Exam Number:

Department of Mechanical Engineering

Michigan State University

Thermodynamics

Ph.D. Qualifying Examination

August 2004

Instructions:

- Four Questions
- Open Book, ~~Open Notes~~
- All Problems Carry Equal Weight

Examination Prepared By

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1. A saturated air-water vapor mixture at $20\,℃$ and $100\ kPa$ is contained in a closed $5\ m^3$ tank in equilibrium with $1\ kg$ of water. The tank is then heated to $80\,℃$. Is there any liquid water in the tank?

2. Air is contained in a cylinder fitted with a frictionless piston. Initially the cylinder contains *500L* of air at *150 kPa, 20 ℃*, which is also the temperature of the surroundings. The air is then compressed reversibly in a polytropic process until the final pressure is *600 kPa* at which point the temperature is *120 ℃*. Determine:

- The polytropic exponent
- The final volume of air
- The work done on the air and the heat transfer for the process
- The net change in entropy for the process.

3. A spark ignites a mixture of methane gas (CH_4) and air ($O_2 + 3.76N_2$) according to the stoichiometric reaction $CH_4 + 2(O_2 + 3.76N_2) \rightarrow CO_2 + 2H_2O + 7.52N_2$. For a volume ΔV of gas with radius ½ mm and initially at 300K ($\rho = 1.1\ kg/m^3$) calculate:

- The flame temperature.
- The heat released to the gas in the volume ΔV: use $\Delta h_C = 50{,}000\ kJ/kgCH_4$ as the overall heat release for this reaction. Note that Δh_C is written per kg of the *fuel*.
- The heating rate, given that the heat release occurs in 10^{-2} *sec*.

4. A volume ΔV of gas (radius $\frac{1}{2}$ *mm*) undergoes chemical reaction, and releases 1.5 J. Write the first law of thermodynamics. Assume the gas is air, and calculate the change in temperature it undergoes. If this process occurs over 10^{-2} seconds, calculate the rate of temperature rise $\Delta T/\Delta t$. Calculate, if possible, the contribution of the work rate $\dot{W}$.