AUBURN UNIVERSITY
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AEROSPACE

AERO 4970/7970 **Rocket Propulsion I** **SET VI**
Liquid Propellants

1. The average specific gravity δ_{av} is defined as the mass of the fuel and oxidizer divided by the sum of their volumes. Derive an equation for δ_{av} as function of δ_o, δ_f, and the propellant mixture ratio r. Show that:

$$\delta_{av} = \frac{\delta_o \delta_f (1+r)}{r\delta_f + \delta_o}$$

   How does your result compare to the result in the textbook?

2. (a) What should be the approximate percent ullage volume for a nitrogen tetroxide tank when the vehicle is exposed to ambient temperatures between about 50 ^{o}F and about 150 ^{o}F?
   (b) What is the maximum tank pressure at 150 ^{o}F?
   (c) What factors should be considered in part (b)?
   Answers: (a) 15 to 17%; the variation is due to the non-uniform temperature distribution in the tank; (b) 6 to 7 atm; (e) vapor pressure, nitrogen monoxide content in the oxidizer, chemical reactions with wall materials, or impurities that result in largely insoluble gas products.

3. An insulated, long vertical, vented liquid oxygen (LOX) tank has been sitting on the sea-level launch stand for a period of time. Assume no heat loss to the tank walls. The surface of the liquid is at atmospheric pressure and is 10.2 meters above the closed outlet at the bottom of the tank. If there is no circulation, what will be the temperature, pressure, and density of the oxygen at the tank outlet?
   Answers: 90 K; 2.12 atm; 1,140 kg/m^3.

4. Prepare a table/matrix comparing the relative merits of liquid oxygen and nitric acid as rocket oxidizers.