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## **Thermodynamic Investigation of Steam Injected Gas Turbine Cycle**

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### **Abstract**

Today gas turbine power plants play an important role in power generation. Different methods have been proposed to improve the performance of this plant. One attractive method is to produce steam and then inject it into combustion chamber. In this paper the effect of different parameters like turbine inlet temperature, compressor pressure ratio, pinch point temperature difference,... on performance parameters of the steam injected cycle is investigated. The attempt has been made to model the actual behavior of this system. It has been observed that the efficiency and power output of steam injected cycle is always higher than corresponding simple cycle. For example, at turbine inlet temperature of 1400K, the efficiency and work output is higher about 10-38% and 49-90% respectively depending on cycle pressure ratio.

**Key words: Steam Injected Gas Turbine Cycle, Heat Recovery Boiler, Gas Turbine, Pinch Point Temperature Difference**

(San jose)  
(Tuzson) [6]  
(% )  
[7]  
(Steam Injection Gas Turbine=  
STIG)  
(Heat Recovery Boiler)  
(pinch Point)  
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[8]  
[1]  
[9]  
(Turbo Pascal 7)  
[2]  
[3] (Aegidus Ellving)  
( )  
(Bultzo)  
(4)  
( $P_A$  )  $T_1$   $\varpi_1$   
( $DP_C$ )  
( $\eta_{oc}$ )  
(R)  
(Alison KB 501) (3.5 MW)  
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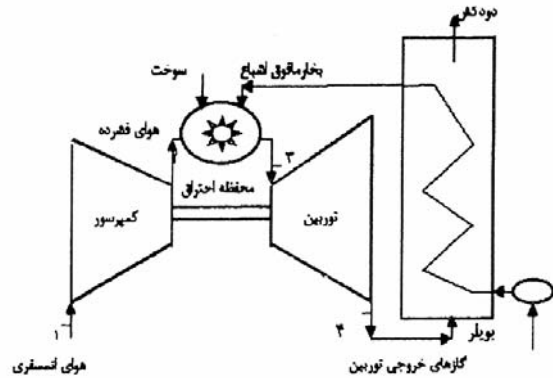
$$\eta_{oc} = \frac{dh_s}{dh} = \frac{\bar{R}Tdp/p}{\bar{C}p_{air}dT} \Rightarrow \quad (10)$$

$$\int_{T_1}^{T_2} \bar{C}p_{air} \times \frac{dT}{T} = \int_{P_1}^{P_2} \frac{\bar{R}}{\eta_{oc}} \times \frac{dp}{p} \quad (11)$$

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$$W_{comp.} = \frac{\left[ \int_{T_1}^{T_2} \bar{C}p_{air} dT + \omega_1 \int_{T_1}^{T_2} \bar{C}p_{vap} dT \right]}{(28.97 + 18.05 \times \omega_1)} \quad (12)$$



(DP<sub>cc</sub>)

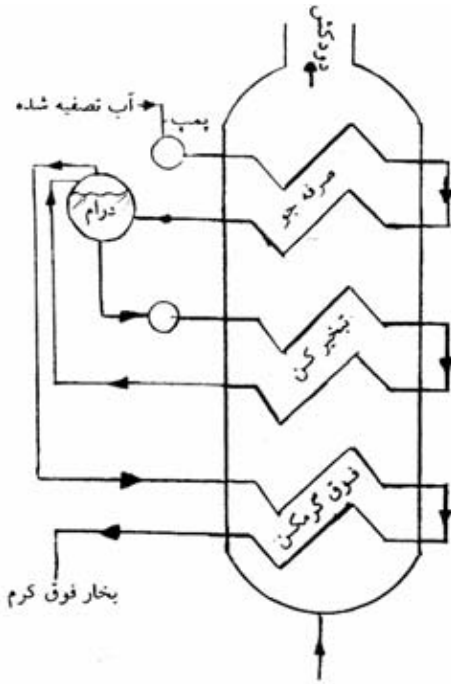
$\omega_1$

(A)

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(A)

$$\begin{aligned} & C_n H_m + A(n + m/4)[O_2 + 3.76N_2 + \omega_1 H_2O] \\ & + 1.61A(n + m/4)(m_s/m_a)[4.76 + \omega_1]H_2O \\ \Rightarrow & nCO_2 + 3.76A(n + m/4)N_2 + [A(n + m/4) \\ & [\omega_1 + 1.61(m_s/m_a)(4.76 + \omega_1)] + m/2]H_2O \\ & + (A-1)(n + m/4)O_2 \quad (13) \end{aligned} \quad (\Delta T_{PP})$$



( )

$$\sum_{I=Re\ act.} n_i h_i = \sum_{j=Prod.} n_j h_j$$

$$h = h_{form.} + \int_{T_1}^T \bar{C}_p dT \quad ( )$$

:

$$f_{act} = \frac{f_{th}}{\eta_{cc}}$$

$$f_{act} = \frac{(12n + m)(1 + \varpi_1) / (A \cdot \eta_{cc})}{(n + m/4)(4.76 + \varpi_1)(28.97 + 18\varpi_1)} \quad ( )$$

:

$$\bar{C}_{p_g} = \frac{\sum_{j=Prod.} n_j \bar{C}_{p_j}}{\sum_{j=Prod.} n_j} \quad ( )$$

-(Economiser)

(Superheater)

(T<sub>4</sub>)

$$T_g = T_4 - \frac{m_s}{m_g \bar{C}_{p_g}} (h_{w2} - h_{fB}) \quad ( )$$

(T<sub>g</sub>)

$$T_5 = T_g - \frac{m_s}{m_g \bar{C}_{p_g}} (h_{fB} - h_{wi}) \quad ( )$$

:

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$$\eta_{act} = \frac{dh}{dh_s} = \frac{\bar{C}_{p_g} dT}{\bar{R} T (dp/p)} \Rightarrow$$

$$\int_{P_3}^{P_4} \eta_{act} \bar{R} (dp/p) = \int_{T_3}^{T_4} \bar{C}_{p_g} (dT/T) \quad ( )$$

$$w_{tur.} = \frac{1 + \varpi_1}{(28.97 + 18.05\varpi_1)} \int_{T_3}^{T_4} \bar{C}_{p_g} dT \quad ( )$$

( )

: (Constraint Equations)

$$w_{net} = (1 + f_{act})w_{tur} - w_{comp} \quad ( )$$

$$T_g - T_B = \Delta T_{pp} \quad ( )$$

$$T_4 - T_{w_2} = \Delta T_{ap} \quad ( )$$

$$T_3 = Const. \quad ( )$$

$$\eta_{th} = \frac{w_{net}}{(LHV \cdot f_{act})} \quad ( )$$

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$$\left( \frac{\Delta T_{ap}}{\Delta T_{pp}} \right)$$

$$S.F.C = \frac{(3600 \cdot f_{act})}{w_{net}} \quad ( )$$

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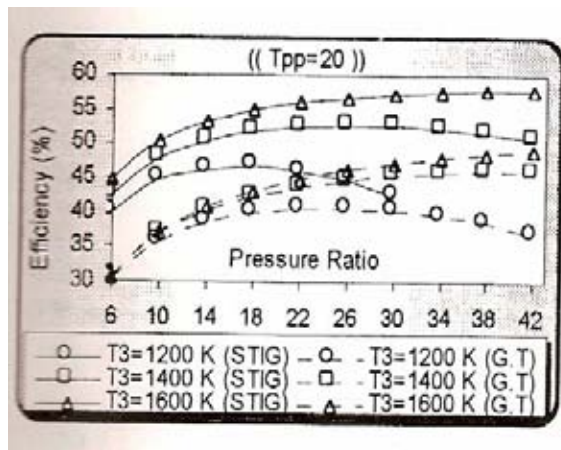
$$\left( \Delta T_{pp} \right)$$

(Turbo Pascal 7)

(( ) )

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$$\left( \frac{m_s}{m_a} \right) \quad (1)$$

$$(T_{w_2})$$

$$(T_{w_2}, T_4)$$

$$(T_{w_2})$$

$$()$$

$$() (m_s/m_a)$$

$$()$$

$$\Delta T_{ap}, \Delta T_{pp}, T_3$$

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$$(\Delta T_{pp} = 20C) \quad ()$$

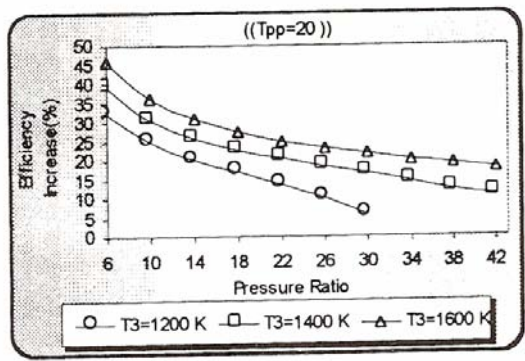
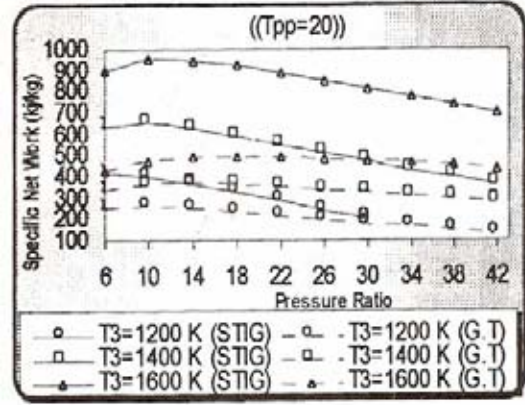
$$()$$

$$(T_3 = \text{const.})$$

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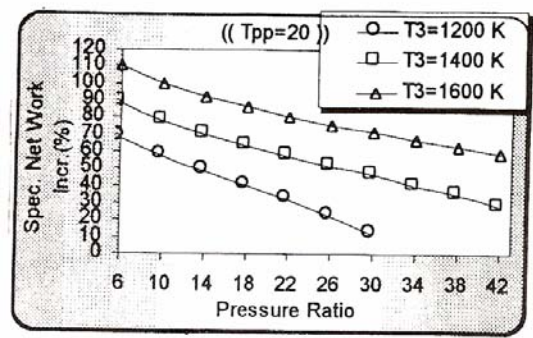
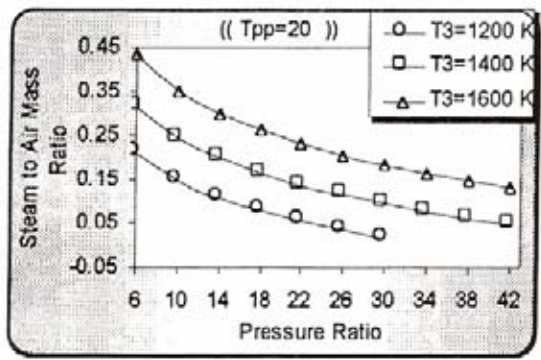
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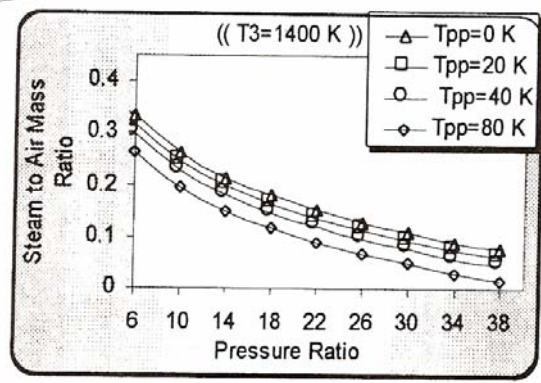
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( $T_3 = 1400k$ )

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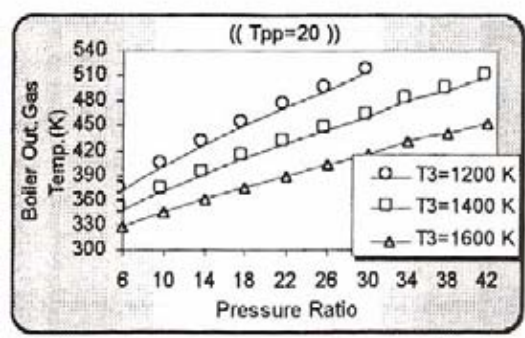
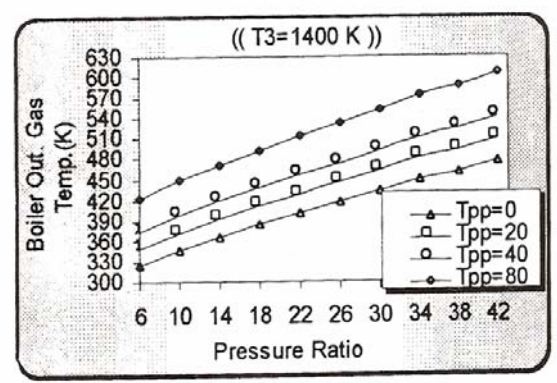


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( $\Delta T_{pp}$ )

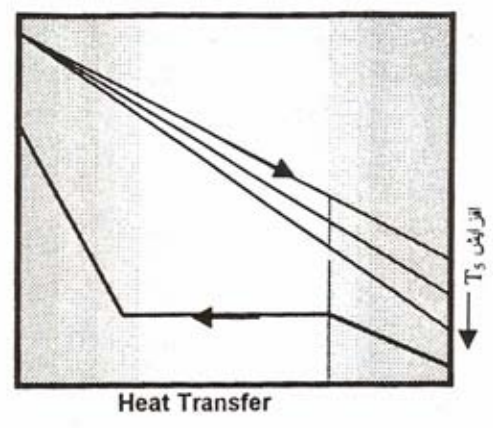


( $\Delta T_{pp}$ )

( $\Delta T_{pp}$ )

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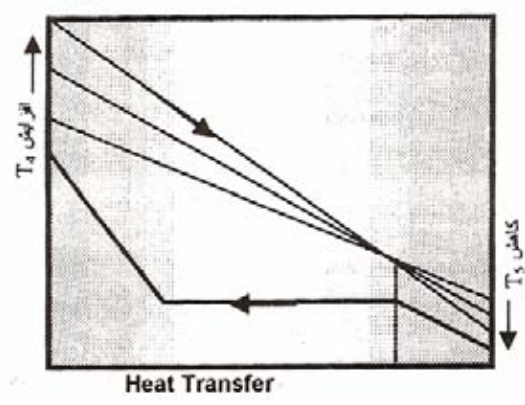
Temperature



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Temperature



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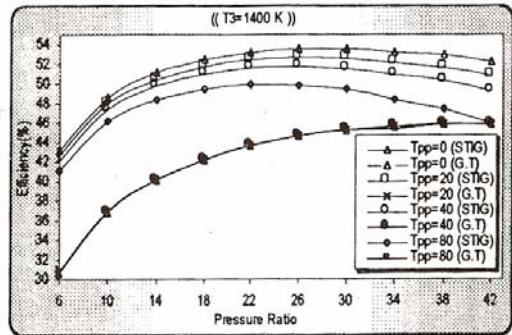
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( ) ( )

( $\Delta T_{pp}$ )

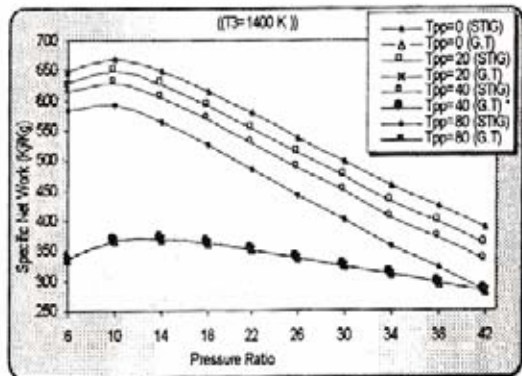
( $\Delta T_{pp}$ )

[2] Bolland



( T3 )

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[15] MA-13-CC

% C C° C° %  
 %  
 Kg<sub>steam</sub>/Kw.h STIG /  
 Kawasaki  
 %  
 % / C  
 % /  
 Kj/Kg Inlet air % /

%

K K

A

 $C_p$ [kJ/kgK]

DP[kPa]

f

GT

h [kJ/kg]

L.H.V [kJ/kg<sub>fuel</sub>]

m,n

n

p [kPa]

q [kw]

R

 $\bar{R}$  [kJ/kmol K]S.F.C. [kg<sub>fuel</sub>/kw.h]

STIG

T[K]

W[kj]

w[kj/kg]

 $\varpi$ 

K

K

K

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