Energy output of Geopressured Geothermal Reservoir for Electricity Generation

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Abstract

An investigation of electricity generation from geopressured geothermal reservoir in Croatia as example, involves calculation of hydraulic power, net power of binary cycle, Hydraulic and binary power ratio for different temperature of geothermal fluid at the entrance and exit wells. the increase in power ratio occur at temperature range of(393 to 413 K^o) , while the power ratio was decreased at temperature range of (413 to 453 K^o), then it increased at temperature range of (433 to 453 K^o) , that in the range $T_{gf\ in}$(393 to 413 K^o) there is a decrease in net power of binary cycle, then the net power will increasing in the range of (413 to 453 K^o), then it decreased in the range between (453 to 433 K^o) , the increase in power ratio occur at temperature range of(393 to 413 K^o) , while the power ratio was decreased at temperature range of (413 to 453 K^o), then it increased at temperature range of (433 to 453 K^o) and the power ratio was increased with decreased the net power of binary cycle, then decreased with increased the net power of binary cycle , and then increased with decreased the net power of binary cycle.

Keywords: geothermal energy, hydraulic and electrical power, cycle and utilization efficiency, binary power plant, Rankine cycle.

Introduction

Geopressured resources are deep reservoirs of high-pressured hot water that contain dissolved natural gas. A geopressured reservoir is formed in sedimentary formations when water percolates into the pores of a layer of sand. When non-porous shale settles on top, it traps the fluid into the sand layer at very high pressures. Over millions of years, this pressure increases even more as additional sedimentary layers build on top of the reservoir. If the sand body in which the water is trapped is large enough, the reservoir can economically produce energy for quite a long time. An important characteristic of geopressured reservoirs, at least from an energy perspective, is that they contain dissolved methane, or natural gas. This, therefore, yields three sources of energy that can be utilized from the reservoir [Geo Energy, 2000]:

1. Hydraulic energy from extreme pressure.
2. Heat energy from the fluid.
3. Dissolved natural gas.

Comparing to other natural gas reservoirs, the amount of dissolved methane in these types of reservoirs is very small. For the natural gas alone, the reservoir would be uneconomical. However, with two more sources of energy, their utilization becomes worthwhile.

Development activities are currently in progress to utilize the thermal and hydraulic energy available in geopressured-geothermal (geopressured) resources for a variety of direct uses. The higher pressure and temperature found in geopressured resources create the opportunity for many new applications.

Geothermal energy can be defined by splitting it into its components, geo meaning 'Earth' and thermal meaning 'heat', making geothermal the heat within the Earth. Geothermal energy represents the natural, internal heat of the Earth that is stored within the rock and fluid [Ben Lunis, 1990].

Example for Electrical and Hydraulic Power at the reservoir VELIKA CIGLENA

Geothermal reservoir Velika Ciglena shown in Figure (1).Optimal production of the geothermal energy can be obtained on the well VC-1A, because of its production equipment and the thermodynamic conditions of the reservoir. The production layer is at 2545 m, with the static pressure of 247.3bar and the static temperature of 175 C^o. total energy production from the VC-1A can be obtained through two heat exchanger cycles.

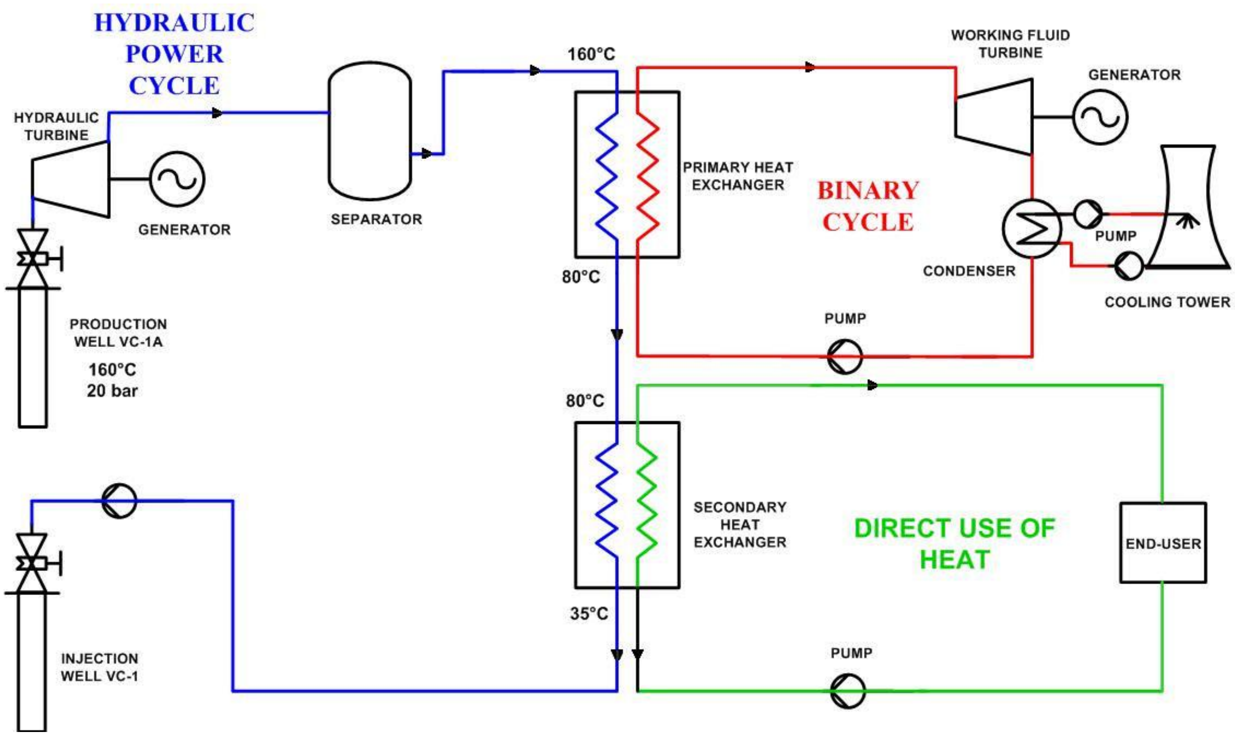

Fig. (1) Scheme of Geothermal Power Production [Olurvody,1984**]**

Input Parameter for Velika Ciglena Geothermal Reservoir [Olurvody,1984**]**

$m^{\cdot}$=84 kg/s=7200m^3/d (maximum flow rate at the wellhead conditions)

ρ=990kg/m^3 (at the wellhead conditions)

Pwh=20 bar=20x10^5 pa

T_{gfin}=433K^o(160C^o)

T_{gfout}=353K^o(80C^o)

T_o=284.6K^o(11.6C^o)

Hydraulic Power

$P_h=m^{\cdot}[\frac{1}{J}(\frac{Pwh}{\rho}+\frac{W2}{2}+g.z)]$

If second and third terms are omitted:

$W^2/2$=velocity at the wellhead is omitted because of small influence to the power output

g.z=elevation at the wellhead is zero

Finally equation for hydraulic power could be written:

$P_h=m^{\cdot}P_{wh}/J.\rho_{wh}$ [KWm]

Thus hydraulic power would be:

P_h=84x2000000x10^{-3}/990=170 KWm

If we suppose efficiency of hydraulic turbine approximately 90%, net hydraulic power would be:

$P_{h\ net}$=170x0.9=153 KWm

If capacity factor is assumed β=8000 hours annually total produced energy would be:

$E_{h\ net}=P_{h\ net}.\ \beta$=1224 KWhm=1.2MWhm

Available electrical power from Clausis-Rankine binary cycle according to new expression for maximum useful work:

$P_{bin}=m^{\cdot}.C_{pgf}.(T_{gf\ in}-T_{gf\ out})^2/2.T_{gf\ out}$

Where P_{bin}=maximum useful theoretical work from binary cycle,KWe

$T_{gf\ out}$=heat sink temperature from primary side of heat exchanger,K^o

P_{bin}=84x4.1(433-353)^2/2x353=3122 KWe

Cycle efficiency according to new expression:

$\eta_{cycle}=(T_{gf\ in}-T_{gf\ out})/2.T_{gf\ out}$

=(433-353)/2.353

=0.113

Utilization factor according to [Milora, 1976] is a direct measure of the efficiency of the reservoir utilization (Table1):

$\eta_{util}=\Delta T.\ \eta_{cycle}/[(T_{gf\ in}-T_o)-T_o.\ln T_{gf\ in}/T_o]$

=(433-353).0.113/[(433-284.6)-284.6 ln433/284.6]

=0.312

$P_{bin\ net}=P_{bin}.\ \eta_{util}$

=3122x0.312=974 KWe

$E_{bin\ net}=P_{bin\ net}.\ \beta$ =974x8000=780MWhe

If we compare both hydraulic and binary cycle power,the ratio gives total power output for end use :

$E_{tot}=E_{h\ net}+E_{bin\ net}$=1.2+780=781.2 MWhe

Hydraulic and binary power ratio

$P_{h\ net}/P_{bin\ net}$=153/974.1=0.157

Hydraulic power is the mechanical power could be used for injection of geothermal water back into the reservoir.

The above calculations are repeated for other temperatures of geothermal fluid at entrance and exit and listed in table (1).

Results and Discussions

Results were obtained for geopressured geothermal reservoir in Velika Ciglena station in Croatia as example, where the temperature at the production well was 160C^o, pressure of 20 bars and 11.6C^o at the reinjection well.

Fig. (2) represents the relationship between the temperature of geothermal fluid at the exit ($T_{gf\ out}$) with the temperature of geothermal fluid at the entrance ($T_{gf\ in}$) ,the increase in $T_{gf\ in}$ will increase $T_{gf\ out}$.

Fig. (3) represent the relationship between net power of binary cycle with temperature of geothermal fluid at the entrance ($T_{gf\ in}$), at which we observe that in the range $T_{gf\ in}$(393 to 413 K^o) there is a decrease in net power of binary cycle, then the net power will increasing in the range of (413 to 453 K^o), then it decreased in the range between (453 to 433 K^o).

Fig. (4) represent the relationship between hydraulic/binary power ratio with ($T_{gf\ in}$) , the increase in power ratio occur at temperature range of(393 to 413 K^o) , while the power ratio was decreased at temperature range of (413 to 453 K^o), then it increased at temperature range of (433 to 453 K^o).

Fig. (5) represent the relationship between power ratio with net power of binary cycle , in which one can observe that the power ratio was increased with decreased the net power of binary cycle, then decreased with increased the net power of binary cycle , and then increased with decreased the net power of binary cycle.

Conclusions

We can write the following conclusions:

1.Maximum temperature of the geothermal fluid at the exit occurs at 453K of entrance temperature of geothermal fluid.

2.Maximum net power of binary cycle at temperature of geothermal fluid at the entrance of 433 K^o.

3.Maximum value of hydraulic/binary power ratio can be obtained at temperature of geothermal fluid at the entrance of 413 K^o, and minimum value at 433 K^o.

References

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Table (1) Net Power, Produced Energy, and Hydraulic /Binary Power Ratio for Different Resource Temperature in Croatia

$T_{gf\ in}(K^o)$	$T_{gf\ out}(k^o)$	$\Delta T(K^o)$	$P_{bin\ net}$(Kwe)	$E_{bin\ net}$(MWhe)	Hydraulic/Binary Power Ratio (%)
393	333	60	601	4.8	25
403	343	60	480	3.8	31
413	353	60	398	3.1	38
433	353	80	974	7.8	16
443	363	80	822	6.5	18
453	373	80	703	5.6	21

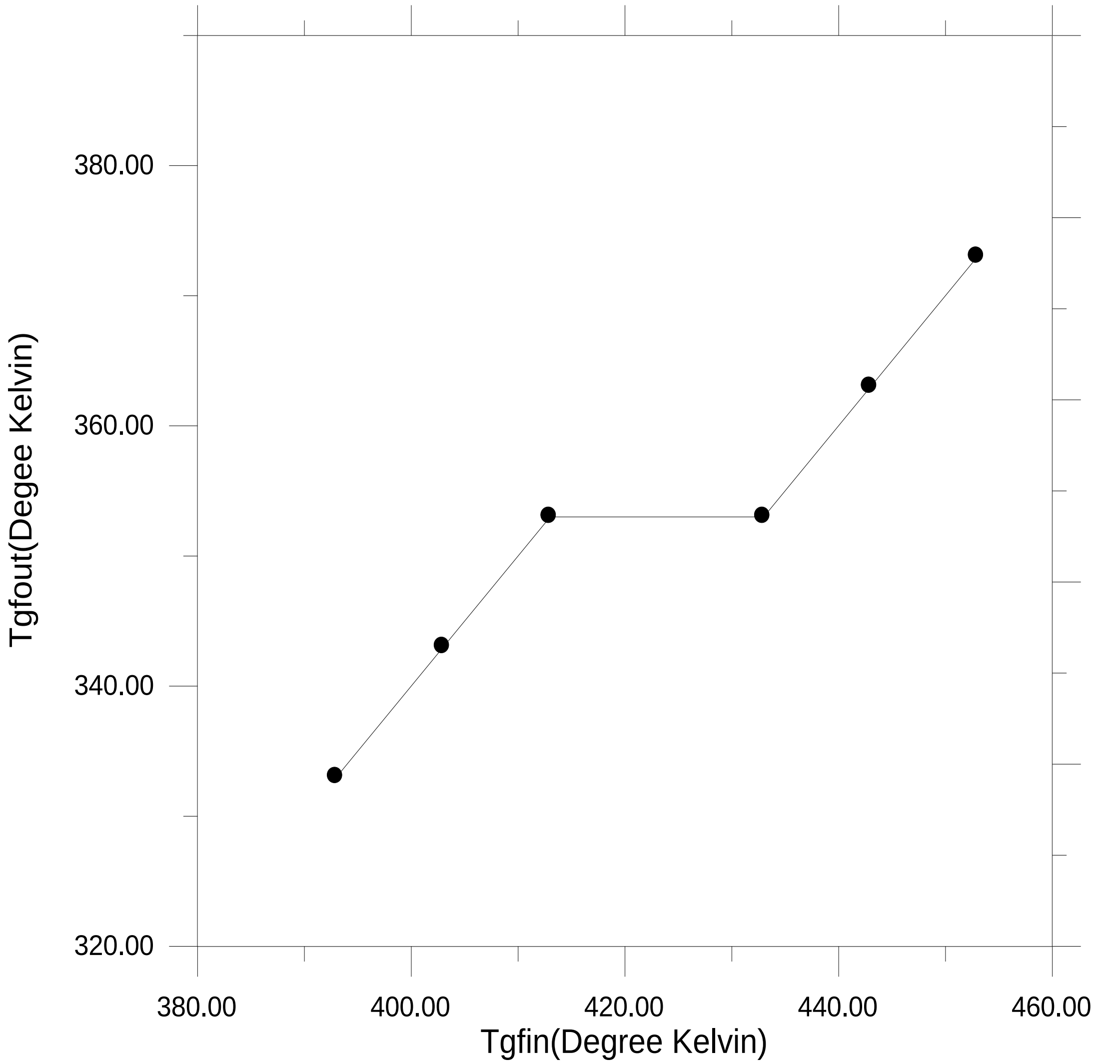

Fig.(2) Variation of Temperature of Geothermal Fluid at the Entrance(Tgfin) with Temperature of Geothermal Fluid at Exit(Tgfout).

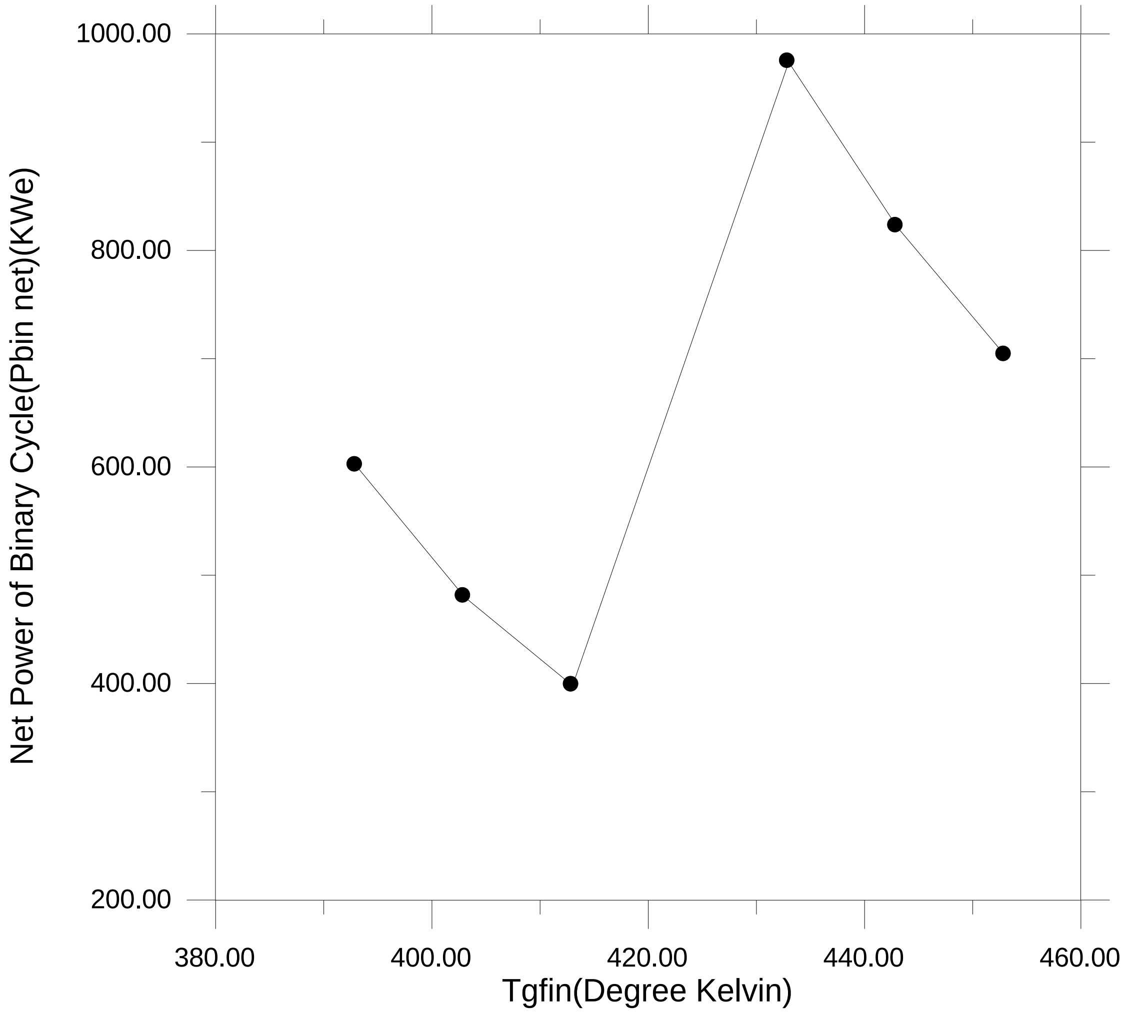

Fig.(3) Variation of Temperature of Geothermal Fluid at the Entrance with Net Power of Binary Cycle.

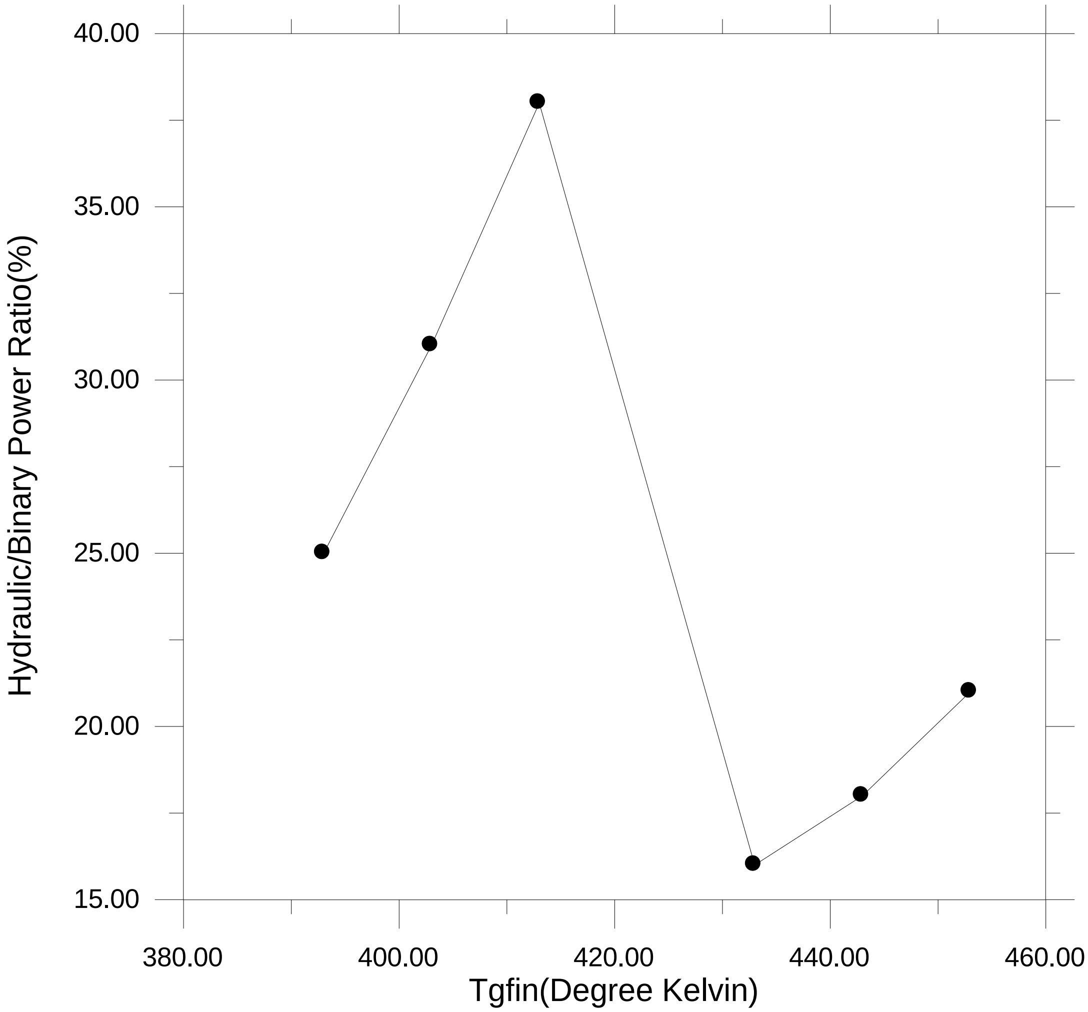

Fig.(4) Variation of Hydraulic/Binary Power Ratio with Temperature of Geothermal Fluid at the Entrance.

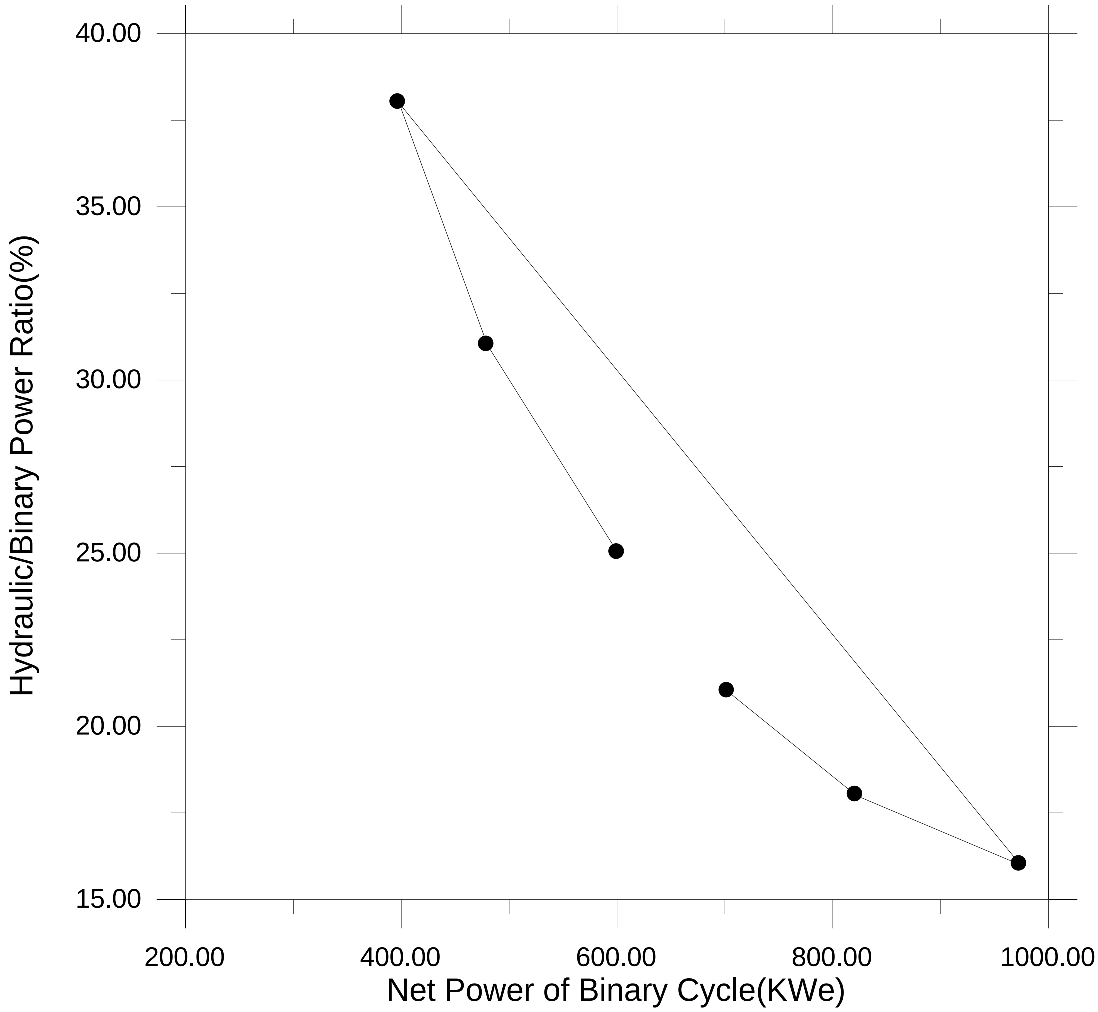

Fig.(5) Variation of Hydraulic/Binary Power Ratio with Net Power of Binary Cycle.