ITEM 14

PROGRESS REPORT

EVALUATION OF 85KR DISCHARGES FROM A

TRIO-TECH LEAK DETECTION SYSTEM

APRIL 1973

TRIO-TECH, INC.
OF CALIFORNIA

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INTRODUCTION

The Trio-Tech Leak Detection System uses ^{85}Kr to determine the integrity of the seals of small integrated electronic components. The device uses a 25 Curie (Ci) supply of ^{85}Kr; a smaller but similar system which will employ a 5 Ci supply is also being considered. Under normal operating conditions, a small amount of ^{85}Kr is discharged to the atmosphere during each instrument operating cycle. The maximum hypothetical accident that could occur using the equipment would be the release of the entire ^{85}Kr inventory, i.e., up to 25 Ci. The probability of such an accident occurring is extremely small. In ~80 logged instrument operating years, there has not been such an accident.

The meterological model used to evaluate the atmospheric dispersion of ^{85}Kr discharged and to determine the off-site atmospheric concentration of ^{85}Kr resulting from such a discharge is the Pasquill Model. In this model, the off-site concentration is given by:

$$X = \frac{Q}{\pi \sigma_y \sigma_z u} \exp -\frac{1}{2} \frac{H}{\sigma_z}^2 ,$$

where X = downwind concentration ($\mu Ci/m^3$)

Q = discharge rate ($\mu Ci/sec$)

X = distance downwind (m)

y = distance from plume centerline in the horizontal plane (m)

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z = height above ground level at which the concentration is being calculated (m)

H = effective height of the discharge point (m)

σ_y, σ_z = standard deviations of concentration in the plume in the horizontal and vertical planes, respectively, = f(X) (m)

u = wind speed (m/sec)

In the model, the plume is assumed to be described by Gaussian distributions in the two orthogonal cross-flow planes. The equation shown considers the case of ground level concentrations at the horizontal plume centerline resulting from an elevated discharge A schematic diagram of a typical plume is shown in Figure 1.

The values of σ_y and σ_z are functions of both the downwind distance and the Pasquill stability type. Stability type F describes the most stable meteorological condition, and therefore results in the least degree of atmospheric dispersion and the most conservative analysis. In Figure 2, the function Xu/Q is plotted as a function of the downwind distance, X, for F type stability and an effective stack height of 10 m. The equipment will generally be installed in a single story building with the exhaust vent on the roof, $\sim$5 m above ground level. The plume rise due to the exit velocity from the exhaust vent will be $\sim$5 m, thereby yielding an effective stack height of 10 m. From Figure 2, we see that the peak value of $Xu/Q = 1.15 \times 10^{-3}\ m^{-3}$ occurs at a downwind distance of $X \approx 350$ m.

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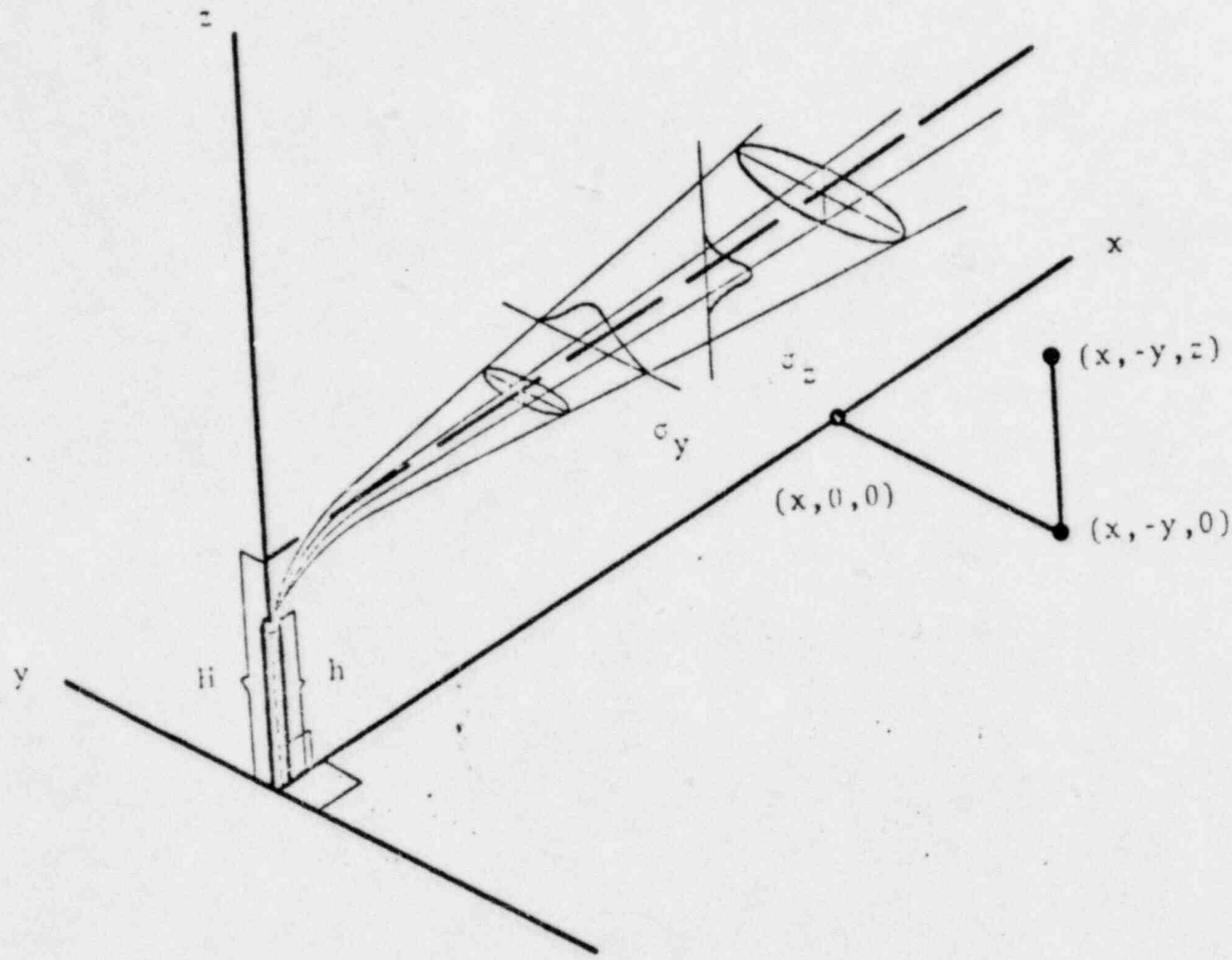
FIGURE 1

PLUME GEOMETRY SHOWING THE COORDINATE AXES
AND THE GAUSSIAN DISTRIBUTIONS
IN THE HORIZONTAL AND VERTICAL DIRECTIONS



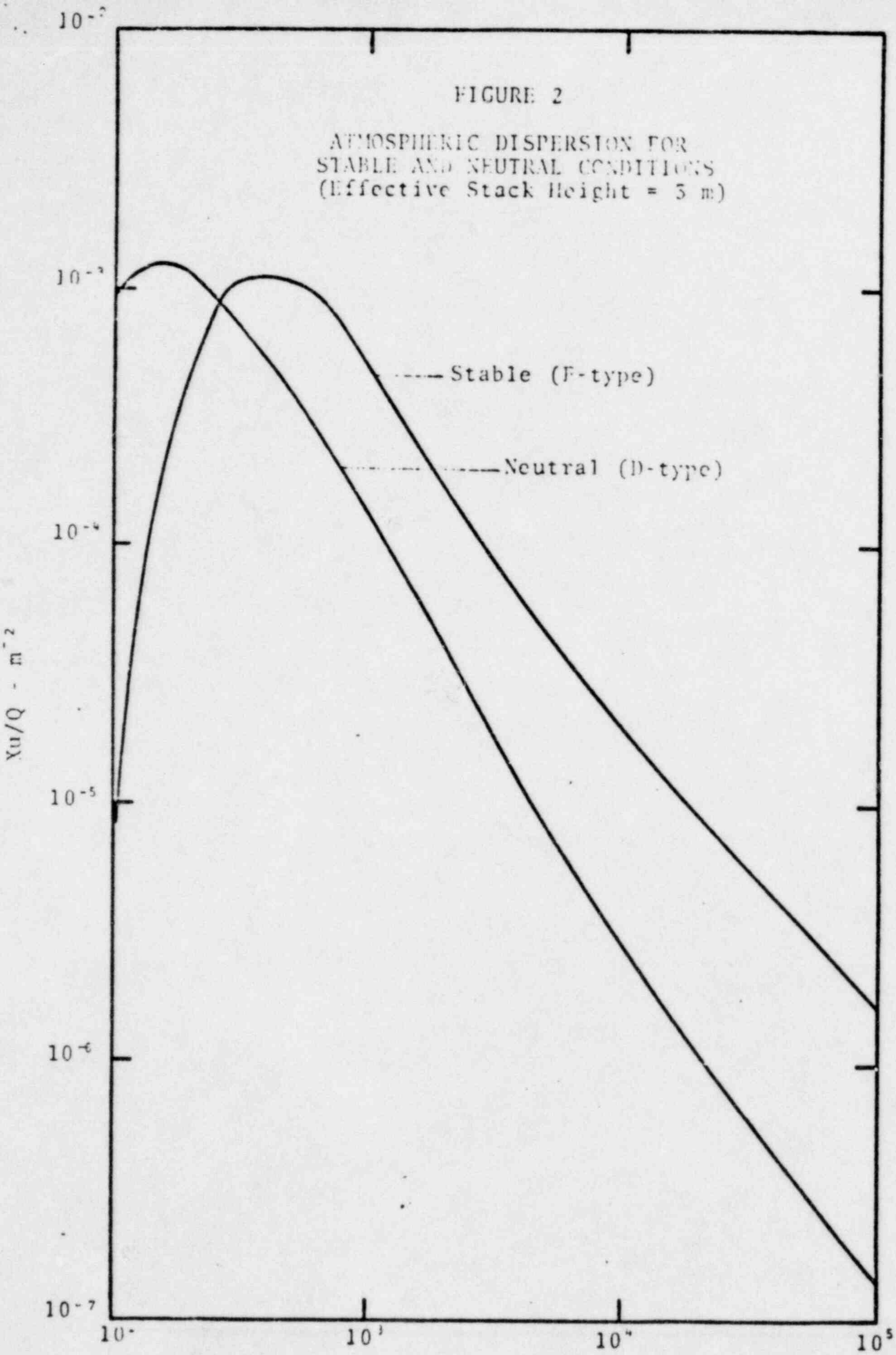


FIGURE 2

ATMOSPHERIC DISPERSION FOR STABLE AND NEUTRAL CONDITIONS (Effective Stack Height = 3 m)

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ANALYSIS OF NORMAL OPERATIONAL DISCHARGES

Typical operation of a Trio-Tech Leak Detection System will involve twelve cycles per day (over an eight hour period), 260 days per year. The amount of ^{85}Kr discharged during each cycle is given by:

$$La = (S)(Pas)(Fva)$$

where La = loss of gas per cycle (μCi/cycle)

S = concentration of gas in the chamber (μCi/atm-cm³)

Pas = pressure in the activation chamber after completion of the store cycle (atm)

Fva = volume of the activation chamber (cm³)

Two chamber pressures are being considered:

$$2 \text{ torr} = 2.64 \times 10^{-3} \text{ atm}$$

$$0.5 \text{ torr} = 6.57 \times 10^{-4} \text{ atm}$$

Two chamber volumes are being considered:

$$2.5 \text{ gallons} = 9.46 \times 10^{3} \text{ cm}^3$$

$$1 \text{ quart} = 9.46 \times 10^{2} \text{ cm}^3$$

Four values of discharge per cycle therefore result and are summarized in Table 1. Using these per cycle discharges and twelve cycles per day over an eight hour period, we arrive at the discharge rates

TABLE 1

^{85}Kr DISCHARGE/CYCLE

Pas / Fva	2 torr	0.5 torr
2.5 gallons	5.00×10^3 μCi/cycle	1.25×10^3 μCi/cycle
1 quart	5.00×10^2 μCi/cycle	1.25×10^2 μCi/cycle

TABLE 2

^{85}Kr DISCHARGE RATES - Q

Pas / Fva	2 torr	0.5 torr
2.5 gallons	2.1 μCi/sec	0.52 μCi/sec
1 quart	0.21 μCi/sec	0.052 μCi/sec

shown in Table 2. The maximum discharge rate of 2.1 μCi/sec results from operation of the system with Pas = 2 torr and Fva = 2.5 gallons. Assuming a very conservative wind speed of u = 0.5 m/sec, the peak downwind concentrations will be as shown in Table 3. The maximum value of downwind concentration, $X_{max} = 4.83 \times 10^{-9}$ μCi/cm³ is 1.61×10^{-2} of the maximum permissible concentration (MPC) for ^{85}Kr in an occupied, non-occupational area. Exposure to the MPC level of 3×10^{-7} μCi/cm³ for 24 hours per day, 365 days per year will result in a total dose of 500 mRem/yr. Since we are considering exposure at 8 hours per day and 260 days per year to 1.61×10^{-2} of the MPC, the peak annual off-site dose rate will be:

$$\dot{D} = \frac{8}{24}\ \frac{260}{365}\ (1.61 \times 10^{-2})(5 \times 10^{2}\ \text{mRem/yr})$$

$$\dot{D} = 1.9\ \text{mRem/yr}$$

This value, while quite low is still a conservative over-estimate of the actual exposure level: the calculated value is based on the assumptions of extremely low wind speed, extremely stable meteorological conditions the year around, and the wind continuously blowing in a single direction. Consideration of more realistic conditions would reduce the exposure level to on the order of 1×10^{-2} mRem/yr, or approximately one ten thousandth of the natural background radiation level.

TABLE 3

PEAK DOWNWIND CONCENTRATIONS - X

Pas / Fva	2 torr	0.5 torr
2.5 gallons	4.83×10^{-9} μCi/cm³	1.21×10^{-9} μCi/cm³
1 quart	4.83×10^{-10} μCi/cm³	1.21×10^{-10} μCi/cm³

III

ANALYSIS OF AN ACCIDENTAL RELEASE

At a typical installation, the Leak Detection System will operate in a room with dimensions 3 m x 3 m x 2.6 m; an exhaust fan will discharge air from the room at a rate of 2400 cfm (1.13 m^3/sec). The time to discharge one room volume is therefore 20.7 sec. In the worst case accident, the entire 25 Ci of ^{85}Kr will instantaneously be released into the room and exhausted to the atmosphere. The release rate is therefore:

$$Q = \frac{25 \times 10^6 \ \mu Ci}{20.7 \ sec} = 1.21 \times 10^6 \ \mu Ci/sec$$

As shown earlier, the peak value of Xu/Q is $1.15 \times 10^{-3} \ m^{-2}$, and occurs at ~350 m downwind. Again assuming a very low wind speed of 0.5 m/sec, the peak downwind concentration is given by:

$$X_{max} = \frac{(1.15 \times 10^{-3} \ m^{-2})(1.21 \times 10^6 \ \mu Ci/sec)}{0.5 \ m/sec} \times 10^{-6} \ m^3/cm^3$$

$$X_{max} = 2.78 \times 10^{-3} \ \mu Ci/cm^3$$

Continuous exposure to the MPC level of 3×10^{-7} µCi/cm³ will result in a dose rate of 500 mRem/yr or ~1×10^{-3} mRem/min. Exposure to the calculated peak concentration of 2.78×10^{-3} µCi/cm will result in a dose rate of

$$\dot{D} = \frac{2.78 \times 10^{-3}}{3 \times 10^{-7}} \ (1 \times 10^{-3} \ mRem/min)$$

$$\dot{D} = 9.2 \ mRem/min$$

The "time length" of the plume will be ~20 sec: by the time the last parcel of released ^{85}Kr is exhausted, the first parcel exhausted will be 20 sec downwind. The effective exposure time will be about four plume "time lengths" or ~80 sec (1.33 min). This is shown in Figure 3; with the leading edge of the plume more than one "time length" away (40 m at a wind speed of 0.5 m/sec), the dose rate at the point of measurement, point P, will be essentially zero. Therefore the total dose received as the plume passes will be:

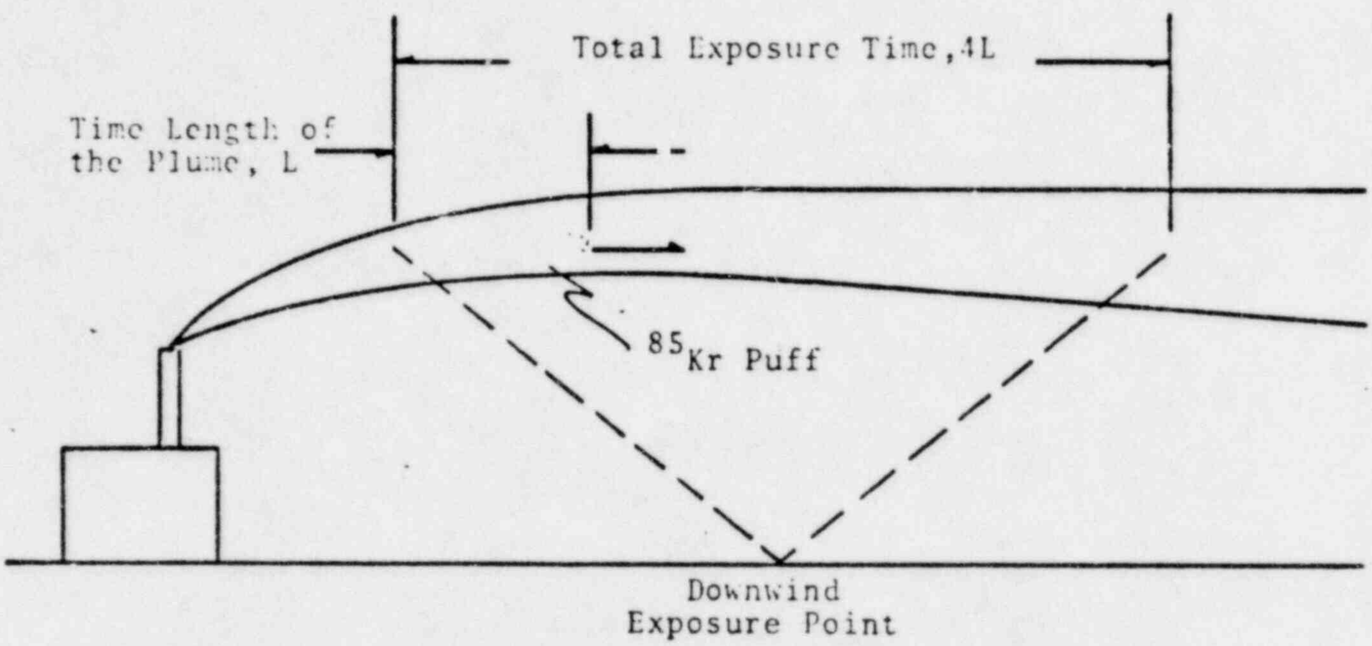
$$D = (9.3 \text{ mRem/min})(1.33 \text{ min})$$

$$D = 12 \text{ mRem}$$

This is the maximum total dose received by an individual downwind of a facility using a Leak Detection System in the event of a maximum hypothetical accident. The total exposure corresponds to approximately 10% of the annual exposure to natural background radiation. Since no accident has yet occurred, and the systems have logged ~80 system operating years, the probability of such an accident occurring can quantitatively be estimated at $\leq 10^{-2}$/system/year, or qualitatively be said to be fairly remote.

FIGURE 3

EXPOSURE TO AN OVERHEAD PLUME



IV

SUMMARY

There are two cases of operation which should be considered in evaluating the off-site radiation exposure resulting from a Trio-Tech Leak Detection System: normal operating conditions, and worst case accident conditions. Under normal operating conditions an extremely conservative estimate of the peak off-site dose rate is ~2 mRem/yr; a more realistic estimate would be lower by approximately two orders of magnitude, or 1×10^{-2} mRem/yr. For the worst case accident, the peak off-site dose would be 12 mRem; this is again based upon highly conservative meteorological conditions, and the exposure level does not reflect the low probability of the assumed accident occurring. Built-in safeguards make the assumed accident virtually impossible. The results are based on a Pasquill atmospheric dispersion model which indicates that under the assumed meteorological conditions, the peak concentration will occur ~350 m downwind from the point of discharge.