block

The following table shows the component balance across the absorber column:

COMPONENTS	Inlet moles/hr		Outlet moles/hr		Total I/O ratio
NITROGEN	1.86E-09	36.89829335	36.8966631	1.63E-03	1
CO2	7.85E-06	24.8146189	24.75254307	6.21E-02	1
H2S	2.88E-08	1.14E-03	1.12E-03	2.11E-05	1
METHANE	1.25E-06	415.7378997	415.6745758	6.33E-02	1
ETHANE	2.69E-07	11.99835718	11.99330657	5.05E-03	1
PROPANE	7.99E-07	4.643722897	4.639265955	4.46E-03	1
i-BUTANE	3.28E-06	1.006597628	0.997514644	9.09E-03	1
n-BUTANE	1.18E-06	1.509892388	1.508264288	1.63E-03	1
i-PENTANE	6.84E-06	0.675752755	0.665252758	1.05E-02	1
n-PENTANE	3.79E-07	0.67575264	0.674139446	1.61E-03	1
n-HEXANE	1.38E-05	0.791938633	0.787560614	4.39E-03	1
n-HEPTANE	1.83E-05	0.68118831	0.672797807	8.41E-03	1
TEGlycol	3.379553648	0	4.00E-04	3.379153853	1
H2O	2.94E-02	0.359203915	4.89E-03	0.383735399	1

The following table shows the component balance across the TEglycol Regenerator:

COMPONENTS	Inlet moles/hr	Outlet moles/hr		Total I/O ratio
NITROGEN	1.63E-03	1.63E-03	1.37E-10	1
CO2	6.21E-02	6.21E-02	2.31E-07	1
H2S	2.11E-05	2.11E-05	6.54E-10	1
METHANE	6.33E-02	6.33E-02	8.96E-08	1
ETHANE	5.05E-03	5.05E-03	1.37E-08	1
PROPANE	4.46E-03	4.46E-03	4.42E-08	1
i-BUTANE	9.09E-03	9.09E-03	6.90E-08	1
n-BUTANE	1.63E-03	1.63E-03	1.47E-07	1
i-PENTANE	1.05E-02	1.05E-02	1.26E-07	1
n-PENTANE	1.61E-03	1.61E-03	1.02E-08	1
n-HEXANE	4.39E-03	4.39E-03	5.45E-07	1
n-HEPTANE	8.41E-03	8.41E-03	3.99E-07	1
TEGlycol	3.379153853	4.44E-01	2.93484193	1
H2O	3.84E-01	3.83E-01	2.52E-04	1

The following table shows the component balance across the MIXER (MX-100):

COMPONENTS	Inlet moles/hr		Outlet moles/hr	Total I/O ratio
NITROGEN	0.00E+00	1.86E-09	1.86E-09	1
CO2	0.00E+00	7.85E-06	7.85E-06	1
H2S	0.00E+00	2.88E-08	2.88E-08	1
METHANE	0.00E+00	1.25E-06	1.25E-06	1
ETHANE	0.00E+00	2.69E-07	2.69E-07	1
PROPANE	0.00E+00	7.99E-07	7.99E-07	1
i-BUTANE	0.00E+00	3.27E-06	3.27E-06	1
n-BUTANE	0.00E+00	1.18E-06	1.18E-06	1
i-PENTANE	0.00E+00	6.84E-06	6.84E-06	1
n-PENTANE	0.00E+00	3.79E-07	3.79E-07	1
n-HEXANE	0.00E+00	1.38E-05	1.38E-05	1
n-HEPTANE	0.00E+00	1.83E-05	1.83E-05	1
TEGlycol	5.78E-02	3.321722883	3.38E+00	1
H2O	0.00E+00	2.94E-02	2.94E-02	1

The following table shows the component balance across the RECYCLE block:

COMPONENTS	Inlet moles/hr	Outlet moles/hr	Total I/O ratio
NITROGEN	1.86E-09	1.86E-09	1
CO2	7.85E-06	7.85E-06	1
H2S	2.88E-08	2.88E-08	1
METHANE	1.25E-06	1.25E-06	1
ETHANE	2.69E-07	2.69E-07	1
PROPANE	7.99E-07	7.99E-07	1
i-BUTANE	3.27E-06	3.28E-06	1
n-BUTANE	1.18E-06	1.18E-06	1
i-PENTANE	6.84E-06	6.84E-06	1
n-PENTANE	3.79E-07	3.79E-07	1
n-HEXANE	1.38E-05	1.38E-05	1
n-HEPTANE	1.83E-05	1.83E-05	1
TEGlycol	3.379555541	3.38E+00	1
H2O	2.94E-02	2.94E-02	1

The following table shows the energy balance across the model system:

	Unit	**Q-CONDENSER**	**Q-REBOILER**	**Q-COOLER**	**Q-THERM**
Heat Flow	*kJ/h*	156811.7	613721.5	50047.8	4602.747

CONCLUSION

There are several processes involved in processing the reservoir fluid into oil, gas and water. One of the most important processes offshore is gas dehydration, because wet gas increases corrosion and can course plugs from ice or gas hydrate. Absorption with TEG offers the best cost benefit choice for the dehydration process. The dehydration process is divided into two parts, the dehydration and the regeneration. In the dehydration part, gas is dried by the glycol. In the regeneration part the water is removed from the glycol so it can be used for dehydration once more. There are several possibilities in the design of the dehydration plant. The design options include the integration of heat exchangers and the recovery rate of the glycol. The main problem involved in simulation of the dehydration process is the non-ideal liquid behaviour of the water/glycol mixture. Process simulation calculations are conducted with thermodynamic equations, designed for ideal liquid mixtures. The problem can be solved by introducing thermodynamic equations that include the liquids excess parameters. The Wong-Sandler mixing rule is an example of equations that include the excess liquid parameters. The Wong-Sandler mixing rule can be combined with the classic equation of state like PR and PRS [3].

REFERENCES

[1] Mohammadi, Amir & Richon, Dominique. (2008). Determination of Water Content of Natural Gases: State of the Art.

[2] Patel, Sunil, and Jennifer Dyment. "Optimizing the Dehydration Process with Advanced Process Simulation." *Offshore World*, www.oswindia.com/jennifer_sunil_feature.html.

[3] Dan Laudal & Christensen [Feb. 2009] "Thermodynamic simulation of the water/glycol mixture" Aalborg University Esbjerg (AAUE) Niels Bohrs Vej, 86700 Esbjerg, Denmark

APPENDIX

STREAM DATA: MATERIAL

		Vapour Fraction	Temperature	Pressure	Molar Flow	Mass Flow	Liquid Volume Flow	Heat Flow
Unit			*C*	*bar*	*kgmole/h*	*kg/h*	*m3/h*	*kJ/h*
FEED		0.998535	26.66667	62.05283	500.5333	9761.051	26.93371	-4.4E+07
GAS PHASE		1	26.70391	62.05	499.7944	9747.718	26.9198	-4.4E+07
TO LNG PLANT		0	26.70391	62.05	1.238938	22.3407	0.022937	-351342
TEG		0	270.5398	62.05	3.409031	508.0385	0.450273	-2392900
DRY GAS		1	44.28164	62.05283	499.2683	9734.538	26.90158	-4.3E+07
RICH TEG		0	27.35878	62.05283	3.935095	521.2187	0.468487	-2912939
WET TEG GAS		1	257.1573	1.01	0.999999	80.4917	0.077927	-411692
REG. TEG		0	289.2001	1.01	2.935096	440.727	0.39056	-2044339
RECOVERY		0.512435	170	1.01	0.999999	80.4917	0.077927	-461740
SALE GAS		1	170	1.01	0.512434	14.3232	0.019164	-119259
COND. TEG		0	170	1.01	0.487565	66.16849	0.058762	-342481
TEG-VAP		0.020879	272.2954	1.01	3.422661	506.8955	0.449322	-2386821
WET TEG GAS II		1	272.2954	1.01	0.071462	7.541383	0.006745	-36070.8
REGENERATED TEG		0	272.2954	1.01	3.351199	499.3541	0.442577	-2350750
MAKE UP TEG		0	48.89	62.05	0.057833	8.684673	0.007696	-46756.9
REGENERATED TEST		0	268.8533	1.01	3.409031	508.0387	0.450273	-2397507
SAT VAP		0	48	62.05	0.5	9.00755	0.009026	-142021
GAS TREAT		0.997527	26.70391	62.05	501.0333	9770.059	26.94273	-4.4E+07
REGENERATED TEST 2		0	270.5379	62.05	3.409031	508.0387	0.450273	-2392904

STREAM DATA: COMPOSITION

Unit															
FEED		0.073718	0.049579	2.29E-06	0.8306174	0.023972	0.009278	0.0020111	0.0030166	0.0013501	0.00135007	0.0015824	0.001360932	0	0.002162824
GAS PHASE		0.073827	0.04965	2.29E-06	0.8318179	0.024007	0.009291	0.002014	0.003021	0.0013521	0.00135206	0.0015845	0.001362937	0	0.000718703
) LNG PLANT		5.09E-05	0.001051	1.11E-07	0.0111194	0.000195	4.09E-05	1.19E-06	5.05E-06	7.59E-07	8.52E-07	0.0001051	2.83E-06	0	0.987427449
TEG		5.45E-10	2.30E-06	8.46E-09	3.66E-07	7.90E-08	2.34E-07	9.61E-07	3.45E-07	2.01E-06	1.11E-07	4.05E-06	5.36E-06	0.991353069	0.008631106
DRY GAS		0.073901	0.049578	2.25E-06	0.8325675	0.024022	0.009292	0.001998	0.0030209	0.0013325	0.00135025	0.0015774	0.001347568	8.01E-07	9.80E-06
RICH TEG		0.000414	0.015777	5.35E-06	0.0160924	0.001284	0.001133	0.002309	0.000414	0.00267	0.00041005	0.0011161	0.00213687	0.858722405	0.097516183
/ET TEG GAS		0.00163	0.062084	2.11E-05	0.0633251	0.005051	0.004458	0.0090862	0.0016291	0.0105067	0.00161356	0.0043913	0.008408395	0.444312445	0.383483731
REG. TEG		4.66E-11	7.85E-08	2.23E-10	3.05E-08	4.66E-09	1.51E-08	2.35E-08	5.01E-08	4.29E-08	3.48E-09	1.86E-07	1.36E-07	0.999913531	8.59E-05
RECOVERY		0.00163	0.062084	2.11E-05	0.0633251	0.005051	0.004458	0.0090862	0.0016291	0.0105067	0.00161356	0.0043913	0.008408395	0.444312445	0.383483731
SALE GAS		0.003181	0.120949	4.08E-05	0.1235224	0.009848	0.008685	0.0176712	0.0031707	0.0204013	0.0031411	0.0084857	0.01625322	0.019926933	0.64472369
COND. TEG		3.48E-07	0.000216	3.06E-07	5.74E-05	8.81E-06	1.47E-05	6.33E-05	8.98E-06	0.0001074	8.11E-06	8.80E-05	0.000163432	0.890344476	0.108918775
TEG-VAP		4.96E-08	3.08E-05	4.37E-08	8.20E-06	1.26E-06	2.10E-06	9.04E-06	1.32E-06	1.53E-05	1.16E-06	1.27E-05	2.34E-05	0.984305199	0.01558936
ET TEG GAS II		2.35E-06	0.001367	1.69E-06	0.0003752	5.66E-05	8.96E-05	0.0003872	4.69E-05	0.000639	5.02E-05	0.0004148	0.000864867	0.66076754	0.334937151
ENERATED TEG		5.54E-10	2.34E-06	8.61E-09	3.72E-07	8.03E-08	2.38E-07	9.77E-07	3.51E-07	2.04E-06	1.13E-07	4.12E-06	5.45E-06	0.991204411	0.008779494
IAKE UP TEG		0	0	0	0	0	0	0	0	0	0	0	0	1	0
:NERATED TEST		5.45E-10	2.30E-06	8.46E-09	3.66E-07	7.90E-08	2.34E-07	9.61E-07	3.45E-07	2.01E-06	1.11E-07	4.05E-06	5.36E-06	0.991353625	0.008630554
SAT VAP		0	0	0	0	0	0	0	0	0	0	0	0	0	1
GAS TREAT		0.073645	0.049529	2.28E-06	0.8297885	0.023948	0.009268	0.002009	0.0030136	0.0013487	0.00134872	0.0015809	0.001359574	0	0.003158603
NERATED TEST 2		5.45E-10	2.30E-06	8.46E-09	3.66E-07	7.90E-08	2.34E-07	9.61E-07	3.45E-07	2.01E-06	1.11E-07	4.05E-06	5.36E-06	0.991353625	0.008630554