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HEAVY GAS DISPERSION MODEL WITH LIQUID RELEASE

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SUMMARY

NILUs heavy gas dispersion model (Eidsvik, 1) does easily include a liquified gas release.

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1 INTRODUCTION

It is often judged desirable to model simultaneously the release of a liquified gas, and the boiling and dispersion of the resulting heavy gas cloud. Only a very complicated model of this type exists (Havens, 2). Formally a liquid release with boiling is easily included into Eidsvik's (1) heavy gas dispersion model. However, the release model should be consistent, either with the "constant continuous" or "instantaneous" gas dispersion model. For the "constant continuous" model, requiring stationarity, this means that the gas release details become relatively uninteresting. For the "instantaneous" case the release must be rapid enough so that the gas cloud sentre is quasi-stationary during the evaporation time. That is, the gas frontal velocity during the release must be significantly higher than the bulk transport velocity. The turbulence is assumed intense enough to be modelled as "instantaneous" mixing inside the cloud.

2 LIQUIFIED GAS RELEASE

Since the gas model (1) is valid with time-varying gas mass, $M_g(t)$, the modification needed is an equation for the evaporation of liquid gas:

$$\frac{dM_g(t)}{dt} = \int_{A_L(t)} \frac{d^2M_g(t)}{dA_L dt} \, dA_L(t)$$

$$\simeq A_L(t) \frac{d^2M_g(t)}{dA_L \, dt} \qquad (1)$$

Here $A_L(t)$ is the area of the liquid pool, and $\frac{d^2M_g(t)}{d\ A\ dt}$ is the evaporation per unit area and time. The fraction of liquid mass thrown into the cloud as droplets is δ. All three variables to parameterize the boiling are uncertain (Ytrehus, 3).

The normalization velocity of the quadratic sideways entrainment, $U_g(0)$, is taken as the frontal velocity of an unmixed, cold cloud with height/radius ratio equal to one.

This gives a model with simultaneous evaporation and entrainment, having approximately correct behaviour as the cloud density approaches the atmospheric.

3 EXAMPLES

3.1 Instantaneous liquid release on water

Supposing LNG is released instantaneously on a sea surface. The liquid area is assumed to increase as if boiling did not occur:

$$A_L(t) \simeq A_L(0) + \pi 2\alpha_1 \left(g \frac{\rho_w - \rho_L}{\rho_w} \cdot \frac{M_L}{\pi\rho_L}\right)^{\frac{1}{2}} t \qquad (2)$$

with ρ_w and ρ_L the densities of water and liquid LNG, respectively. M_L is the total LNG mass. The evaporation rate is obtained from Burgess et al. (4):

$$\frac{d^2M_g}{dA_L dt} \simeq 0.15 \text{ kg/m}^2\text{s} \qquad (3)$$

and $\delta = 0.5$. The atmospheric variables and experimental coefficients are chosen as in Figure 4 of Ref. (1) with $\alpha_2 = 0.7$. Some of the variables characterizing the cloud development are shown in Figure 1.

The cloud height grows very rapidly to a height of ca 2 m during the boiling phase, whereafter the height variation proceeds approximately as in Ref (1). The relative density difference increases as long as there are droplets left to cool the entrained air.

3.2 Release into a concrete dike

When the liquid is released into a solid dike of constant area A_L, the evaporation will decrease with time because the solid surface will cool. The evaporation is then modelled as:

$$\frac{dM_g}{dt} \simeq \min \begin{cases} \dfrac{dM_L}{dt} \\ \dfrac{T_s - T_g}{L_g} \quad \left(\dfrac{\rho_s \lambda_s c_s}{\pi} t\right)^{-\frac{1}{2}} A_L \end{cases} \tag{4}$$

Here $\frac{dM_L}{dt}$ is the liquid release rate, and T_s, ρ_s, λ_s, c_s the surface temperature, density, heat conductance and specific heat, respectively.

The gas cloud resulting from a dike release is illustrated in Figure 2. The cloud is formally predicted non-hazardous long before M_L has been released. This is obviously caused by the assumption of instantaneous mixing inside the cloud.

4 REMARKS

As the conditions of liquid release can be varied considerably, it is formally simple to compute the resulting gas dispersion. However, due to the large release variability and generally sparse data, it is impossible to know if the complicated process is really realistically modelled. This suggests that simple release models should be used.

5 REFERENCES

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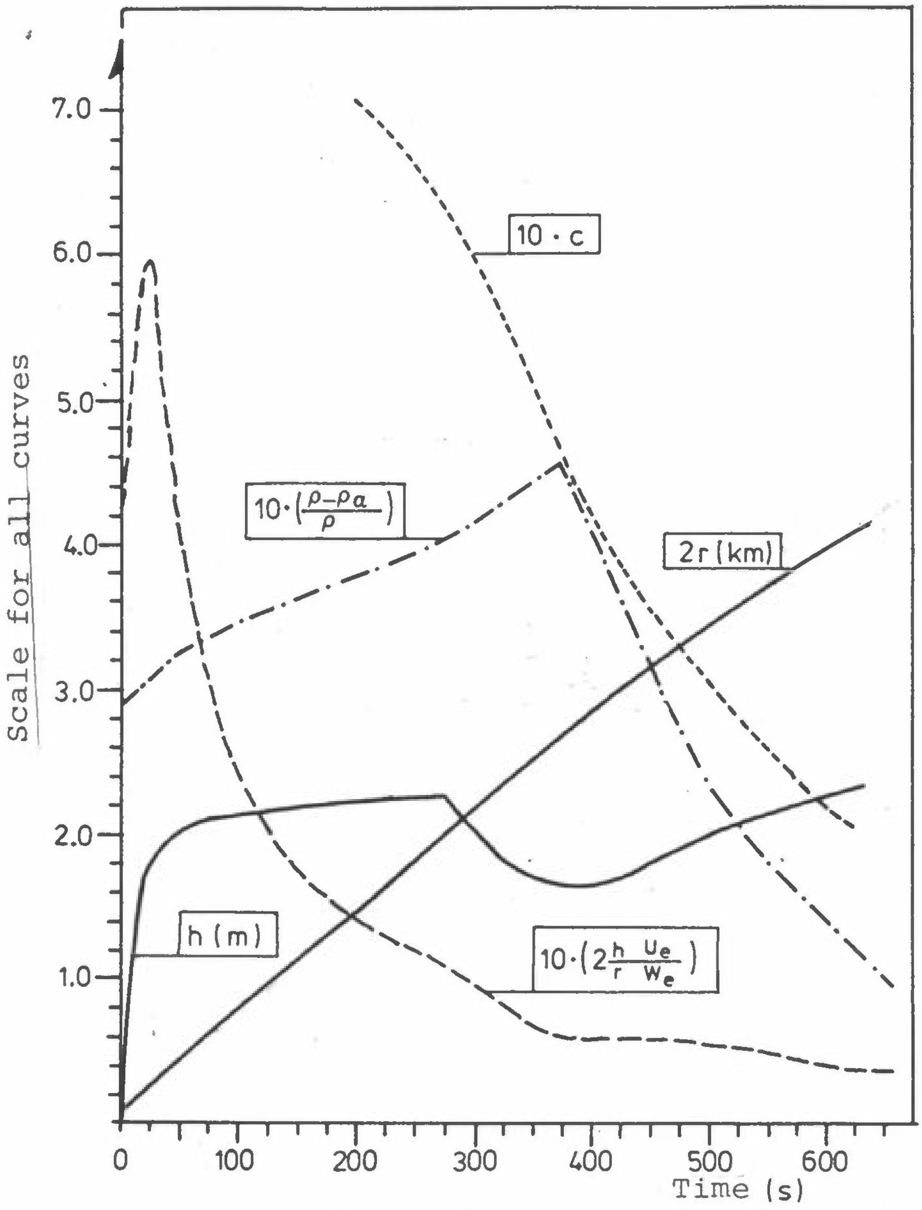

Figure 1: Cloud variables resulting from an instantaneous release of 10^7 kg liquid methane into water.

$h_L(o)/r_L(o) = 10^{-1}$, $\delta = 0.5$; $U_a = 0.5$ ms^{-1}; $c_f = 2 \cdot 10^{-3}$; $T_a - T_{da} = 5$; $\alpha_1 = 1.3$, $\alpha_2 = 0.7$; $\alpha_3 = 1.3$; $\alpha_4 = 3.5$; $\alpha_5 = 0.5$; $\alpha_6 = 0.3$.

———— cloud height, h and cloud diameter, $2r$

- - - - - - - mass concentration, c

—— · —— relative density difference, $\frac{\rho - \rho_a}{\rho}$

— — — — ratio of entrainment rate at cloud side and top, $2 \frac{h}{r} \frac{u_e}{w_e}$

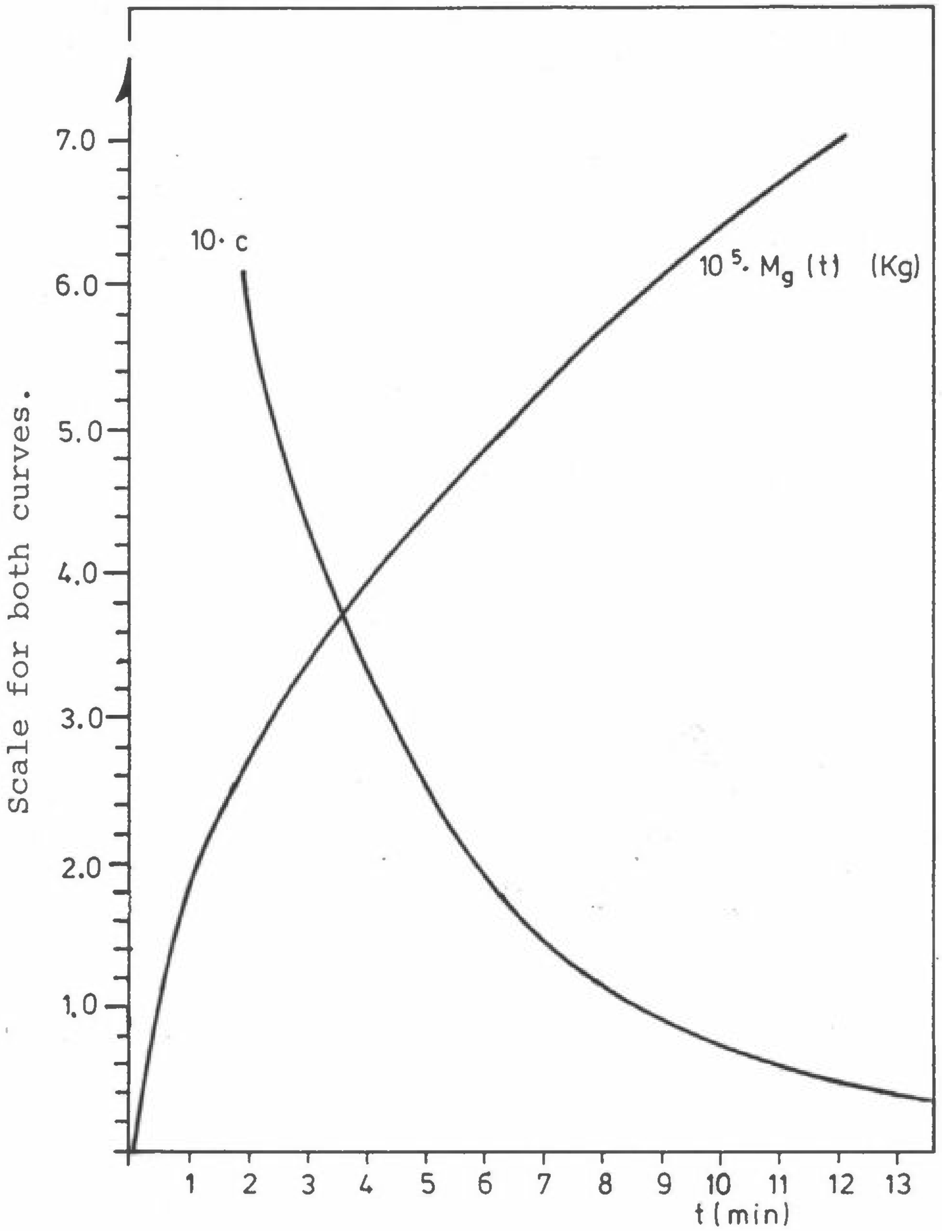

Figure 2: *Gas mass and concentration resulting from a release of* $M_L = 3 \cdot 10^7$ *kg LNG, released into a* $4 \cdot 10^4 m^2$ *dike at a rate*

$$\frac{dM_L}{dt} = 9 \cdot 10^3 \text{ kg/sec.}$$

$h_L(o)/r_L(o) = 10^{-1}$, $\delta = 0.3$, $U_a = 0.5\ ms^{-1}$; $c_f = 2 \cdot 10^{-3}$; $T_a - T_{da} = 5$; $\alpha_1 = 1.3$, $\alpha_2 = 0.7$; $\alpha_3 = 1.3$; $\alpha_4 = 3.5$; $\alpha_5 = 0.5$; $\alpha_6 = 0.3$.

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OPPDRAGSGIVER STATOIL		
3 STIKKORD (á maks.20 anslag) Tunge gasser	Eksplosive gasser	Gassutslipp

REFERAT (maks. 300 anslag, 5-10 linjer)

NILUs modell for spredning av tunge kalde gasser (Eidsvik , 1) er modifisert slik at utslippet kan være flytende.

TITLE Heavy gas dispersion model with liquid release

ABSTRACT (max. 300 characters, 5-10 lines)

NILUs heavy gas dispersion model (Eidsvik , 1) is modified to include a liquified gas release.

**Kategorier:	Åpen - kan bestilles fra NILU	A
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