SUITABILITY OF SONGOSONGO NATURAL GAS FOR INDUSTRIAL AND DOMESTIC USE

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ABSTRACT

Natural gas from Songosongo in Kilwa - Tanzania was analyzed to determine its suitability for industrial and domestic use. Equal fractions of raw gas from each of the five wells was conditioned and processed through a conventional gas processing train comprising of pressure let down station, gas preheaters & coolers, compressors & expanders, demethaniser, deethaniser, depropaniser, debutaniser and a butane splitter with all heat exchangers, pumps, and necessary equipment, control and safety instruments in place. Results indicated that processed Songosongo gas (sales gas) meets specification requirements as a domestic / industrial firing gas. The gross calorific value (GCV) for the sales gas was 37.637 MJ/Sm^3 while the Wobble index (WI) value was 50.0 MkJ/Sm^3. The hydrocarbon dew point of the gas was found to be -75.98^{0}C in a pressure range of 1-69 barg. Water dew point through the same pressure range was 0^{0}C when the gas was considered to be 100% dry and between -40^{0}C and -70^{0}C when water concentration in the gas was assumed to be 10 mg/Sm^3 which is a typical value of water concentration in sales gas.

INTRODUCTION

Tanzania is a nation whose economy to a large extent depends on agriculture. Most of its people live in villages where they carry out small to medium scale farming of food and cash crops. The source of energy in villages is predominantly firewood. The main source of energy for town dwellers on the other hand is either kerosene, charcoal, electricity, town gas or a combination of these. Few people in towns use firewood. The energy sources for industries have predominantly been hydropower electricity and oil. Recently few plants (SPM and Mbeya Cement Factory) have started using coal from south western parts of the country. Gasoline and diesel are the only sources of energy in the transportation sector. The ever increasing global crude oil, machinery and spare parts prices have thrown the economy of the country into a rather bad shape. On the whole the energy supply in the country, especially electricity has untill very recently been very unfavourable.

A glance on the global and hence national energy scenario indicate that

- growing demand of fire wood and charcoal by rural and urban masses has lead to wide deforestation, making it more difficult to gather firewood. This has created more favourable conditions for drought, soil erosion and desertification
- shortages of trees have given rise to high prices of charcoal and kerosene for low income earners to afford
- severe drought causing low water levels at hydro-electric power stations has forced the country to ration its electricity supply, causing most industries to either shut down or operate below capacity and people to live a constrained life dictated by the availability of electricity. Demand of electric power unmatched by its supply has prompted a hike in electricity tariffs
- high global crude oil prices and unstable prices of kerosene, fuel oil, lubricants as well as crude oil products, on one hand and low cash crop prices on the other hand have caused unbearable hardships on the common man.

In such a situation news of natural gas ventures in Songosongo and plans to tap and transport the gas to Dar Es Salaam is most welcome for a number of reasons:

- It has been possible to install gas turbines to produce electricity which has been connected to the national grid to alleviate / end the present hydro power electricity crisis.
- Industries will have wider options of energy sources.
- The price of energy per kilo-watt-hour may fall, allowing people to use more energy. This is expected to make life of most inhabitants more comfortable. Recent developments of using diesel have led to yet another hike in electric tarrifs.
- The country will have wider opportunities of increased energy usage, increased production & higher GNP, cheaper commodity prices and consequently higher standard of living.
- Reduction of oil use and increased gas use will eleviate the present burden on the nation and reduce current pollution and environmental destruction.
- The country will be able to save money which can be used in other sectors like health, education, housing, transportation, etc.

The use of natural gas is however associated with higher safety risks as regards to explosion and self ignition. These aspects are nevertheless known and should be no cause for alarm. In this paper the potentials of natural gas from Songosongo - in Kilwa are investigated and reported with respect to suitability of the gas for use in industries and homes.

LITERATURE REVIEW

The ranking of energy consumption by the chemical and process industry in UK in the seventies stood as follows[8]

a) coal and oil
b) electricity
c) natural gas and naphtha.

Most of this energy went to fluid heating processes[6] although part was also used for other processes like electrolysis, compression, drying, calcination, etc. As regards to Tanzania, the energy consumption has been similar to the first two[8] with oil and electricity taking dominant role (top of the list). The use of coal in Tanzania started in the eighties while natural gas technology is currently under development. From 1965 to date there has been a significant worldwide shift away from coal to oil and then natural gas[11,12] as a result of the 1973 - 1974 oil embargo and subsequent oil price hike and supply shocks[5]. This shift saw increased use of natural gas and interest in alternative renewable energy sources. Consequently the growth of gas equipment technology is expected to continue given current positive price and supply outlook[5]. Among major new gas utilization technologies are[5]:

a) the use of gas for cleaner environment
b) industrial and commercial co-generation
c) combined cycle power plants
d) high efficiency gas heating and cooling systems including heat pumps
e) fuel cells and natural gas powered vehicles

In recent years concern for environmental pollution and control has increased tremendously. For these reasons it is not surprising that natural gas is considered as an alternative fuel due to its low sulfur and nitrogen content as well as low carbon dioxide generation. Natural gas has long been recognized as an environmentally superior fuel for utility boilers, major industrial facilities and residential purposes[5]. Of all fossil fuels, the combustion of the gas produces fewest environmentally detrimental compounds like S, NOx, SOx, COx and particulates in a form of heavy metals, dust and soot[5]. For example, the ratios between CO_2 emissions for coal:oil:natural gas are 100:88:58[11], due to fewer carbon atoms in the gas. This fact combined with efficiency and price benefits indicate that natural gas will have significant advantages over other fossil fuels[5,11,12]. In addition, the gaseous state of natural gas makes it easy to handle, control and use as fuel with high efficiency in nearly all applications. The aforementioned advantages together with the mode of transportation of the gas (which does not contribute to traffic density incase of pipeline use) give natural gas an environmental and economic edge over other conventional fuel sources[12]. However before natural gas can make these contributions, it must meet certain quality specifications as indicated in this presentation.

For convinient use of natural gas, knowledge of few parameters is important. One such important parameter for gas burners is relative density[3] (or gas molecular weight). This is due to Graham's law of diffusion which states that at constant pressure, the volume of a gas passing through an orifice is inversely proportional to the square root of its relative density. Another very important parameter is the gas calorific value (either gross or net value). These two parameters are more conveniently combined into one parameter called Wobble Index (WI) which is the ratio of the calorific value to the square root of the relative density. Wobble Index represents the potential heat flow through an orifice at constant pressure. Suitable values for natural gas range between 47,000 kJ/m^3 - 53,000 kJ/m^3.

For a gas to burn satisfactorily on a burner:

-combustion must be complete i.e. sufficient air must either be pre-mixed or entrained to give low carbon monoxide content in the flue gas
-flame speed must be low enough to prevent "flash back"
-flame speed must be high enough to prevent "blow off" i.e. around 13 to 40 cm/s[3].

While hydrogen addition increases flame speed and WI, carbon decreases WI. The high methane in Songsongo natural gas qualifies it to a "low speed gas" Other important parameters such as the limit of flammability of the gas in air, ignition temperature and other specifics of burner design will have to follow before the gas is put into any successful use.

EXPERIMENTAL WORK

Gas samples from Songosongo were simulated using PRO/II simulation program version 3.30 from SIMSCI International[9]. The gas was initially assumed to be at 3°C and 127 bar pressure after the pressure let-down station. Enthalpy, K-values, vapor density and entropy of the liquid and vapor phases were calculated using the Soave-Redlich-Kwong (SRK) equation of state[1]. Liquid viscosity, surface tension and conductivity of the liquid & vapor phases were calculated from the ideal gas equation while liquid density was calculated using Lee-Kesler equation[9].

The Wobble Index (WI) was calculated from standard routine[3]. Equipment used during conditioning and process simulation of the natural gas is fairly standardized[1,2,5]. Gas from the wells was also tested before as well as after process simulation to determine its suitability for firing purposes.

RESULTS

Gas samples at a pressure of 127 bar and a temperature of 3°C from five different wells in Songosongo were mixed in equal ratios and simulated through a standard process train[1,2,5] using PRO/II simulation program version 3.30 from SIMCI Intern[9]. The program is very versatile, robust and is currently the most used (and recommended by Gas Manufacturers Association). The process train consisted of a demethaniser, deethaniser, depropaniser, debutaniser, and butane splitter. All necessary auxiliary equipment like preheaters, coolers, control valves, flash drums, expanders, compressors, pumps and safety instruments were also assumed to be in place. Product specification targets[6] were chosen and maintained constant throughout. Results tabulated in Table 2 through Table 5 indicate that Songosongo natural gas is suitable for firing purposes in industry and homes.

Table 1: Composition of natural gas from different parts

Composition of different werlls in mol %								
Component	Rich gas-Norw.fields[6] Austin Leduc			Lean gas Norw[6] / USA[1] Louisiana Deeplak				
	Typical	Statfjd	Snorre	Viking	Lusiana	Gulfax1	Algeria	Northsea
N_2	0.7	0.59	2.66	0.24	-	0.9	1.5	14
CO_2	0.9	0.67	0.62	2.26	0.3	1.5	0.2	0.9
H_2S	10ppm v	-	-	-	-	-	-	-
He	-	-	-	-	-	-	-	-
CH_4	77.10	74.43	58.22	88.76	96.65	88	44.4	81.8
C_2H_6	10.7	11.66	15.97	4.76	2.05	6.7	30.	2.7
C_3H_8	6.8	8.22	15.58	2.67	0.47	1.4	0.5	0.4
$I\text{-}C_4H_{10}$	0.3	0.89	1.53	0.42	0.08	0.5	0.2	0.4
$N\text{-}C_4H_{10}$	0.4	2.24	4.43	0.21	0.09	0.4	-	-
$I\text{-}C_5H_{12}$	0.3	0.37	0.47	0.38	0.05	(I) 0.6	0.1	0.1
$N\text{-}C_5H_{12}$	0.3	0.437	0.46	0.3	0.31		-	-
C_6H_{12}	C_6+0.5	0.49	0.06	0.38	0.05	-	0.1	
C_7H_{12}+	-	0	0	0.38	0.05	-	-	-
Total	97.80	99.99	100	100.7	99.80	100.1	80.00	86.31

Note:- values not adding to 100% although they may easily be normalised
Norw = Norway

Table 2: Composition of natural gas from Songosongo[13]

Composition of different wells in mol %					
Component	Well No1	Well No1	Well No3	Mixmol%	Mix wt%
N_2	0.68	0.60	0.68	0.653	1.0989
CO_2	0.35	0.29	0.47	0.411	1.0857
H_2S	-	-	-	-	-
CH_4	97.2	97.4	96.81	97.32	93.7609
C_2H_6	1.1	0.94	1.05	1.032	1.8635
C_3H_8	0.3	0.31	0.32	0.311	0.8225
$I\text{-}C_4H_{10}$	0.069	0.073	0.071	0.071	0.2476
$N\text{-}C_5H_{12}$	0.028	0.028	0.029	0.0321	0.1389
C_6H_{14}	0.031	0.025	0.04	0.1054	0.5455
C_7H_{16}	0.076	0.1	0.14	0.0531	0.3196
C_8H_{18}	0.043	0.053	0.063	0.017	0.1168
C_9H_{20}	0.018	0.023	0.01	0.0	0
Total	98.87	98.95	98.53	98.94	97.82

- values not adding to 100%. Difference may be attributed to H_2O and experimental errors. However if interested, values can easily be normalised.
- % volumes not of interest and thus not calculated

Note: For mixture compositions (mix), equal fractions from all five wells was assumed. Compositions are in mol% and wt% respectively.

Sales gas composition and its characteristics was determined after the natural gas was conditioned and processed. Results are tabulated in Table 3 and Table 4 respectively.

Table 3: Characteristics of sales gas at 69 barg

Parameter	Values from Ref[6]			Songo songo	Pipe specs[5] Sample-6
	Rich	Sales	Mixed	Sales	
Molecular wt	22.5	18.4	19.1	16.41	-
GCV (J/Sm^3)	48	41	42.2	37.63	40
WI (MJ/Sm^3)	55.5	51.4	52.1	50	50
H.C Dpt. (^0C)	Apr 40	-40	-17	-75.98	-10.7
Water Dpt(^0C)	-14	-70	-30	-	-18
Water(mg/Sm^3)	40	1	9	0	-

- these values were not of interest and were not calculated.

Note The water content of Songosongo gas reported as 0.0% is doubted. Natural gases will always contain a certain amount of water. For safety operations, correlations from the literature[2] at appropriate conditions have been used in order to determine dew point conditions during gas transportation in a pipe. These correlations at 127 bar and 3°C give water content of Songosongo natural gas equal to 80 mg/Sm^3. For the feed gas this is equivalent to water mole fraction of 1.065E-04. Water content of the sales gas was assumed to be 1-10 mg/Sm^3. Using Campbell[2] correlations this gives water dew point of -40°C to -70°C for a sales gas pipe pressure of up to 70 bar which is typical value for operation of sales gas pipes[1,2,11].

Suitability of sales gas depends on how close it can approach specification requirements as a burning gas[6] . Table 5. indicates how close Songosongo gas approaches specification requirements of a sales gas.

Table 4: Composition and properties of sales gas at 69

barg

Component	Typical val[6]		Firing gas [6]		Songosongo	
	Mole %	Wt. %	Mole %	Wt. %	Mole %	Wt. %
H_2O	-	-	-	-	-	-
N_2	0.71	1.08	0.95	1.53	0.656	1.1209
CO_2	0.95	2.27	0.74	1.88	0.4156	1.148
CH_4	84.76	73.28	92.26	85.34	97.804	95.623
C_2H_6	12.72	20.75	5.16	8.95	1.0475	1.92
C_3H_8	0.7800	1.870	0.8	2.03	0.0701	0.1770
I-C_4H_{10}	0.03	0.09	0.03	0.10	0.0005	0.0181
N-C_4H_{10}	0.05	0.16	0.06	0.17	0:0	0.0000
C_6+	≡50ppm	<0.02	<0.01	< 0.01	8.5E-4	4.5E-3
Total sulphur (vol ppm)			1-2			
Water/vapor dew pt. (^{0}C)			-74			
Calor. value (GCV)(MJ/Sm^3)			41.2	39.09		
Wobble Index (WI) (MJ/Sm^3)			51.7	50.46		
Molecular weight (g/mol)			18.4	17.35	16.32	16.32

- The accuracy in some cases is reported to the fourth decimal place. This can alternatively be expressed in exponential manner but should not be truncated or rounded.

DISCUSSION

Results of this study have shown and suggest that Songosongo natural gas from Kilwa meets the basic requirements for both industrial and domestic firing gas (Table 1 - 5). Comparison of Tables 1 and 2 indicate that Songosongo natural gas has highest percentages of methane but

Table 5: Specification requirements for sales gas [6]

Component	Specification[6]	Songosongo
Cal.value (GCV)MJ/Sm^3	39.7 - 43.7	37.631
Wobble Index MJ/Sm^3	48.4 - 52.8	50.00
Hydr.carb dewpt.^{0}C	Less than -10.7	-75.98
Water dew point °C	Less than -18	-40 - -70
Oxygen mole	Max. value = 0.1	- 0.201
CO_2 mol%	Max. value = 2.5	0.4156
H_2S mg/Sm^3	Max. value = 14.2	
Mercaptans mg/Sm^3	Max. value = 14.2	
Total sulfur mg/Sm^3	Max. value = 142.2	

lowest percentage of ethane, propane, butane and C_5^+ fractions. Consequently, recoverable LPG and gasoline is relatively small. During simulation, a standard gas processing train consisting of five columns was used. In practice there seems to be no need of either a demethaniser or a butane splitter! Three columns - a deethaniser, depropaniser and a debutaniser will equally do well the desired gas separation since n-butane (strangely) appears to be absent! However if later analyses suggest that n-butane is present in any amount, then still a three column train will be adequate but one will have to replace the debutaniser by a butane splitter. Table 3 shows GCV of processed Songosongo gas to be lower than that specified[6]. The same applies to Wobbe Index (WI), hydrocarbon dew point (H.C), water dew point and molecular weight. This is due to low percentage of C_2 in the sales gas as confirmed by Tables 2 and 4 respectively. However Table 5 which gives specification requirements range for sales gas shows that WI for the gas lies within acceptable range. Only GCV for the gas is lower (outside recommended range).

One should note that specifications given are for sales gas derived from rich gas. The author could not get specifications for sales gas derived from lean gas. It is authors belief that such values will not be very different from those used in this work. Slightly lower than specified GCV for Songosongo gas does not reduce its potentiality as an industrial or domestic firing gas. In fact the gas has additional advantages of low CO_2 and no sulfur content. This will reduce corrosion dangers to burners. N_2 content however compares well with that in other natural gases although the value for Songosongo gas appears to be slightly lower. One can therefore not justifiably comment on low NOx pollution risks for Songosongo gas compared to other gases but clearly there is ample reduction in NOx pollution when using the gas than when using other fossil derived fuels as discussed earlier. An obvious drawback in using natural gas lies in the behaviour of natural gas combustion to generate vast amounts of water vapour. This will especially be a problem in kitchens unless measures are taken to arrest the problem. Another problem is associated with high costs of supply pipe network. As for the condensate, although the amount of recoverable LPG is relatively small, it might be considered worth recovering it and C_5^+ fractions for the chemical industry. If it is thought to be uneconomic to install an ethylene cracker, then the LPG and C_5^+ fractions may be sold outside to other firms that process them. Such a move will require a prior economic / viability study to be conducted.

CONCLUSION

Natural gas from Songosongo - Kilwa district in Tanzania was investigated for its suitability as a firing gas in industry and homes. As expected results have shown slightly low gas gross calorific value (GCV) due to the high methane content of the gas (Table 5). Other specification requirements for sales gas were fairly met. The slightly low gas gross calorific value can however be ignored (since WI is more than compensated by the low molecular weight hence relative gas density of the gas - Table 3) in respect of other qualities and added advantages of the gas such as low CO_2 generation and absence of sulfur. The use of the gas in homes or industry will nonetheless require modification to the existing conventional burners (nozzles) and air entry points due to the higher calorific value of the gas[3] and hence higher stoichiometric air requirements. There is unquestionably high potential for the Songosongo natural gas for firing in industry and homes. Enhanced efforts must be directed towards its immediate exploitation since there do