Given: Wet steam throttled adiabatically and aergonically

$P_1 = 800$ psia

$P_2 = 5.0$ psia
$T_2 = 200°F$

$V_1 = V_2$, $z_1 = z_2$

Find: The ratio of the exit area to the inlet area $\frac{A_2}{A_1}$.

Solution: The First Law for the throttling process is,

$$\cancel{\dot{Q}} - \cancel{\dot{W}} + \dot{m}_1\left(h_1 + \cancel{\frac{V_1^2}{2g_c}} + \cancel{\frac{g}{g_c}z_1}\right) - \dot{m}_2\left(h_2 + \cancel{\frac{V_2^2}{2g_c}} + \cancel{\frac{g}{g_c}z_2}\right) = \cancel{\frac{dE_{cs}}{dt}}$$

Continuity: $\dot{m}_1 - \dot{m}_2 = \cancel{\frac{dm_{cs}}{dt}} \rightarrow \dot{m}_1 = \dot{m}_2$

Therefore,

$h_1 = h_2$ ← throttling is <u>isenthalpic</u> !

How does this relate to the flow areas??

$$\dot{m} = \frac{AV}{v} \rightarrow \quad \therefore \quad \frac{\dot{m}_2}{\dot{m}_1} = \frac{A_2 \cancel{V_2}}{v_2} \cdot \frac{v_1}{A_1 \cancel{V_1}} = \frac{A_2}{A_1} \cdot \frac{v_1}{v_2}$$

Therefore,

$$\frac{A_2}{A_1} = \frac{v_2}{v_1} \cdot \cancel{\frac{\dot{m}_2}{\dot{m}_1}}^{\,1} = \frac{v_2}{v_1}$$

State 2: $P_2 = 5$ psia, $T_2 = 200°F$ } $v_2 = 78.15$ ft³/lbm, $h_2 = 1148.6$ Btu/lbm — Table C.3a

State 1: $P_1 = 800$ psia, $h_1 = 1148.6$ Btu/lbm } $h_f = 509.7$ Btu/lbm, $h_g = 1199.3$ Btu/lbm, $v_f = 0.02087$ ft³/lbm, $v_g = 0.5691$ ft³/lbm — Table C.2a

State 1 is wet!

$$x_1 = \frac{h_1 - h_f}{h_g - h_f} = \frac{(1148.6 - 509.7)\text{ Btu/lbm}}{(1199.3 - 509.7)\text{ Btu/lbm}} = \underline{0.9265}$$

Therefore,

$$v_1 = (1-x_1)v_f + x_1 v_g$$

$$v_1 = (1-0.9265)\left(0.02087 \frac{ft^3}{lbm}\right) + (0.9265)\left(0.5691 \frac{ft^3}{lbm}\right) = \underline{0.5288 \frac{ft^3}{lbm}}$$

Then,

$$\frac{A_2}{A_1} = \frac{v_2}{v_1} = \frac{78.15\ ft^3/lbm}{0.5288\ ft^3/lbm} = \underline{\underline{147.8}} \leftarrow$$

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P[1]=800[psia]
h[1]=h[2]
v[1]=Volume(steam_iapws,P=P[1],h=h[1])
T[1]=Temperature(steam_iapws,P=P[1],h=h[1])
x[1]=Quality(steam_iapws,P=P[1],h=h[1])

P[2]=5[psia]
T[2]=200[F]
v[2]=Volume(steam_iapws,T=T[2],P=P[2])
h[2]=Enthalpy(steam_iapws,T=T[2],P=P[2])

Aratio=v[2]/v[1]
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SOLUTION

Unit Settings: Eng F psia mass deg

Aratio = 147.8

No unit problems were detected.

Arrays Table: Main

	h_i [Btu/lbm]	P_i [psia]	T_i [F]	v_i [ft^3/lbm]	x_i
1	1149	800	518.3	0.5288	0.9263
2	1149	5	200	78.15	

```
P[1]=200[psia]
h[1]=h[2]
v[1]=Volume(steam_iapws,P=P[1],h=h[1])
T[1]=Temperature(steam_iapws,P=P[1],h=h[1])
x[1]=Quality(steam_iapws,P=P[1],h=h[1])

P[2]=5[psia]
T[2]=200[F]
v[2]=Volume(steam_iapws,T=T[2],P=P[2])
h[2]=Enthalpy(steam_iapws,T=T[2],P=P[2])

Aratio=v[2]/v[1]
```

SOLUTION

Unit Settings: Eng F psia mass deg

Aratio = 36.3

No unit problems were detected.

Arrays Table: Main

	h_i	P_i	T_i	v_i	x_i
	[Btu/lbm]	[psia]	[F]	[ft^3/lbm]	
1	1149	200	381.8	2.153	0.9404
2	1149	5	200	78.15	