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APPROVED BY: <i>J. E. Owens by J. E. Owens</i> (SUPERVISOR) J. E. Owens		PROGRAM	SUB-ACCT. 4473	
OTHER		SRE	TNR	
		PROJECT	DATE October 7, 1958	
		Analysis of SRE Performance	PAGE 1 OF 9	

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SUBJECT: Converting Data From the Water Test Loop to Sodium

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I STATEMENT OF PROBLEM

Provide a simple method for converting data taken on the water test loop to sodium flow rate in pounds per second and pressure drop in psi.

Specify how the water test data on the fuel clusters and orifice plates in the modified test loop (which is a mockup of the SRE) should be converted to sodium flow and pressure drop.

II SUMMARY OF RESULTS AND RECOMMENDATIONS

The pressure tap locations are shown in Figure 1. They are at the lower plenum, one foot, three feet, and five feet beyond the fuel entrance and at the upper plenum. The ΔP data taken between the lower plenum and second pressure tap from the water test should be converted to 550°F sodium; between pressure taps 2 and 3 convert to 650°F sodium; between pressure taps 3 and 4 convert to 850°F sodium; and between pressure taps 4 and the upper plenum convert to 950°F. There is no need to calculate orifice coefficients, friction factor, Reynolds' Number, discharge coefficient, etc. The test data can be directly converted to the pressure drop in psi and flow in lbs/sec by using the following formula:

$$\Delta P_{Na} = \frac{(W\sqrt{v})_{Na}}{(W\sqrt{v})_{H_2O}} \Delta P_{H_2O}$$

$$\text{Sodium flow, lbs/sec} = \frac{(W\sqrt{v})_{Na}}{(W\sqrt{v})_{H_2O}} \quad (\text{Water flow, lbs/sec})$$

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Values of $\frac{(W\sqrt{2})_{Na}}{(W\sqrt{2})_{H_2O}}$ are plotted in Figure 2, and values of $\frac{(W\sqrt{2})_{Na}}{(W\sqrt{2})_{H_2O}}$ in

Figure 3 for water temperatures from 40°C to 78°C, and for sodium temperatures of 550°F, 650°F, 850°F, 950°F.

III METHOD USED, DESCRIPTION OF EQUIPMENT, SAMPLE CALCULATIONS

Since the water test is done on a full scale mockup, the flow cross sections with sodium are the same as with the water test, and at the same Reynolds' Numbers the orifice coefficients, friction factors, entrance and exit coefficients will be the same for sodium as they are with water. As seen from the formula for Reynolds' Numbers, this will occur when the ratio of the sodium velocity to the water velocity is equal to the ratio of the sodium viscosity to the water viscosity. This fact is very useful since the velocity is changing all along the length of the fuel channel, for any particular flow rate, because of the changing flow cross section area along the length of the channel. The viscosity is also changing with temperature along the channel but this is a simple function of the distance along the channel, as shown in Figure 1. Then in the formula for the ratio of the sodium pressure drop to the water pressure drop and the formula for the ratio of the sodium flow rate to the water flow rate the ratio of the sodium viscosity to the water viscosity (which is known) is substituted for the ratio of the sodium velocity to the water velocity (which is not known).

The pressure losses with sodium flow due to pipe friction, orifice plate, entrances and exits can then be simply calculated from the water flow test and the following formula:

$$\Delta P_{Na} = \frac{(W\sqrt{2})_{Na} \Delta P_{H_2O}}{(W\sqrt{2})_{H_2O}}$$

The ratio $\frac{(W\sqrt{2})_{Na}}{(W\sqrt{2})_{H_2O}}$ is plotted in Figure 2 for various water test temperatures

and for SRE sodium temperatures.

The sodium flow rate can simply be calculated from the flow in the water loop test and the following formula:

$$\text{Sodium flow, lbs/sec} = \frac{(W\sqrt{2})_{Na}}{(W\sqrt{2})_{H_2O}} (\text{water flow, lbs/sec})$$

Values of $\frac{(W\sqrt{2})_{Na}}{(W\sqrt{2})_{H_2O}}$ are plotted in Figure 3 for various water test temperatures

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and for SRE sodium temperatures.

The appendix contains calculations for flow and pressure drop for pipe friction, orifice plate, entrances and exits, and a sample calculation sheet.

IV REFERENCES AND APPENDICES

1. Pipe Friction Pressure Loss

$$\Delta P = \frac{f W V^2}{2gD}$$

Therefore the relationship between sodium and water is

$$\frac{\Delta P_{Na}}{\Delta P_{H_2O}} = \frac{(f W V^2)_{Na}}{(f W V^2)_{H_2O}}$$

Where: f = friction factor
 W = fluid weight, lbs/ft³
 V = average velocity, ft/sec
 g = 32.2 ft/sec²
 D = pipe diameter, ft.

But for a sodium velocity such that the Reynolds' Numbers are equal, the friction factors will be equal

$$R_{Na} = R_{H_2O} \cdot \frac{(DV)_{Na}}{(\nu)_{Na}} = \frac{(DV)_{H_2O}}{(\nu)_{H_2O}}$$

Where: R = Reynolds' Number

ν = Kinematic viscosity, ft²/sec

and $D_{Na} = D_{H_2O}$ because a scale model is used and therefore

$$\frac{V_{Na}}{V_{H_2O}} = \frac{\nu_{Na}}{\nu_{H_2O}}$$

then

$$\frac{\Delta P_{Na}}{\Delta P_{H_2O}} = \frac{(W \nu^2)_{Na}}{(W \nu^2)_{H_2O}}$$

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The flow rate is given by the following expression

Flow rate, lb/sec = AVW

Where: A = cross section area, ft²

$$\frac{(\text{flow rate})_{Na}}{(\text{flow rate})_{H_2O}} = \frac{(AVW)_{Na}}{(AVW)_{H_2O}} = \frac{(\sqrt{W})_{Na}}{(\sqrt{W})_{H_2O}}$$

2. Orifice ΔP

$$V = C \sqrt{2g \frac{\Delta P}{W}}, \text{ Reference 1, Page 119}$$

$$\frac{V_{Na}}{V_{H_2O}} = \frac{\left(C \sqrt{2g \frac{\Delta P}{W}} \right)_{Na}}{\left(C \sqrt{2g \frac{\Delta P}{W}} \right)_{H_2O}}, \text{ C = velocity coefficient for orifice plate}$$

but for $R_{Na} = R_{H_2O}$, $C_{Na} = C_{H_2O}$ and

$$\frac{V_{Na}}{V_{H_2O}} = \frac{\sqrt{W_{Na}}}{\sqrt{W_{H_2O}}}$$

Therefore

$$\frac{\sqrt{W_{Na}}}{\sqrt{W_{H_2O}}} = \frac{\Delta P_{Na}}{\Delta P_{H_2O}} \text{ which is the same relationship as with the pipe friction } \Delta P \text{ ratio}$$

The flow rate is given by the following

flow rate, lbs/sec = $C_d AVW$, Reference 1, Page 120

Where: C_d = discharge coefficient

A = orifice plate flow cross section area, ft²

$$\frac{(\text{Flow rate})_{Na}}{(\text{Flow rate})_{H_2O}} = \frac{(C_d AVW)_{Na}}{(C_d AVW)_{H_2O}}$$

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$$= \frac{(\frac{1}{W})_{Na}}{(\frac{1}{W})_{H_2O}}$$

3. Entrance Loss (sudden contraction)

$$\Delta P = K_e W \frac{v^2}{2g}, \text{ Reference 1, page 221}$$

Where: K_e = entrance coefficient

Similarly this reduces to

$$\frac{\Delta P_{Na}}{\Delta P_{H_2O}} = \frac{(Wv^2)_{Na}}{(Wv^2)_{H_2O}}$$

4. Exit Loss (sudden enlargement)

$$\Delta P = \left(\frac{A_2}{A_1} - 1 \right)^2 \frac{W v_2^2}{2g}, \text{ Reference 1, page 216}$$

Again this reduces to

$$\frac{\Delta P_{Na}}{\Delta P_{H_2O}} = \frac{(Wv^2)_{Na}}{(Wv^2)_{H_2O}}$$

Reference:

1. "Hydraulics," by R. L. Daugherty, Fourth Edition, McGraw-Hill.

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	First Orifice Plate and Fuel	Second Orifice Plate and Fuel	Third Orifice Plate and Fuel
Water Temp. °C			
Water Flow lbs/sec			
Water P ₁₂ psi *			
Sodium P ₁₂ (550°F)			
Sodium Flow ₁₂ (550°F)			
Water P ₂₃ *			
Sodium P ₂₃ (650°F)			
Sodium Flow ₂₃ (650°F)			
Water P ₃₄ *			
Sodium P ₃₄ (850°F)			
Sodium Flow ₃₄ (850°F)			
Water P ₄₅ *			
Sodium P ₄₅ (950°F)			
Sodium Flow (950°F)			

Items marked thus () are data from the water loop test and the other items are calculated by use of Figures 2 and 3.

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SAMPLE CALCULATION SHEET FOR CONVERSION TO SODIUM

Figure 1

FIGURE 2
WATER TEST ΔP
CONVERSION TO SODIUM ΔP

FIGURE 3
WATER TEST FLOW
CONVERSION TO SODIUM FLOW

Test Water Temperature, °C