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PENETRATION OF A RADIATION RAVE INTO URANIUM

Re: Landshoff

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PENETRATION OF A RADIATION WAVE INTO URANIUM

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:

\[
(d/cm) = 0.1 \frac{(T/\text{Kev})^3}{(t/\mu\text{sec})^{3/2}}
\]

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

\[
\frac{\partial T}{\partial t} = D \frac{\partial^2 T}{\partial x^2} T^7
\]

Equation (1)

We can find a similarity solution for (1) if we set: \( y = X/t^{3/2} \) and \( T = T(y) \). If we make this transformation we obtain the ordinary differential equation:

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

Equation (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.
\[ T = A \left(1 - \frac{X}{Y_o}\right)^{1/6} \]  

(3)

with

\[ A^6 = \frac{3}{7} \left(\frac{Y_o^2}{D}\right) \]  

(4)

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)

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

(5)

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

\[ T_o = A \left(1 - \frac{13}{163}\right)^{1/7} \]  

(6)

We can now express \( \int T \, dy \) in terms of \( T_o \) as

\[ \int T \, dy \approx 1.31 \sqrt{D} T_o^4 \]  

(7)

If we transform back to \( X \) and \( t \) we obtain simply \( \int T \, dX = t^{3/2} \int T \, dy \).

We can define a depth of penetration \( d = \int T \, dX/T_o \) which is given by:

\[ d = 1.31 \sqrt{D} T_o^3 \left(\frac{t}{2}\right) \]  

(8)
From equation (5) of LA-322 we find:

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

(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**

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

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:

\[ d/cm = 0.107 (T_e/\text{Kev})^3 (t/\mu\text{sec})^{\frac{1}{2}} \]

(11)

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