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Thermodynamic Analysis of Trigeneration System

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ABSTRACT:

Tri-generation is an innovation that includes three types of energy output which are heating and cooling and electrical power. A framework known as Trigeneration is incredibly useful in providing hot water, heat, AC, and power through the independent framework.For producing chilled H2O by the heat by adding absorption chillers Trigeneration plant is very helpful also this plant cogenerates the power. Also, it would have been wasted by cogeneration process. Economically it is very helpful and has various advantages like, it saves us from greenhouse effect, and it also saves us from carbon dioxide which is very harmful. Also, a huge benefit we have is, it makes us independent as we can no longer rely on foreign energy suppliers. If we compare to congested plants this plant is very beneficial.

Keywords: TRIGENERATION, COOLING, FUEL,HEAT LOSSES, STEAM TURBINE, EFFICIENCY

1. INTRODUCTION:

Tri-generation is an innovation that includes three types of energy output which are heating and cooling and electrical power. A framework known as Trigeneration is incredibly useful in providing hot water, heat, AC, and power through the independent framework. The two results, heating, and cooling might work equally based on need and framework development.

1.1 CCHP System:

It is also known as Combined Cooling, Heat and Power. This system utilizes waste of heat that further utilized in conventional power plants and utilizes this waste heat to provide energy, heat and also produce chilled water that can be used for cooling further waste heat cannot be used to produce electricity by mechanical means such as through steam turbines etc. Trigeneration systems are now reached to the maximum utilization of power plants around 280% having total efficiency of system is around 88%. There are some congested "central “plants, which is no more needed to generate the heat from the process like power generation and combust, which is just around 33% productive.

1.2 Trigeneration:how it works:

For producing chilled H2O by the heat by adding absorption chillers Trigeneration plant is very helpful also this plant cogenerates the power.Also, it would have been wasted by cogeneration process. Economically it is very helpful and has various advantages like, it saves us from greenhouse effect, and it also saves us from carbon dioxide which is very harmful. Also, a huge benefit we have is, it makes us independent as we can no longer rely on foreign energy suppliers. If we compare to congested plants this plant is very beneficial.

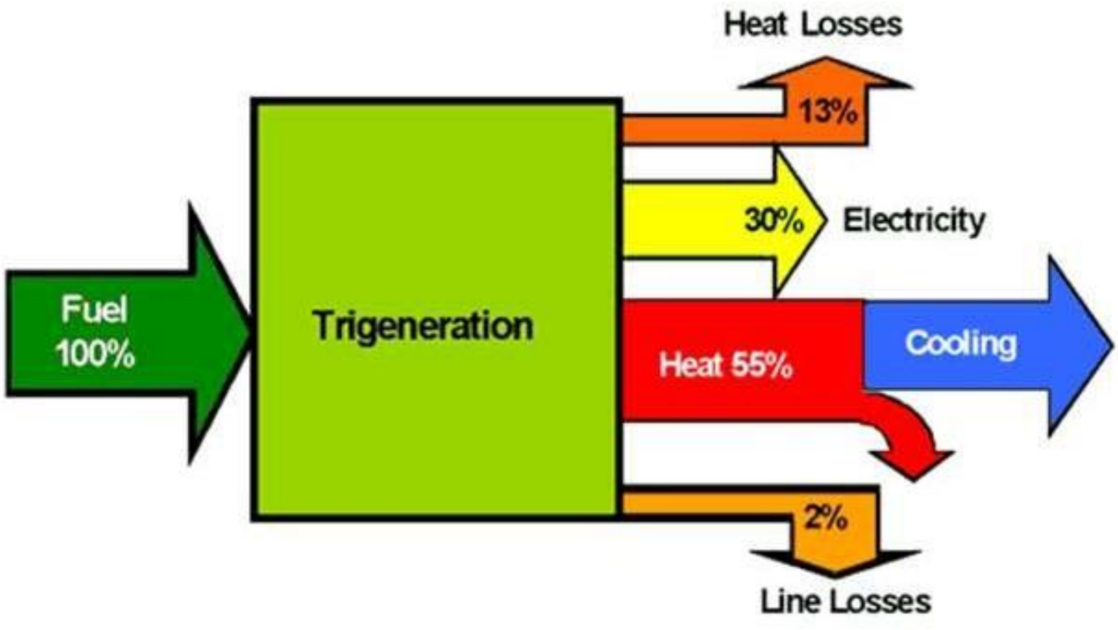


Fig. 1:TRIGENERATION SYSTEM

1.3 Benefits of Trigeneration:

- Trigeneration systems are very easy to maintain, highly reliable, cost effective, quiet and really compact.
- It Increase the efficiency of energy conversion and its uses.
- As compared to the conventional plants good energy efficiency will be provided by this system whether in case of energy or cost saving it always provides better efficiencies.
- Installation of trigeneration system will become even more cost effective when it will run within day time when there is a high-power tariff.
- On the other hand, where use of biomass the maintenance system that is the cost related with maintenance on overall life cycle can be attained on various cogeneration installations.
- There will be also less emissions of gases to the environment especially co2 which is the main gas causing greenhouse effect.
- is increased and other materials that are no longer in use like agricultural waste products refinery gas wastes or other wastes through these materials are then be utilized as a fuel cogeneration plant either aerobically digested or gasified, cost efficacy and there will be no requirement for waste disposal.
- It gives a chance to go through the more form of power generation like decentralization form, where a plant is so designed that it will be utilized to meet consumer need.
- It will also provide higher efficiency and flexibility to the system avoiding transmission losses. This will be done only if the main energy fuel is the natural gas.

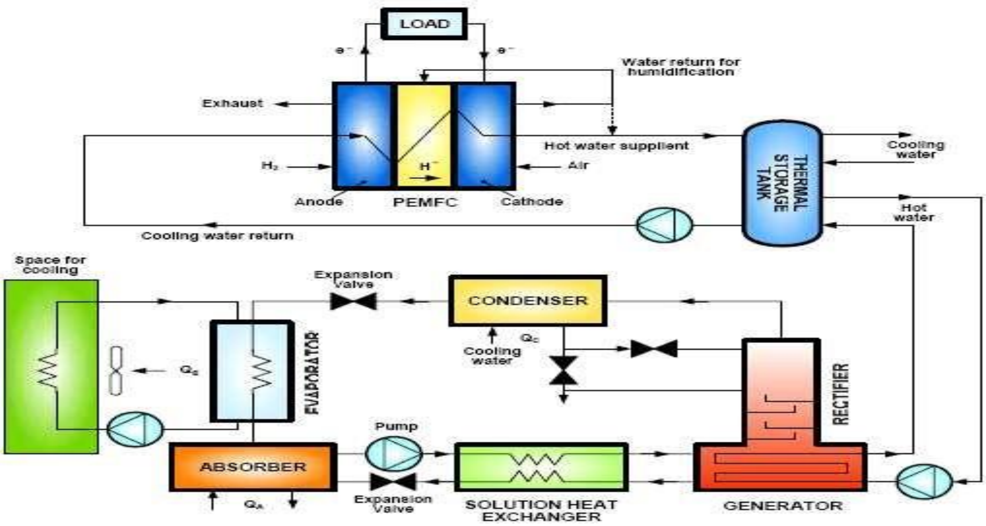
1.4 Industrialapplications:

- Brewing industry
- Paper and board manufacture industry
- Distillation malting
- Food processing
- Textile processing
- Mineral processing
- Ceramics

- Pharmaceuticals and chemicals
- Brick and cement industry
- Iron and steel industry

1.5 Trigeneration with Proton exchange membrane fuel cell (PEMFC):

Somewhere around 25% of primary energy consumed by some of the countries is utilized for hot water supply and heating places. The temperature levels required fulfilling these demands are less as compared to others, hence the most appropriate and suitable technology is PEMFC technology. Figure shows the working in trigeneration mode of PEMFC technology. During the process of trigeneration for determining the optimum operation of the air conditioning system the simulation software has been developed. With a thermal efficiency of 35% and electric efficiency of 42% a PEMFC of 1.5 kW has been considered working at full load. According to the results we have got shows that it is veryconvenient to utilize this technology in poligeneration processes. With the temperatures of generator between 65 to 70ºC this generation system is very appropriate. This temperature is generally seems compatible with the temperature of heat that is coming out from PEMFC, that is usually shown in the range of 81ºC .its cop varies between 0.45 and 0.58,having



evaporation temperature of 6 to 11 ºC.

Fig.2: **Trigeneration with Proton exchange membrane fuel cell**

1.6 Trigeneration using Phosphoric acid fuel cell (PAFC):

In Kuwait, there is a facility situated where PAFC technology has been used or can say operated for air conditioning. There have been more than 76% of power is consumed by air conditioning in Kuwait during peak load condition. By using this system, it is very well known that how this configuration has been adopted by absorption cooling system. This system is having rated power capacity of 200 KW as this technology produces 110KW of thermal power at 65 and 102KW at 125 .the combination of water and lithium bromide are used as a working substance by this system and also it has the electrical efficiency of 47% at full load condition and 37% thermal efficiency.

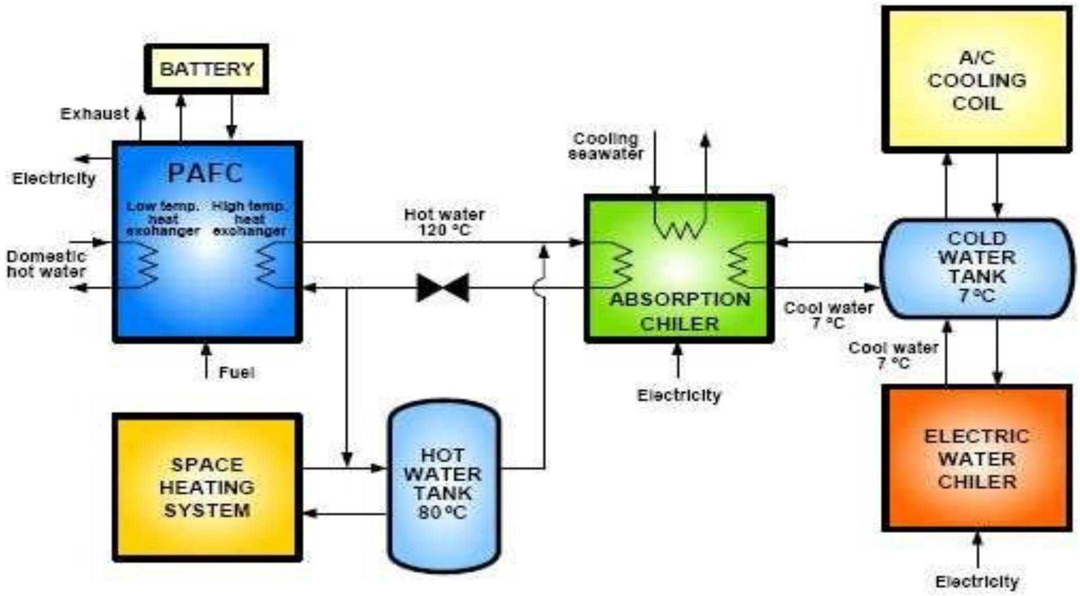


Fig.3: Trigeneration using Phosphoric acid fuel cell (PAFC)

1.7 Trigeneration with Molten carbonates fuel cells (MCFC):

By using this system, the overall efficiency usage of fuel is about 87.48% can be gathered. Other efficiencies like thermal and electrical efficiency are about 43.25% and 43.30% respectively, as a result that is shown with the molten carbonate fuel cell by this cooling procedure.

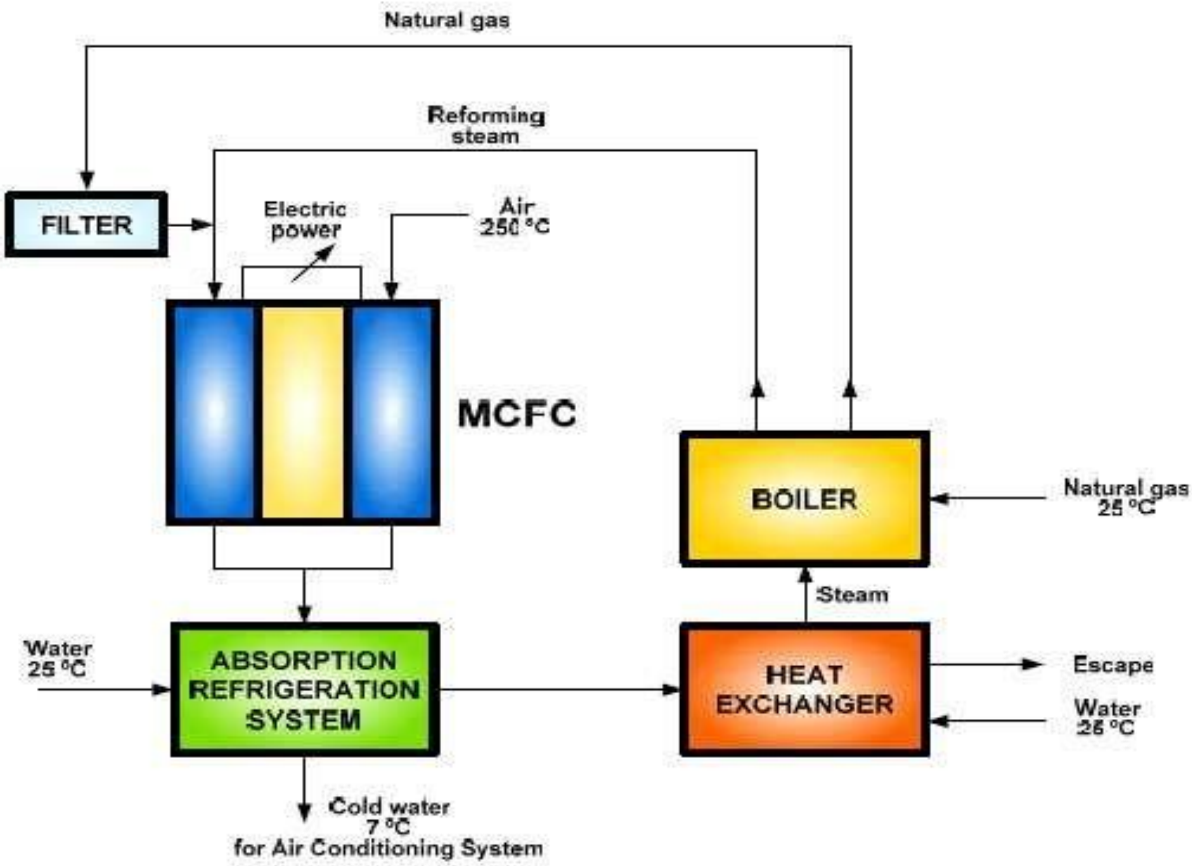


Fig.4: Trigeneration with Molten carbonates fuel cells (MCFC)

2.LITERATUREREVIEW

H.T.CHUA. ET AL. (2000) [1] : This paper presents a thermodynamically consistent set of specific enthalpy, entropy, and heat capacity fields for LiBr-H2O solution. The temperatures span from 0 to 190 , while the concentrations span from 0 to 75 wt%. The work is based on the empirical inputs of Du' hring's gradient and intercept, specific heat capacity data at a reference concentration of 50 wt% and density data. These properties have been evaluated using most of the experimental data available in the literature. The paper approached ensures thermodynamic consistency among the specific enthalpy, entropy, and heatcapacity fields to within numerical accuracy. Based on the above-mentioned approach, an improvement has been made on the accuracy in predicting the specific heat capacity at low solution temperature that has been achieved by Feuerecker et al.

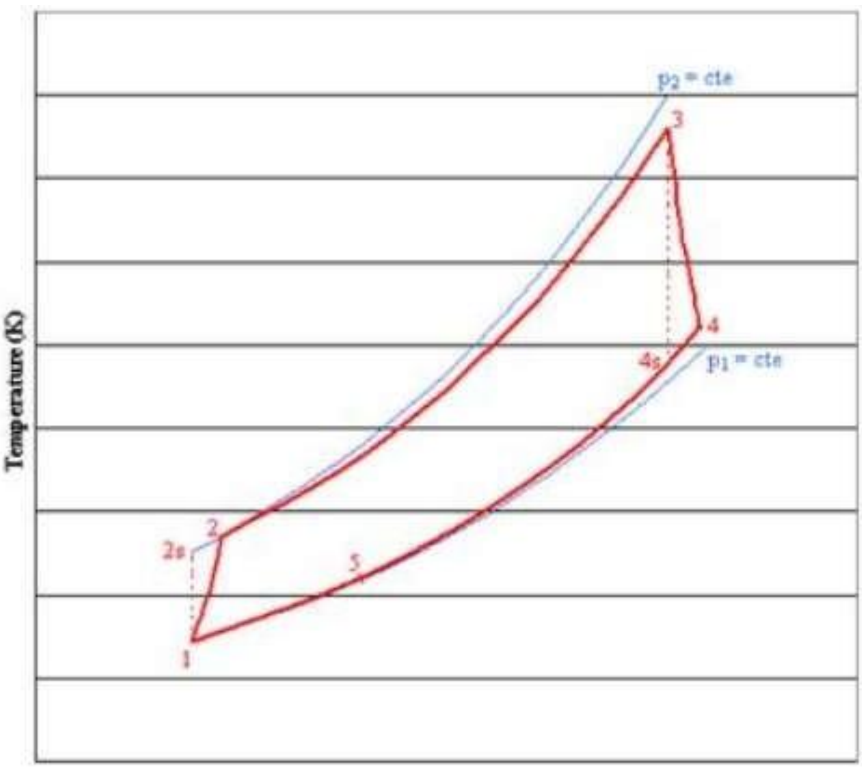
S. APHORNRATANA ET AL.(1995) [2]: The paper provided an easy to follow description of the second law (of thermodynamics) method as applied to a single-effect absorption refrigerator cycle. Results are presented in a novel graphical format, which aids insight and understanding of those factors that most affect the performance of absorption refrigerators, and which in turn provides strong indicators for the direction of future research. A novel method of calculating the entropy of lithium bromide solutions is offered.Heat-operated absorption refrigeration cycles are attracting increasing interest first, because an absorption refrigeration cycle can be driven by low-temperature heat sources, and may therefore provide a means for converting waste heat into useful refrigeration; second, because the use of CFC refrigerants and the consequent environmental damage are easily avoided.

Havelsky(1999)[3]: This paper deal with the problem of energetic efficiency evaluation of cogeneration systems for combined heat, cold and power production. Cogeneration systems have a large potential for energy saving, especially when theysimultaneously produce heat, cold and power as useful energy owns. Various cogeneration systems for combined heat, cold and power production are designed by means of computer simulation to minimize consumption of the primary energy. Equations of energetic efficiency of this combined cogeneration systems are presented, that relate the primary energy rate (PER) and comparative primary energy saving (qp) to energy parameters of designed systems. Comparison of energetic efficiency of combined cogeneration systems with contemporary conventional separate production of heat, cold and power shows a large potential for energy saving by designed combined cogeneration systems.

Khaliq et al. (2004) [4]: The aim of the present paper is to use the second-law approach for the thermodynamic analysis of the reheat combined Brayton/Rankine power cycle. There are different expressions are involved for the variables of specific output power and thermal efficiency, destruction of the energy in each component of the combined cycle, process for the second-law of efficiency for each gas-turbine cycle and second law of efficiency for the steam power cycle has been derived. The standard approximation for air with constant properties is used for simplicity. pressure ratio effects, cycle pressure-drop, number of reheats and cycle temperature ratio on the combined cycle performance parameters have been investigated. It is found that the energy destruction in the combustion chamber has found more than 50% of the total energy destruction in the overall cycle. The combined cycle efficiency and its power output were maximized at an intermediate pressure-ratio, and increased sharply up to two reheat-stages and more slowly thereafter.

3.METHODOLOGY

Gas Turbines operate on the same thermodynamic cycle, known as Brayton cycle. In this cycle, atmospheric air is compressed in Compressor, heated in Combustion Chamber, and then expanded in Turbine, with the excess power produced by the expander (also called the Turbine) over that consumed by the Compressor used for power generation. The expanded gas is utilized in the HRSG to generate process heat$\dot{Q}p$.The stack gas coming out of HRSG is sent to the Generator of vapor absorption system. The following expression were used to find out the different values required to form the table show the variation of efficiency of Trigeneration at different compressor pre-ratio,different Turbine inlet temperature.



Entropy (kJ/kgk)

Fig 5 :Temperature Entropy diagram for Brayton cycle (simple gas Turbine)

3.RESULT AND ANALYSIS

In the present work the effects of pressure ratio across the compressor turbine Inlet temperature (TIT), percentage pressure drop(%)on the first law efficiency and electrical to thermal energy ratio (RET) is obtained by energy balance approach or the first law analysis of the cycle. However, the exergy destruction or thermodynamic losses in each component, and the second law efficiency of the trigeneration cycle have also been investigated under the exergy-balance approach or the second law analysis of the cycle. Using the above equation and properties the following values and graph were obtained.

4.1 Process parameter (For different pressure ratio)

γ_a=1.4

c_{pa}=1.005kJ/kgK

γ_g=1.33

c_{pg}=1.147kJ/kgK

Compressor isentropic
efficiency =
85%Turbineisentropicefficie
ncy(η_T)=90%Combustioncha
mberefficiency(η_{cc})=95%Ele
ctrical conversion
efficiency(η_g)=95%Pressure
drop in combustion chamber
=4%PressuredropinHRSH=2
%

Processsteampr.=5bar,TIT=1
500KEvaporatortemp.=T_E=2
78K

L.H.Voffuel(Methane)=5001
6kJ/kgAmbientPressure=1bar

Ambienttemp.=298temperatureof
inletwaterofcondenserEvaporatorandAbsorber=
298K

Table 1 Performance assessment of various component of Trigeneration (for diff. Compr. pr.ratio)

Compr-essor Pr.ratio	T_2 (K)	T_3 (K)	T_4 (K)	m_f kg/s	Air fuel ratio	$\dot{W}_{net}$ kW	$\dot{w}_{el}$ kW	Q_{in} kJ/kg	S.F.C kg/kWh	Q_f kJ/kg	Q_p kJ/kg
4	467	1500	1127	0.0237	42	268	254	1225	.3198	1285	853
8	581	1500	963	0.0211	47	344	324	1090	.2226	1147	638
12	659	1500	892	0.0193	51	348	330	998	.20283	1050	533
16	719	1500	839	0.0180	55	348	330	926	.18808	974	455
20	769	1500	801	0.0170	58	342	324	867	.1914	912	394

Table1continued…..

Comp. pr.ratio	$\eta_{I(tri.)}$ (%)	$\eta_{I(cog.)}$ (%)	$\eta_{I(G.T.)}$ (%)	$\eta_{II(tri.)}$ (%)	$(\eta_{II(cog.)}($%)	$\eta_{II(G.T)}$ (%)	$R_{ET(tri.)}$	$R_{ET(cog.)}$
4	89.4045	86.1478	21.8775	41.2460	41.0116	19.7665	2.8	3
8	87.5194	83.8709	31.5596	42.8955	42.6329	28.2476	4.8	5.1
12	86.8919	82.1904	34.8697	44.09638	43.8095	31.4285	5.7	6.1
16	84.8919	80.5954	37.5809	44.9708	44.6611	33.8809	6.6	7.2
20	83.3167	78.7280	39.4463	46.2732	45.9429	35.5263	7.4	8.2

4.2 Processparameter (for different Turbine inlet Temperature)

γ_a=1.4,c_{pa}=1.005kJ/kgK,γ_g=1.33,c_{pg}=1.147kJ/kgK

Compressor isentropic efficiency=85%

Turbine isentropic efficiency (η_T)=90%

Combustion chamber efficiency (η_{cc})=95%Electrical conversion efficiency(η_g)=95%Pressure drop in combustion chamber=4%

Pressure drop in HRSH=2%,Processsteampr.=5 bar,π_C=16bar

Evaporatortemp.=T_E=278K

L.H.Voffuel(Methane)=50016kJ/kg, AmbientPressure=1 bar, Ambient temp.=298KTemperatureof inlet water of condenser, Evaporator and Absorber=298K

Table 2 Performance assessment of various component of Trigeneration

T.I.T. (K)	T_2 (K)	T_4 (K)	π_c (bar)	m_f Kg/s	A/F	$\dot{W}_{net}$ kW	$\dot{w}_{el}$ kW	Q_{in} kJ/kg	S.F.C. kg/kWh	Q_f kJ/kg	Q_p kJ/kg	$\dot{e}_{in}$ kJ/kg
1200	719	673	16	.01103	90	186	177	566	.2150	595	247	.7272
1400	719	785	16	.0156	64	295	280	806	.1907	848	349	1.0358
1600	719	898	16	.0201	50	398	378	1047	.1809	1102	464	1.3439
1800	719	1010	16	.0247	40	505	479	1290	.1782	1357	589	1.6563

Table 2continue……

TIT (K)	Q_E kJ/kgofsol	$\eta_{I(tri.)}$ (%)	$\eta_{I(cog.)}$ (%)	$\eta_{I(G.T.)}$ (%)	$\eta_{II(tri.)}$ (%)	$\eta_{II(cog.)}$ (%)	$\eta_{II(G.T)}$ (%)	$R_{ET(tri.)}$	$R_{ET(cog.)}$
1200	41.85	78.2937	71.2605	32.8621	44.2036	43.6974	29.7478	6.1	7.1
1400	41.85	79.1094	74.1745	36.6004	45.8740	45.5188	33.0188	7.2	8.1
1600	41.85	80.2039	76.1343	38.0133	46.7343	46.4609	34.0290	7.41	8.23
1800	41.85	81.7868	78.7030	39.1471	47.8269	47.6050	35.2982	7.6	8.3

4.3Processparameter(fordifferentpercentagepressuredrop)

γ_a=1.4,c_{pa}=1.005kJ/kgk,γ_g=1.33,c_{pg}=1.147 kJ/kgk

Compressor isentropic efficiency=85%

Turbine isentropic efficiency(η_T)=90%

Combustion chamber efficiency(η_{cc})=95%

Electrical conversion efficiency(η_g)=95%

Turbine Inlet Temperature=1500k

Pressure dropinHRSH=2%,

Processsteampr.=5bar, π_C=16

Evaporatortemp.=T_E=278K

L.H.Vof fuel(Methane)=50016kJ/kg, AmbientPressure=1bar,

Ambienttemp.=298k Temperature of inlet water of condenser,

Evaporator and Absorber=298k

Table 3 Performance assessment of various component of Trigeneration

(%)Prdrop (bar)	T_2 (k)	T_4 (K)	T_3 (K)	π_c (bar)	m_f kg/s	A/F	$\dot{W}_{net}$ kW	$\dot{w}_{el}$ kW	Q_{in} kJ/kg	S.F.C. kJ/kgh	Q_f kJ/kg	Q_p kJ/kg
4	719	839	1500	16	.018	55	348	330	926	.1880	974	476
6	719	842	1500	16	.018	55	345	327	926	.18972	974	478
8	719	845	1500	16	.018	55	342	324	926	.19138	974	480
10	719	849	1500	16	.018	55	337	320	926	.19422	974	483

Table3 continue…

(%)Pr. drop (bar)	$\dot{e}_{in}$ kJ/kg	$\eta_{I(tri.)}$ (%)	$\eta_{I(cog.)}$ (%)	$\eta_{I(G.T.)}$ (%)	$\eta_{II(tri.)}$ (%)	$\eta_{II(cog.)}$ (%)	$\eta_{II(G.T)}$ (%)	$R_{ET(tri.}$	$R_{ET(cog}$
4	1.1938	87.0480	82.7515	37.5809	46.8184	46.5092	33.8809	6.3	6.9
6	1.18839	86.9453	82.6488	37.2570	46.5104	46.2012	33.5728	6.2	6.8
8	1.18297	86.8427	82.5462	36.9330	46.4078	46.0985	33.2648	6.1	6.7
10	1.1757	86.7400	82.4435	36.3930	46.3051	45.3051	32.8542	6.0	6.62

5.CONCLUSION

Onthebasisof calculationsthefollowing conclusionsare made

[1]. As the pressure ratio increase The first law efficiency of cogeneration and trigeneration decreases but the second law efficiency and electrical to thermal energy ratiofor these systems increases with the same..

For the pressure ratio 4bar the first law efficiency of trigeneration is 89.4045%,and when the pressure ratio is 20 bar the$\eta_{I(tri)}$=83.3167%.

For the pr.ratio 4bar,

$\eta_{I(cog)}$=86.1478% and decrease it when the pr.ratio is 20bar,$\eta_{I(cog)}$=78.7280%

For the pressure ratio 4 bar.$\eta_{I(G.T)}$=21.8775% And efficiency of gas turbine increase when pr.ratio20bar$\eta_{I(GT)}$=39.4463%

For the second law efficiency

When pr.ratio= 4bar, $\eta_{II(tri)}$=41.0116%, it increase when the pr.ratio=20bar, $\eta_{II(tri)}$=46.2732%

When pr.ratio=4 bar, $\eta_{II(cog)}$=41.0116%, and the second law eff. of cogeneration cycle is increase when pr.ratio=20 bar,$\eta_{II(cog)}$=45.9424%

When the pr.ratio=4 bar, $\eta_{II(G.T.)}$=19.7665%, and the second law efficiency of gas Turbineincrease when pr.ratio=20 bar,$\eta_{II(G.T.)}$=35.5263%.

[2]. The first law efficiency, electrical to thermal energy ratio, and second law efficiency of cogeneration and trigeneration increases with the increase in turbine inlet temperature.

For the TIT=1800K, first law eff. of trigeneration is higher,,itsvalue$\eta_{I(tri)}$=81.7868%

For the TIT=1800K, second law eff. of trigeneration is higher, its value $\eta_{II(tri)}$=47.8269%

For the TIT=1800K, first law eff. of cogeneration is higher, its value ,$\eta_{I(cog)}$=78.7030%

For the TIT=1800K, second law eff. of cogeneration is higher, its value $\eta_{II(cog)}$=47.6050%

[3]. The first law efficiency, electrical to thermal energy ratio, and second law efficiency of gas turbine, cogeneration and trigeneration cycles are not at all affected with thepressure drop in combustion chamber and HRSG.

[4]. Maximum exergy is destroyed during the combustion and steam generation process; it represents over 80% of the total exergy destruction in the overall system.

[5]. The exergy destruction in combustion chamber and heat recovery steam generator decreases significantly with the increase in pressure ratio but increases significantly with the increase in turbine inlet temperature.

REFERENCE

[1]. A Khaliq, K Choudhary and I Dincer,Exergy analysis of a gas turbine trigeneration system using the Brayton refrigeration cycle for inlet air cooling, Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy2010 224- 449,SAGE On behalf of Institution of Mechanical Engineers.

[2]. D.W. Wu, R.Z. Wang, Combined cooling, heating and power: A review, Progress in Energy and Combustion Science 32 (2006) 459–495, Elsevier.

[3].OzgurBalli, HaydarAras, ArifHepbasli, Thermodynamic and thermoeconomic analyses of a trigeneration (TRIGEN) system with a gas–diesel engine: Part II An application, Energy Conversion and Management 51 (2010) 2260–2271.Elsevier. [4].Yaodong Wang, Ye Huang, Elijah Chiremba, Anthony P. Roskilly , Neil Hewitt , Yulong Ding, Dawei Wu, Hongdong Yu, Xiangping Chen, Yapeng Li, Jincheng Huang, Ruzhu

Wang, Jingyi Wu, Zaizhong Xia, Chunqing Tan. An investigation of a household size trigeneration running with hydrogen,Applied Energy (2011) ,Elsevier.

[5]. J. Deng, R.Z. Wang, G.Y. Han, A review of thermally activated cooling technologies for combined cooling, heating and power systems,Progress in Energy and Combustion Science 37 (2011) 172-203,Elsevier.

[6]. H.T. Chua , H.K. Toh , A. Malek , K.C. Ng , K. Srinivasan, Improved thermodynamic property fields of LiBr-H2O solution, International Journal of Refrigeration, Elsevier, 23 (2000) 412-429.

[7].ArzuSencan, Kemal A. Yakut, Soteris A. Kalogirou, Exergy analysis of lithium bromide/water absorption systems, Renewable Energy, Elsevier, 30 (2005) 645–657.

[8]. S. Aphornratana and I. W. Eames, Thermodynamic analysis of absorption refrigeration cycles using the second law of thermodynamics method, International Journal of Refrigeration, Elsevier,4(1995) 244- *252*, 1995.

[9]. V. Havelsky, Energetic efficiency of cogeneration systems for combined heat, cold and power production, International Journal of Refrigeration, Elsevier, 22 (1999) 479-485. [10]. A. Khaliq, S.C. Kaushik, Second-law based thermodynamic analysis of Brayton/Rankine combined power cycle with reheat, Applied Energy, Elsevier, 78 (2004) 179–197.