# GEORGIA INSTITUTE OF TE[illegible]HNOLO[illegible]

The George W. Woodruf[illegible]

School of Mechanical Engine[illegible]ring

## Ph.D. Qualifiers Exam - Spring [illegible]uarter 1999

Thermodynamic[illegible]

EXAM AREA

Assigned Number **(DO NOT SIGN YO[illegible]R NAME)**

- **Please sign your name on the back of th[illegible] page—**

Please **p r i n t** your name here.

**The Exam Committee will get a copy of this exam and will not be [illegible] whose paper it is until it is graded.**

1(a) Using the Gibbs Equations and the Maxwell Relations below, derive a eneral differential for the enthalpy in terms of the pressure and temperature. In your derivation, please entify and explain each result should be of the form,

$$dh = \left(\frac{\partial h}{\partial T}\right)_P dT + \left(\frac{\partial h}{\partial P}\right)_V dP$$

1(b) The coefficient of $dT$ in the preceding equation is better known by what me and symbol?

1(c) Using the equation derived above, show that the enthalpy of an ideal gas epends only on the te

1(d) Using the result from Parts 2 and 3, derive the formula for the enth y of an ideal gas w.th specific heat in terms of T and P.

1(e) Explain in physical terms why the enthalpy does not depend on the pr ure. Your explanatio reference to the internal energy as well.

1(f) Using the appropriate Gibbs equation derive the integral equation fo he entropy of an ideal function of temperature and pressure. This equation is of the form,

$$s = s(T, P)$$

Why are the previous results important in this derivation?

Table 1. The Gibbs Equations

| |
|---|
| $dU = TdS - PdV$ |
| $dH = TdS + VdP$ |
| $dA = -SdT - PdV$ |
| $dG = -SdT + VdP$ |

Table 2. The Maxwell Relations

$$\left(\frac{\partial T}{\partial V}\right)_{S,N_k} = -\left(\frac{\partial P}{\partial S}\right)_{V,N_k}$$

$$\left(\frac{\partial T}{\partial P}\right)_{S,N_k} = \left(\frac{\partial V}{\partial S}\right)_{P,N_k}$$

$$\left(\frac{\partial S}{\partial V}\right)_{T,N_k} = \left(\frac{\partial P}{\partial T}\right)_{V,N_k}$$

$$-\left(\frac{\partial S}{\partial P}\right)_{T,N_k} = \left(\frac{\partial V}{\partial T}\right)_{P,N_k}$$

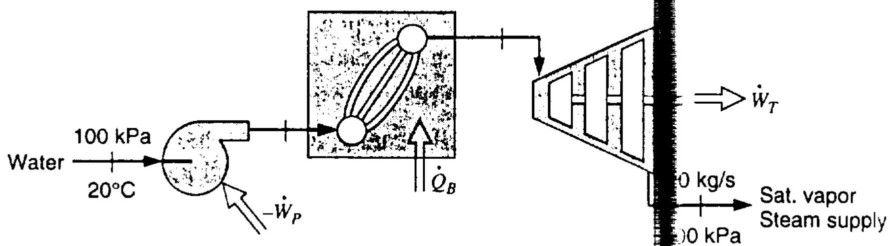
**2.** A 10 kg/s steady supply of saturated-vapor steam at 500 kPa is requi[illegible] for drying a wood p[illegible] in a paper mill. You are to compare two alternative systems for [illegible]roducing this saturat[illegible]d vapor. One is a conventional system using a water pump to pump w[illegible]r to a steam generato[illegible] which exits the boiler at the required steam supply condition, i.e., 50[illegible]Pa, saturated vapor.

The second uses co-generation. In this system, the required steam s[illegible]ply will be the exha[illegible] steam turbine as shown below. In this co-generation system, water [illegible] 20C, 100 kPa, is pu[illegible] pressure of 5 MPa and then fed to a steam generator (boiler) and t[illegible]n to a steam turbine [illegible] exhausts at the required conditions. In both systems the isentropic [illegible]ficiency of the pum[illegible] and in the co-generation system, that of the turbine is 85%. The pum[illegible]and turbine are adiab[illegible]

a) What is the difference in the heat transfer rate required by the st[illegible]n generator betwe[illegible] systems?

b) What is the difference in the net power between the two systems?

c) What is the fraction of additional heat required by the co-generation [illegible]stem that is convert[illegible] by the co-generation system; i.e., the ratio of the additional net wor[illegible]alculated in b) divid[illegible] additional heat required calculated in a)?



**3.** An adiabatic compressor is used to fill a 0.5 $m^3$ rigid tank with atmospheric air (101 kP
Initially, the air in the tank is at 101 kPa, 25°C. The filling process in the tank is isotherm
desired final pressure in the tank is 1000 kPa, what will be the minimum input wor
compressor?

**4.** A tank having a volume of 5 cubic feet contains initially nitrogen g[illegible] at 11 atm and 70F [illegible] develops a slow leak and, after a long time, the pressure drops to 5 [illegible]n. Assume that the n[illegible] an ideal gas. Assume the contents in the tank remain isothermal duri[illegible] the process.

(a) Determine the mass of the nitrogen which escapes from the tank.

(b) Determine the heat transfer, in BTU, through the tank walls.