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PENETRATION OF A RADIATION RAY INTO URANIUM

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Abstract

We consider a plate of cold uranium whose surface is suddenly heated to and then maintained at a temperature T in the neighborhood of 2 Kev. A radiation wave will penetrate into the uranium as:

\[(d/cm) = .1 \frac{(T/Kev)^3}{(t/\mu sec)^2}\]

If we assume the opacity of uranium to go as T^{-3} the diffusion of radiation is described by the following differential equation*:

\[\frac{\partial T}{\partial t} = D \frac{\partial^2}{\partial x^2} T^7\]  \hspace{1cm} (1)

We can find a similarity solution for (1) if we set: \(y = \frac{x}{t^{\frac{1}{3}}}\) and \(T = T(y)\). If we make this transformation we obtain the ordinary differential equation:

\[-\frac{1}{2} y \frac{dT}{dy} = D \frac{d^2}{dy^2} T^7\]  \hspace{1cm} (2)

Equation (2) has solutions of a character represented in Figure 1 with a head at \(y = y_0\). One sees easily that near the head the solution must have the form

* See LA-322.
Instead of actually solving (2) we find an approximate $T$ so that it:

1) agrees with (3) and (4) near the head

2) satisfies the integrated Equation (2)

$$ \frac{1}{2} \int_0^{y_0} T \ dy = - D \left( \frac{d}{dy} T^7 \right) \bigg|_{y=0} $$

which is merely an expression of the law of conservation of energy. We try to achieve this by setting $T = A \varepsilon^{1/6} (1 + \alpha \varepsilon)^{1/7} \left( \varepsilon = 1 - \frac{X}{Y_0} \right)$ and find that $\alpha = \frac{13}{163}$. This leads to a surface temperature of

$$ T_0 = A \left( 1 - \frac{13}{163} \right)^{1/7} \quad (6) $$

We can now express $\int T \ dy$ in terms of $T_0$ as

$$ \int T \ dy \approx 1.31 \sqrt{D} T_0^4 \quad (7) $$

If we transform back to $X$ and $t$ we obtain simply $\int T \ dX = t^{1/3} \int T \ dy$.

We can define a depth of penetration $d = \int T \ dX / T_0$ which is given by:

$$ d = 1.31 \sqrt{D} T_0^3 t^{1/3} \quad (8) $$
From equation (5) of LA-322 we find:

\[
D = \frac{(\gamma - 1) M}{N \lambda} \frac{ac}{3 p^2} \frac{4}{7 \times T^3}
\]

(9)

In the 2 Kev region the heat capacity of uranium is* 200 eV per atom 238 and per eV. Therefore we can write \((\gamma - 1) M = 238/200 = 1.19 \text{ gm/mole}\). The opacity can be represented by the law**

\[
\kappa = 3.76 \times 10^{11} \text{ (T/ev)}^{-3} \text{ cm}^2/\mu\text{m}
\]

and we obtain:

\[
D = 6.75 \times 10^{-15} \text{ cm}^2/\text{ev}^6 \text{ sec}
\]

(10)

We substitute (10) into (8) and obtain:

\[
d/\text{cm} = .107 (T_e/\text{Kev})^3 (t/\mu\text{sec})^{1/2}
\]

(11)

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* AM-1668

** AM-1587

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