LIGO - T890001

#02a

List of 3/1/89

FILE:dubradiso.tex
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FROM: RW January 30,1989.
CONCERNING: Dubinin-Radushkevich Isotherms (Appendix to MEMO61588.TEX)

Boude's Favorite Outgassing theory - Dubinin-Radushkevich

On the urging of Boude I have looked into the Dubinin-Radushkevich (DR) adsorption theory for outgassing. This note is intended to put the DR theory into the same format as in MEMO61588.tex which presented a formulation of the surface physics involved in adsorption with the hope of being able to predict outgassing flux as a function of time and suggested techniques to measure the distribution function of adsorption energies.

The surface coverage, σ molecules per cm^2, of adsorbed molecules at equilibrium (equal emission and readsorption) at a temperature T is given by the RD theory as

$$\frac{\sigma}{\sigma_m} = e^{-(T/T_0)^2 ln^2(P/P_0)}$$

where σ_m is the surface coverage at the saturation vapour pressure P_0 at T. P is the pressure and T_0 is the average energy of adsorption expressed as a temperature. T_0 is also the spread in energy of the adsorption sites as will become clearer below.

The distribution function of sites with adsorption energy T_{act} that leads to the DR equation is the skewed Gaussian distribution which was not included in the MEMO61588.tex. The distribution function is given by

$$\theta(T_{act}) = \left(2T_{act}/{T_0}^2\right) e^{-(T_{act}/T_0)^2}$$

The distribution function is normalized

$$\int_0^{\infty} \theta(T_{act}) \delta T_{act} = 1$$

The outgassing rate with time is given by eq(2) page 6 of MEMO61588.tex using the above distribution as argument in the integral. The explicit form of the outgassing flux with temperature and time is given by

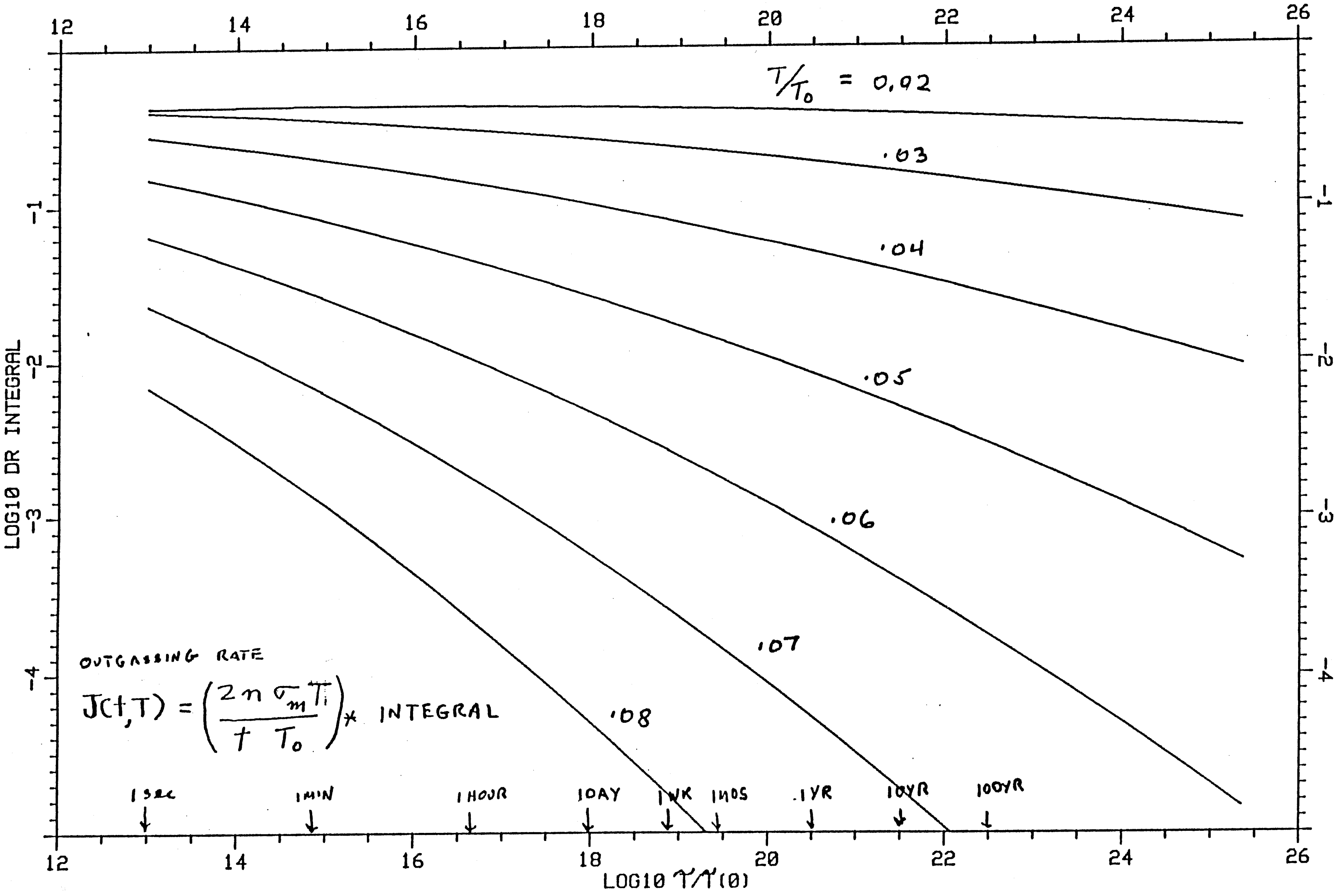
$$J_{H_2O}(t,T) = \left(\frac{2n\sigma_0 T}{tT_0}\right) \int_0^a bln(y/a) e^{-(bln(y/a))^2} e^{-y} dy$$

where $b = T/T_0$ and $a = t/\tau_0$. I could not do the integral analytically, the numerical integration is shown in the figure. The results are very similar to the uniform distribution with $T_m \approx T_0/2$. Both distributions exhibit a predominantly $1/t$ dependence when $T/T_{0,m} << 1$, the case we are experiencing in the VTF and will most likely have in the LIGO. There is a significant difference between the two distributions in the functional form of the deviation from $1/t$ dependence with increasing t. The uniform distribution drops exponentially once $t > \tau(T_m)$, where as the figure shows, the distribution function underlying the DR isotherms gives a slower (almost power law) deviation from $1/t$ dependence. This makes good sense since the Gaussian tail of the distribution function for large T_{act} gives more long residence time adsorption sites than the sharp cutoff of the uniform distribution. It is worth noting that the integral of the total outgassing with time for the DR distribution converges.

If the surface of the first tube tested in the VTF *does* have a distribution function of sites associated with the DR isotherms, it looks like T/T_0 lies between .025 and .030 from the data that I have ; $1.2 \times 10^4 > T_0 > 1.0 \times 10^4$ degrees K. The deviation from $1/t$ behaviour would be only a factor of between 2.5 to 3 in 10 years.

The heating experiment described in the MEMO61588.tex could still be used to predict the outgassing with time. The experiment is model independent since it is designed to measure the distribution of residence times. The only physics that must apply is that the residence time be given by a Boltzmann factor

$$\tau(T_{act}) = \tau_0 e^{T_{act}/T}$$



DR INTEGRAL VS NORMALIZED PUMPING TIME

ASSUME $\tau_0 = 10^{-13}$ sec