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 **********

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

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

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

Fuel Properties **********

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

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

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

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

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

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

Fuel Assembly Properties **********

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

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

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

$mass_{canister} = 43.039\,kg$

$mass_{clad} = 49.91\,kg$

$mass_{fuel} = 225.442\,kg$

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

UO_2 Internal Energy **********

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

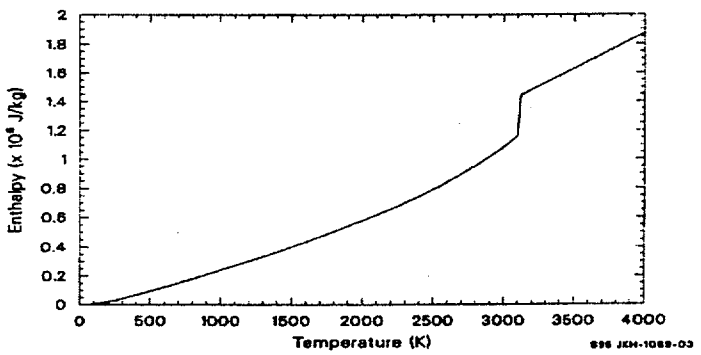
$K_2 := 2.43 \cdot 10^{-2} \cdot K^{-2}$ $\quad E_D := 1.577 \cdot 10^5 \cdot \frac{joule}{mol}$ $\quad Cp_{l\_UO2} := 503 \cdot \frac{joule}{kg \cdot K}$

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

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

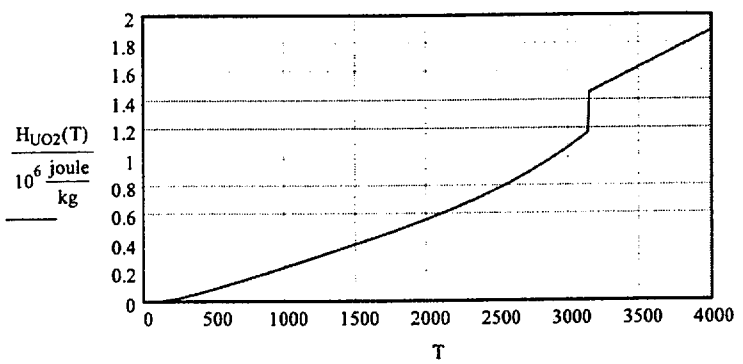
$$H_{UO2}(T) := \Phi(3138K - T) \cdot H_{solid\_UO2}(T) + \Phi(T - 3138K) \cdot \left[H_{solid\_UO2}(3138K) + \Delta H_{f\_UO2} + (T - 3138K) \cdot Cp_{l\_UO2} \right]$$

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



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 **********

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

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

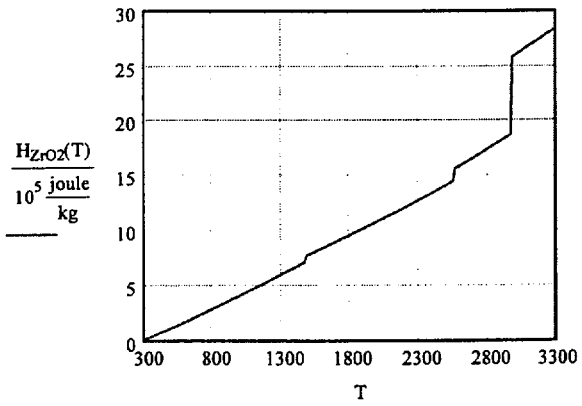
$$H_2(T) := \left[604.5 \cdot \left(\frac{T}{K}\right) - 1.46 \cdot 10^5 + H_{300} \right] \cdot \frac{joule}{kg}$$

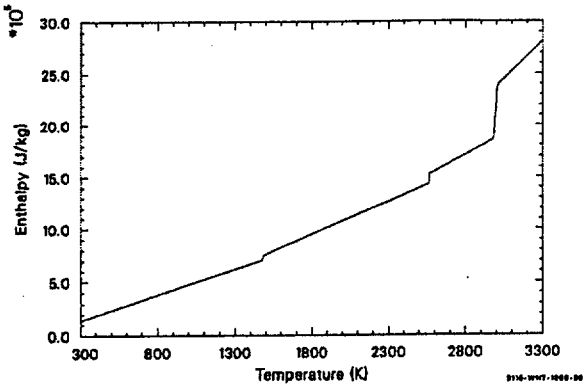
$$H_3(T) := \left[171.7 \cdot \left(\frac{T}{K}\right) + 0.1082 \cdot \left(\frac{T}{K}\right)^2 + 2.868 \cdot 10^5 + H_{300} \right] \cdot \frac{joule}{kg}$$

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

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

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





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