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: Mound Laboratory

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Ceramics

: Calculations for the Atmospheric Diffusion of Stack Effluents at Mound Laboratory

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INTRODUCTION

It is anticipated that the ceramics program will, of necessity, cause larger quantities of radioactive materials to be exhausted through the Mound Laboratory stacks. The purpose of these calculations is to correlate stack effluent concentration and maximum ground concentrations with existing meteorological data. Two cases will be covered - 1) Maximum ground concentration from a continuous source such as is found in normal day-to-day operations; and 2) Maximum total integrated exposure to off-site personnel if an accidental release of large quantities of tritium should occur (instantaneous source).

METHODS USED FOR CALCULATIONS

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General

Table I gives a list of the symbols, definitions, and units used in succeeding calculations.

TABLE I

Symbols, Dimensions, and Units

Symbol		Definition	Dimensions	Units
χ	-	Concentration	ML^{-3}	c/m^3
Q	-	Emission rate	MT^{-1}	c/sec
u	-	Mean horizontal wind speed	LT^{-1}	m/sec
t	-	Time	T	sec
n	-	Dimensionless stability parameter	-	-
c^2	-	Generalized diffusion coefficient	L^n	m^n
h	-	Effective stack height	L	m
x	-	Distance downwind from source	L	m

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Subject: Calculations for the Atmospheric Diffusion of Stack Effluents at Mound Laboratory - Cont'd. 4/5/54

The height of rise of a stack gas plume depends upon several parameters. The primary meteorological effect, however, is a decrease of plume height with increasing wind speed. An empirical formula obtained by Rupp, Beall, Bornwasser, and Johnson (ref. 4) on the basis of wind tunnel experiments gives a simple, inverse relationship between Δh and u but takes into account only the momentum effect. In the specific case at Mound Laboratory, however, the use of this formula will introduce very little error since the buoyancy effect is quite small compared to the effect of the jet itself.

This relationship is:

$$u \Delta h = 1.5 \ vd$$

where Δh is the height, measured above the stack, at which the plume levels off.

v is the stack gas exit velocity

d is the diameter of the stack orifice.

For the Mound stack,

$v = 15.1$ m/sec.

$d = 2.44$ m.

height of orifice = 61 m.

Then:

$$\Delta h = \frac{1.5 \times 15.1 \times 2.44}{u} = \frac{55.3}{u}$$

and

$$h = 61 + \Delta h$$

Table II gives values of h for wind speeds ranging from 0.1 to 10 miles per hour.

TABLE II

u (mph)	h (m)
0.1	1,298
0.3	473
0.5	308
1.0	185
2.0	123
3.0	102
4.0	92
5.0	86
6.0	82
7.0	79
8.0	76
9.0	75
10.0	73

Continuous Point Source

1. For normal operations resulting in a continuous discharge of tritium from the stack, Sutton's general formula for ground concentration is:

$$\chi = \frac{2Q}{\pi e^2 u x^{2-n}} e^{-\frac{h^2}{c^2 x^{2-n}}} \qquad (1)$$

2. The maximum ground concentration and distance of maximum downwind from such a continuous elevated source (Set $\partial \chi / \partial x = o$)

$$\chi \text{ max.} = \frac{2 Q}{\pi e u h^2} \qquad (2)$$

$$x \text{ max.} = \left(\frac{h^2}{c^2}\right)^{\frac{1}{2-n}} \qquad (3)$$

Figure I shows a graph of ground concentrations versus wind speed if a constant emission rate of 100 millicuries per second is maintained.

Instantaneous Point Source

1. An accidental release of large quantities of tritium may be considered as an instantaneous point source. Sutton's equation for ground concentrations under these conditions is:

$$\chi(\bar{u}t) = \frac{2Q}{\pi^{\frac{3}{2}} c^3 (\bar{u}t)^{3\frac{(2-n)}{2}}} e^{-\frac{(\bar{u}t)^{n-2} h^2}{c^2}} \qquad (4)$$

2. For maximum ground concentration and distance of maximum downwind from the instantaneous elevated source (Set $\partial\chi / \partial t = o$)

$$\chi \text{ max.} = \frac{2Q}{\left(\frac{2}{3}\pi e\right)^{\frac{3}{2}} h^3} \qquad (5)$$

$$x \text{ max.} = \left[\frac{2h^2}{3c^2}\right]^{\frac{1}{2-n}} \qquad (6)$$

3. To find the total integrated dosage (TID) at a point on the ground downwind of an instantaneous elevated source, integrate (4) with respect to $x/\bar{u}$ from $-\infty$ to ∞, hold $\bar{u}t$ constant.

$$\text{TID} = \frac{2Q}{\pi c^2 \bar{u} (\bar{u}t)^{2-n}} e^{\frac{-h^2}{c^2 (\bar{u}t)^{2-n}}} \qquad (7)$$

[redacted]

4. To obtain maximum total integrated dose and distance downwind set

$$\frac{\partial}{\partial t} (\text{TID}) = 0$$

$$\text{TID max.} = \frac{2\,Q}{\pi e\, u\, h^2} \quad \text{curie-sec./m}^3 \qquad (8)$$

$$x \text{ max.} = \left[\frac{h^2}{c^2}\right]^{\frac{1}{2-n}} \qquad (9)$$

Note: In (8) Q is total curies released, not emission rate.

5. Values of u and h where the least dilution of the stack effluent is obtained may be found by differentiating and maximizing (8). This condition occurs when h equals two stack heights (at Mound - 122 meters) and

$$u = \frac{1.5\, v\, d}{\text{stack height}} \quad \text{, or at Mound,}$$

$$u = 2.0 \quad \text{mph.}$$

[redacted]

DISCUSSION

Continuous Source

Adequate precautions are being taken in the design of facilities for the Ceramics Program to insure safe concentrations of tritium in off-site air under these conditions. These concentrations may not exceed 2×10^{-6} $\mu c/cc$ for a long-term average (ref.6); nor 20 times this level averaged over a 24-hour period; nor 100 times this level as a peak concentration averaged over one liter of volume (ref.7).

The provision of closed glove-box ventilating systems, automatic dampers in room exhaust ducts, air-tight containers and equipment, stack monitors, and other safety devices should undoubtedly be sufficient to meet the above requirements.

It is, however, of interest to establish the maximum emission rate of tritium from our stack which will maintain safe off-site concentrations at ground level. This is found from equation (2):

$$\chi = \frac{2Q}{\pi e u h^2}$$

where u = 2.0 miles per hour

h = 122 meters, and

Q under these conditions will equal:

$$Q = \frac{\chi \pi e u h^2}{2}$$

$$\chi = 2 \times 10^{-6} \ \mu c/cc = 2 \mu c/m^3$$

$$Q = \frac{2\pi e \times 0.894 \times (122)^2}{2}$$

$$Q = 115{,}638 \ \mu c/sec \quad \text{or} \quad 0.116 \ c/sec.$$

[redacted]

Instantaneous Source

There is, however, another factor to be given serious consideration in this program. The probability of a major accident releasing large quantities of tritium to the stack exhaust is somewhat greater than has been the case in polonium or actinium operations. Here we have no filter banks or other air-cleaning system to remove tritium from the stack effluent.

Although all possible safety devices will be engineered into the process equipment, it was felt that calculations should be made to determine the maximum number of curies of tritium which, if accidentally released, would present no serious exposure problem to persons living or working in areas near Mound Laboratory.

For the purposes of these calculations, the following statements were used:

1. The total number of curies released would be vented from the stack in a short period of time.

2. The maximum total intake of tritium by any person would not exceed $10^4 \mu c$, the presently accepted maximum permissible body burden (ref. 6).

3. It was assumed that all of the tritium released is in the form of vapor and not gas when it reaches the breathing zone of exposed individuals.

4. Only 50 per cent of the total intake will be via inhalation, the remainder being absorbed through the skin.

Using these criteria and equation (8)

$$\text{TID max.} = \frac{2\,Q}{\pi\, e\, u\, h^2} \quad \frac{\text{curie - sec}}{m^3},$$

$$\text{TID max.} = 14.4 \quad \frac{\text{curie - sec}}{m^3}$$

$$u = 2.0 \text{ mph}$$

$$h = 122 \text{ m}$$

$$Q = 832{,}599 \text{ curies or } 86.0 \text{ grams of T.}$$

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Subject: Calculations for the Atmospheric Diffusion of Stack Effluents at Mound Laboratory - Cont'd. 4/5/54

SUMMARY

Calculations made to determine off-site ground concentrations of tritium in the air show:

1. An emission rate of 116 millicuries per second or less will not cause unduly high concentrations of tritium in off-site air. These calculations, however, do not take into account possible build-up of contamination in ground water. This, because of the long physical half-life of tritium, may be considerable. Adequate sampling and monitoring measures will be employed to determine the amount and extent of this contamination. In any event, it is felt that normal emission rates from the stack will be far below 116 millicuries per second.

2. In case of a major accident or disaster, the loss of 86 grams of tritium may result in the intake of 10^4 microcuries by people located in the maximum exposure zone.

3. The location of maximum concentrations is dependent upon meteorological conditions at the time of emission from the stack.

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REFERENCES

1. (No author given) - "A Meteorological Survey of the Oak Ridge Area" - ORO - 99

2. O. G. Sutton - "A Theory of Eddy Diffusion in the Atmosphere" - (1932) - Proc. Roy. Soc., Lond. A, Vol. 135.

3. O. G. Sutton - "Micrometeorology" - (1953) McGraw-Hill

4. A. F. Rupp, S. E. Beall, L. P. Bornwasser, and D.H. Johnson - "Dilution of Stack Gases in Cross Winds" - AECD-1811

5. (No author given) - "Papers Presented at Joint US/UK/Canadian Reactor Siting Conference Held at Harwell, England on Sept. 5, 6, and 7, 1949" - TID-257 (Secret)

6. U.S.Handbook 52 - "Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water"

7. (No author given) - "Proposed Atomic Energy Commission Policy Governing Allowable Radioactivity in Waste Discharged by A.E.C. Contractors"

8. U.S.Weather Bureau, Oak Ridge - "Climatology and Estimates of Disperson for Mound Laboratory" - C.F. - 51-9-50 (Secret).

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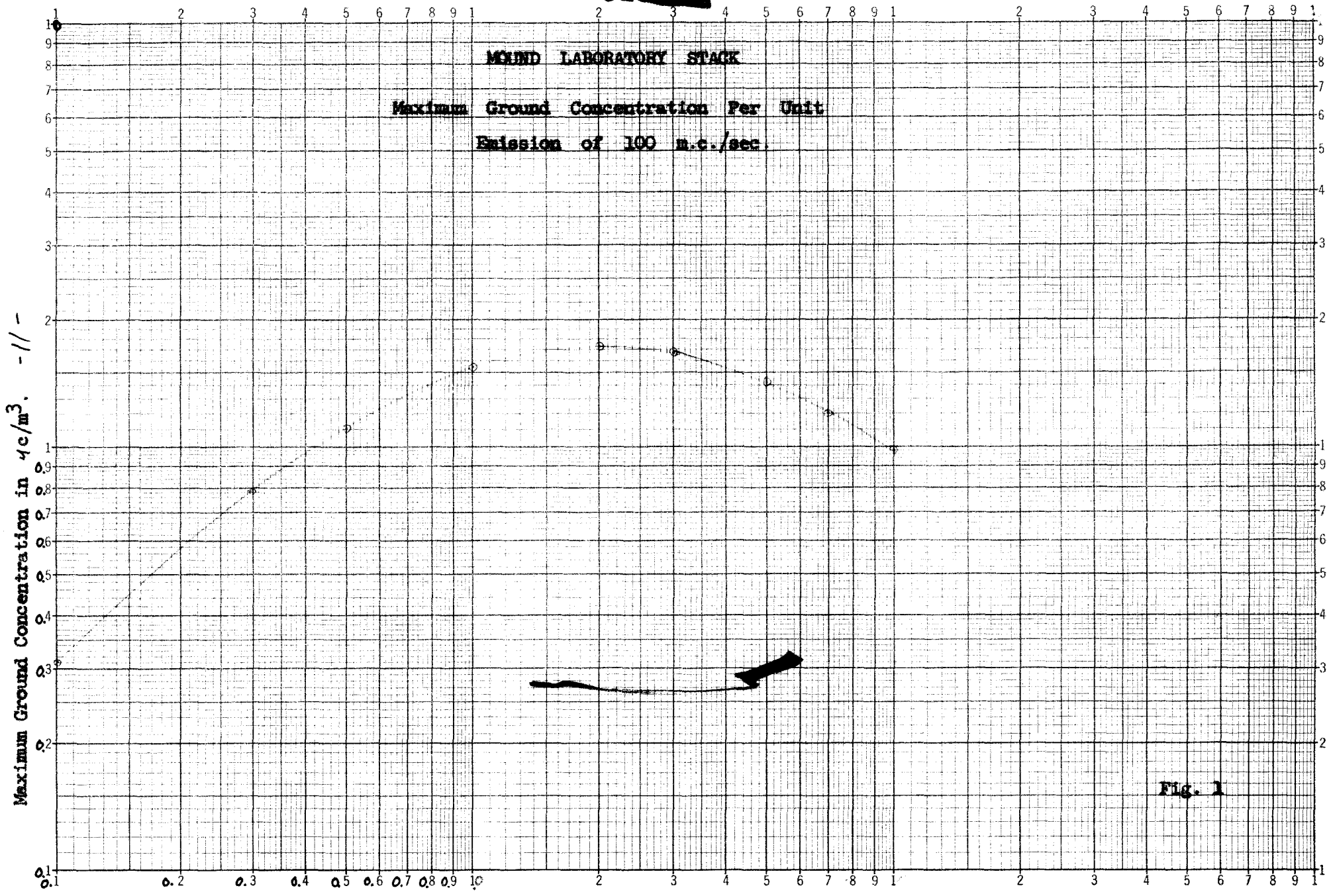

Fig. 1

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