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March 28, 1946

This document contains 4 pages.

PENETRATION OF A RADIATION WAVE INTO URANIUM

R. 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:

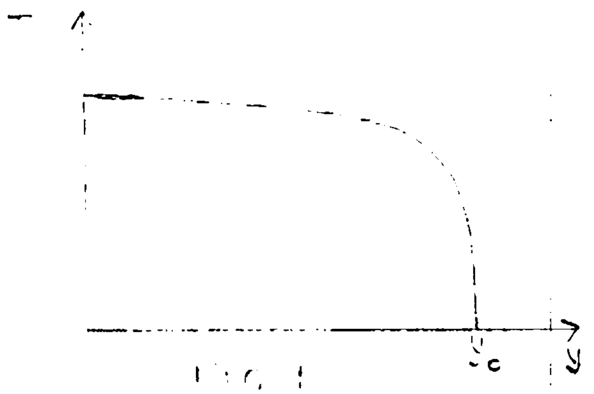
$$(d/cm) = .1\ (T/Kev)^3\ (t/\mu sec)^{\frac{1}{2}}$$

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

$$\frac{\partial T}{\partial t} = D \frac{\partial^2}{\partial X^2} T^7 \qquad (1)$$

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

$$-\tfrac{1}{2} y \frac{dT}{dy} = D \frac{d^2}{dy^2} T^7 \qquad (2)$$



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

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* See LA-322.

$$T = A\left(1 - \frac{y}{y_o}\right)^{1/6} \qquad (3)$$

with

$$A^6 = \frac{3}{7}\,\frac{{y_o}^2}{D} \qquad (4)$$

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)

$$\frac{1}{2}\int_0^{y_o} T\,dy = -D\left(\frac{d}{dy}\,T^7\right)_{y=0} \qquad (5)$$

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

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

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

$$\int T\,dy \approx 1.31\sqrt{D}\;{T_o}^4 \qquad (7)$$

If we transform back to X and t we obtain simply $\int T\,dX = t^{\frac{1}{2}} \int T\,dy$. We can define a depth of penetration $d = \int T\,dX/T_o$ which is given by:

$$d = 1.31\sqrt{D}\;{T_o}^3\;t^{\frac{1}{2}} \qquad (8)$$

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

$$D = \frac{(\gamma - 1)\, M}{N\ \kappa}\ \frac{ac}{3\rho^2}\ \frac{4}{7\kappa T^3} \tag{9}$$

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

$$\kappa = 3.76 \times 10^{11}\ (T/eV)^{-3}\ \ cm^2/gm$$

and we obtain:

$$D = 6.75 \times 10^{-15}\ cm^2/eV^6\ sec \tag{10}$$

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

$$d/cm \sim .107\ \ (T_o/Kev)^3\ \ (t/\mu sec)^{\frac{1}{2}} \tag{11}$$

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