From: "Gauntt, Randall O" <rogaunt@sandia.gov>
To: "'Jason Schaperow'" <JHS1@nrc.gov>, "Gauntt, Randa...
Date: Thu, Jul 13, 2000 2:19 PM
Subject: RE: Plume Energy

OK,
This version seems to be right.
Sorry about the false start.
Randy

-----Original Message-----
From: Jason Schaperow [mailto:JHS1@nrc.gov]
Sent: July 11, 2000 1:12 PM
To: rogaunt@sandia.gov
Cc: AXB@nrc.gov; AXN@nrc.gov; CGT@nrc.gov
Subject: Plume Energy

Please see the attached file (WordPerfect8 format). Also, I just FAXed you a copy of the attached file (FAX number (505)-844-8719), in case you do not have a program handy to read it. Thank you very much.

Sincerely,
Jason

CC: TWFN_DO.twf5_po(AXB,AXN,CGT)

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Analysis of Plume Energy Associated with Spent Fuel Pool Storage Accident
R.O. Gauntt 7/13/2000

Fuel and Canister Dimensions **

$r_{o\_clad} := 6.135\text{mm}$ $\qquad$ $r_{fuel} := \frac{0.410}{2}\cdot\text{in}$

$r_{i\_clad} := 5.322\text{mm}$ $\qquad$ $\text{can\_perimeter} := 4\cdot 5.215\cdot\text{in}$

$\text{assembly\_length} := 4.1\text{m}$ $\qquad$ $\Delta t_{canister} := 0.12\cdot\text{in}$

Fuel Properties **

$\rho_{Zr} := 6500\frac{\text{kg}}{\text{m}^3}$ $\qquad$ $Cp_{UO2} := 370\cdot\frac{\text{joule}}{\text{kg}\cdot\text{K}}$

$\rho_{UO2} := 0.95\cdot 10.96\cdot\frac{\text{gm}}{\text{cm}^3}$

$\rho_{ZrO2} := 5.6\cdot\frac{\text{gm}}{\text{cm}^3}$

$MW_{Zr} := 91.2\frac{\text{gm}}{\text{mol}}$ $\qquad$ $MW_{N2} := 28\cdot\frac{\text{gm}}{\text{mol}}$

$MW_{ZrO2} := 123.2\cdot\frac{\text{gm}}{\text{mol}}$

$MW_{O2} := 32\cdot\frac{\text{gm}}{\text{mol}}$

Fuel Assembly Properties **

$\text{mass}_{clad} := 64\pi\cdot\left(r_{o\_clad}{}^2 - r_{i\_clad}{}^2\right)\cdot\text{assembly\_length}\cdot\rho_{Zr}$

$\text{mass}_{canister} := \text{assembly\_length}\cdot\text{can\_perimeter}\cdot\Delta t_{canister}\cdot\rho_{Zr}$

$\text{mass}_{fuel} := 62\cdot\pi\cdot r_{fuel}{}^2\cdot\text{assembly\_length}\cdot\rho_{UO2}$

$\text{mass}_{canister} = 43.039\,\text{kg}$

$\text{mass}_{clad} = 49.91\,\text{kg}$

$\text{mass}_{fuel} = 225.442\,\text{kg}$

Enthalpy (Internal Energy) of Zircaloy, UO_2 and ZrO_2 ***
Properties from MATPRO

UO_2 Internal Energy ***

$K_1 := 296.7 \cdot K^{-1}$ $\qquad \theta := 535.285 \cdot K$ $\qquad \Delta H_{f\_UO2} := 2.74 \cdot 10^5 \cdot \frac{joule}{kg}$

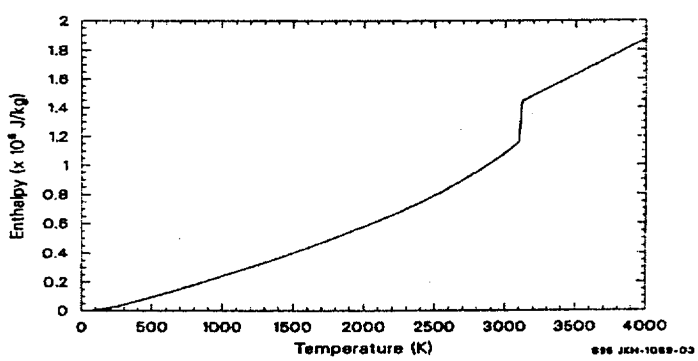
$K_2 := 2.43 \cdot 10^{-2} \cdot K^{-2}$ $\qquad E_D := 1.577 \cdot 10^5 \cdot \frac{joule}{mol}$ $\qquad Cp_{l\_UO2} := 503 \cdot \frac{joule}{kg \cdot K}$

$K_3 := 8.745 \cdot 10^7$ $\qquad R := 8.3143 \cdot \frac{joule}{mol \cdot K}$

$$H_{solid\_UO2}(T) := \left[\frac{K_1 \cdot \theta}{\left(e^{\frac{\theta}{T}} - 1 \right)} + \frac{K_2 \cdot T^2}{2} + K_3 \cdot e^{\left(\frac{-E_D}{R \cdot T} \right)} \right] \cdot \frac{joule}{kg}$$

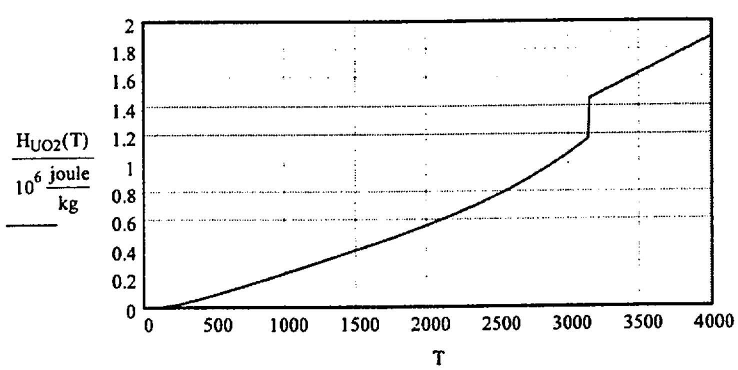
$$H_{UO2}(T) := \Phi(3138K - T) \cdot H_{solid\_UO2}(T) + \Phi(T - 3138K) \cdot \left[H_{solid\_UO2}(3138K) + \Delta H_{f\_UO2} + (T - 3138K) \cdot Cp_{l\_UO2} \right]$$

$T := 0K, 10K .. 4000K$



MATPRO Data

Figure 2-3. Enthalpy of UO_2 as a function of temperature to 4,000 K.



Curve Fit to MATPRO

Zircaloy Oxide Internal Energy **

$$H_{300} := 1.194 \cdot 10^{4}$$

$$H_1(T) := \left[565 \cdot \frac{T}{K} + 3.055 \cdot 10^{-2} \cdot \left(\frac{T}{K}\right)^2 + 1.14 \cdot 10^{7} \cdot \left(\frac{K}{T}\right) - 2.102495 \cdot 10^{5} + H_{300}\right] \cdot \frac{joule}{kg}$$

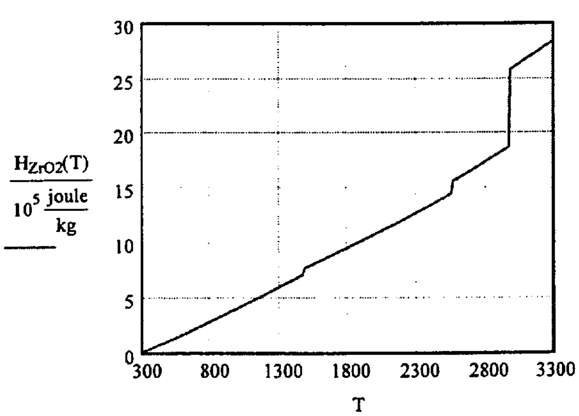
$$H_2(T) := \left[604.5 \cdot \left(\frac{T}{K}\right) - 1.46 \cdot 10^{5} + H_{300}\right] \cdot \frac{joule}{kg}$$

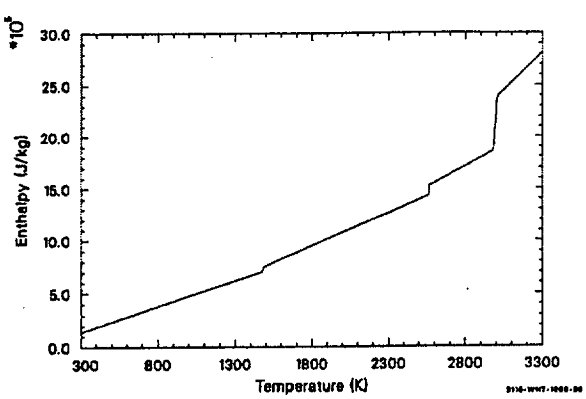
$$H_3(T) := \left[171.7 \cdot \left(\frac{T}{K}\right) + 0.1082 \cdot \left(\frac{T}{K}\right)^2 + 2.868 \cdot 10^{5} + H_{300}\right] \cdot \frac{joule}{kg}$$

$$H_4(T) := \left[171.7 \cdot \left(\frac{T}{K}\right) + 0.1082 \cdot \left(\frac{T}{K}\right)^2 + 3.888 \cdot 10^{5} + H_{300}\right] \cdot \frac{joule}{kg}$$

$$H_5(T) := \left[815.0 \cdot \left(\frac{T}{K}\right) + 1.39 \cdot 10^{5} + H_{300}\right] \cdot \frac{joule}{kg}$$

$$H_{ZrO2}(T) := \begin{cases} H_1(T) & \text{if } [(T > 273.0K) \wedge (T < 1478.0K)] \\ H_2(T) & \text{if } [(T > 1478.01K) \wedge (T < 2000.0K)] \\ H_3(T) & \text{if } [(T \ge 2000.0K) \wedge (T < 2558.0K)] \\ H_4(T) & \text{if } [(T \ge 2558.0K) \wedge (T < 2973.0K)] \\ H_5(T) & \text{if } [(T \ge 2973.01K) \wedge (T < 4100.0K)] \\ 0.0 \frac{joule}{kg} & \text{otherwise} \end{cases}$$





gure 5-3. Zircaloy oxide enthalpy as a function of temperature.