E.I. DU PONT DE NEMOURS & CO. (INC.)
BIOMEDICAL PRODUCTS DEPARTMENT

ATTACHMENT 1 TO REPORT NO. 30-28902/85-01

PERSONAL IDENTIFIERS HAVE BEEN REMOVED TO PREVENT A CLEARLY UNWARRANTED INVASION OF PERSONAL PRIVACY

November 21, 1985

Director
Region 1
United States Regulatory Commission
631 Park Avenue
King of Prussia, PA 19406

Re: License No. 20-00320-09

Dear Sir:

The following is submitted in accordance with 10 CFR 20.403 (b).

A chem-technologist received contamination on the hand which is estimated to result in a dose to the extremity skin.

Name

Social Security Number

Date of Birth

Estimated Quantity of Contamination	40 uCi ^{14}C incorporated in 3 cm^2 of skin
Committed effective dose equivalent to the basal skin layer	250 rem averaged over 300 cm^2

Description of Incident

Time: 1:50 pm

Date: 11/18/85

A chem-technologist attempted to remove a syringe containing 200 mCi of ^{14}C (Acetic Anhydride) from a rubber septum while wearing PVC gloves. Contamination from the syringe and the septum passed through the gloves and incorporated in about 3 cm^2 of skin on the thumb of the left hand.

NEN PRODUCTS
331 Treble Cove Road, No. Billerica, MA 01862 Telephone 617-667-9531 Telex 94-0996

Preventive Actions Under Consideration

Investigate method to prevent external contamination of syringe and septum.

Use of needle guide to prevent syringe needle from jamming in septum.

Retrain chem-technologist in use of proper (Neoprene and PVC) gloves and handling procedures.

Crimp septum in receiving flask to allow remote handling of equipment.

Publicize investigation.

Sincerely,

Francis E. Roy, Jr.
Radiation Safety Officer

ATTACHMENT 2: REPORT 30-28902 /85-01

Skip - some rough calculations on Boston incident.

JL

^{14}C Acetic Anhydride Skin Contam

Thumb 4 cm² contaminated ave 50 k cpm/cm²
Index " " 20 k "

Thumb (50 K cpm)(4 cm²)(0.05 counting eff) = 1.8 µCi / 4 cm²

Index (20 k cpm)(4 cm²)(0.05 counting eff) = 0.7 " "

Σ 2.5 µCi / 8 cm² = 0.31 µCi / cm², over 8 cm²

Assuming T_2 73 days, dose = 286 rad/µCi/cm² *

(0.31 µCi/cm²)(8 cm²)(286 rad/µCi/cm²) = 715 rad/8 cm²

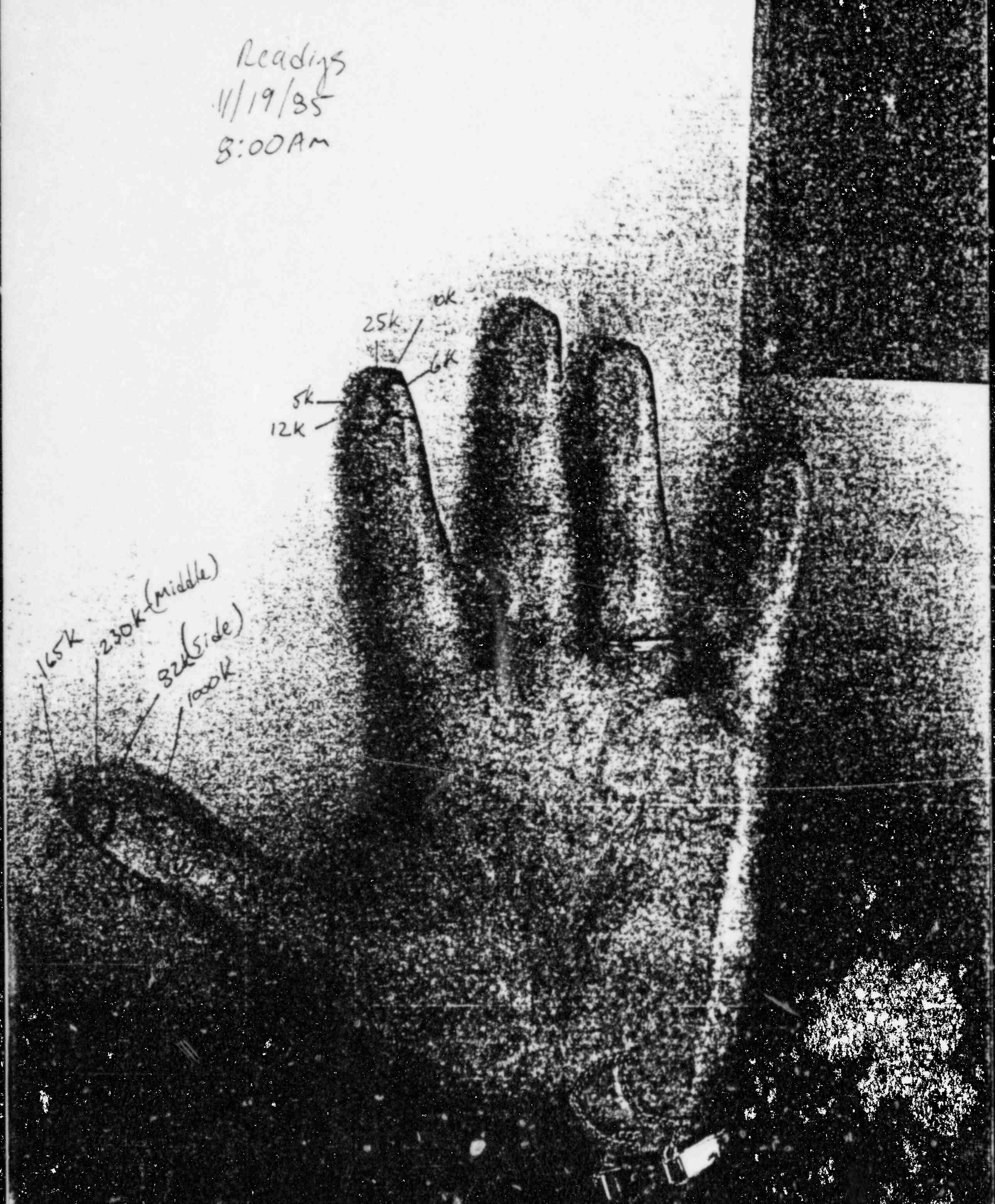
÷ 10/8 = 570 rad/10 cm²

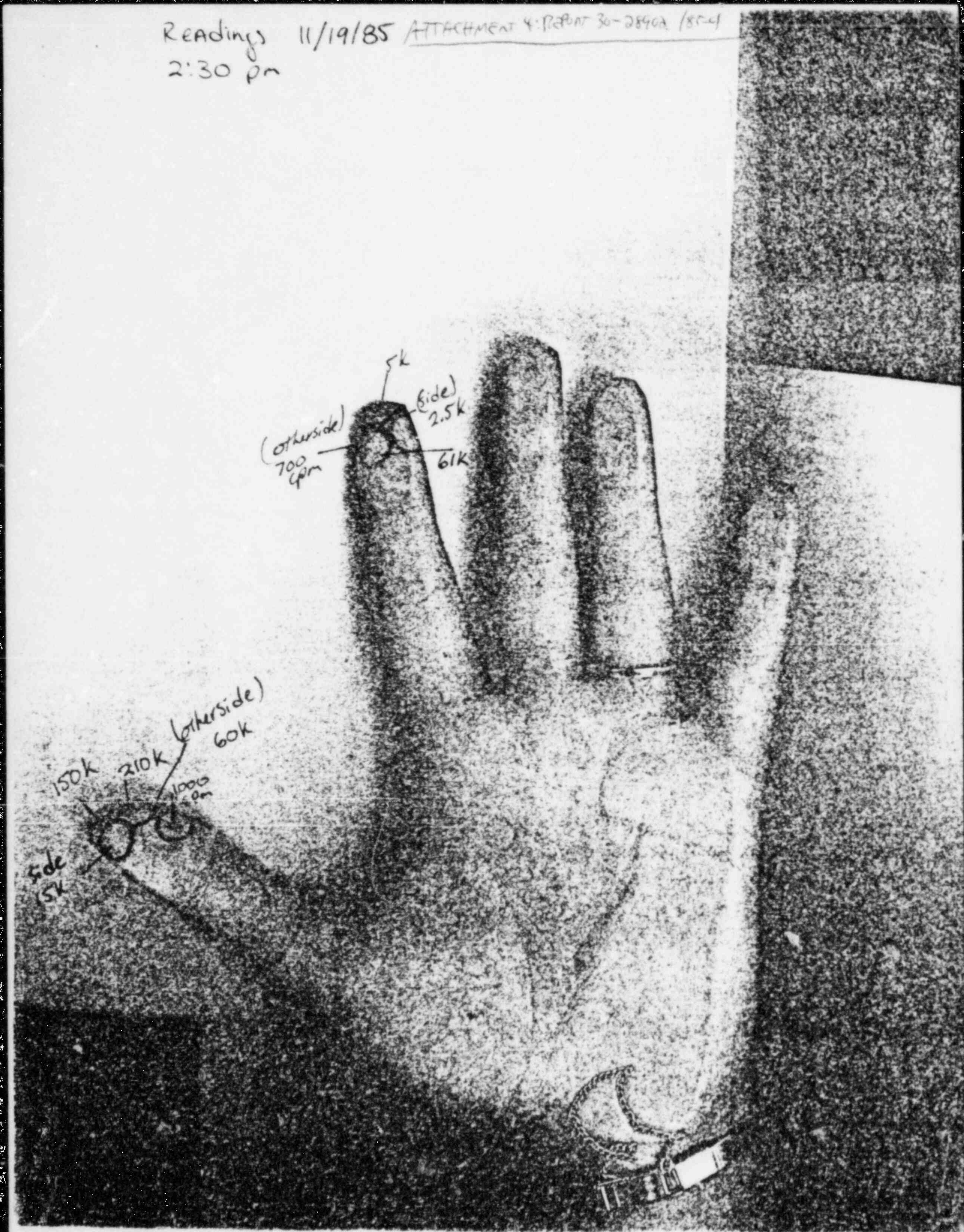
÷ 300/8 = 19** rad/300 cm²

* Per LaBone Tables.

** On shirt

ATTACHMENT 3 : REPORT 30-28902/85-01





Readings 11/19/85
ATTACHMENT 4: REPORT 30-28402/85-4
2:30 pm
5k
(side) 2.5k
(otherside) 700 cpm
61k
(otherside) 60k
150k
210k
1000 cpm
side 15k

ATTACHMENT 5 REPORT 30-28902 / 85-01

INCIDENT REPORT

SITE: Boston

DIVISION: Labeled Chemicals

DEPT: 0301 Custom Synthesis

BUILDING: 100-2

BIOMEDICAL PRODUCTS

REPORT NO.:

REPORT DATE: 11-20-1985

INCIDENT DATE/TIME: 11-18-1985 1:50 PM

Injury Sustained/Injury Potential:

None

Nature of Incident:

Left thumb contamination with ^{14}C.

Description of the Incident:

A chemist working in a hood was adding 200 mCi of acetic anhydride [1-^{14}C] *via* syringe to a glass round bottom vessel through a rubber septum. When the syringe needle first contacted the septum a drop of acetic anhydride [1-^{14}C] spilled onto the outer surface of the septum. When the addition was complete the chemist experienced difficulty in removing the needle from the septum and grasped the septum firmly with PVC gloved hand to assist in needle removal. The chemist then removed the glove and discovered her left thumb to be contaminated with ^{14}C which remained even after repeated washings. Site Safety was immediately notified.

Facts Brought Out:

- The chemist was relatively new (4 months at NEN) but had completed an extensive training program and was working under the direction of a more experienced chemist.
- Prior to this the chemist had manipulated about 100 mCi of ^{14}C.
- A single pair of PVC gloves were worn during the transfer.
- The chemist had been instructed in the use of a syringe but most of her experience was in syringing cold compounds or solutions.
- The rubber septum was not wired.
- Site Safety was immediately notified when hand contamination was discovered.
- Immediate and subsequent bioassay results showed no ^{14}C intake.

Corrective Actions	Responsibility	Timing
• Acquire from the Precursor Lab a list of recommended glove types for handling certain radiochemicals. Review these recommendations and establish as a lab rule the use of neoprene gloves for radiochemicals like acetic anhydride [1-^{14}C].	C. Filer	Immediately
• Review with lab 0301 proper syringe technique and the options available to prevent septum contamination with radioactivity and what to do if it occurs. We will also incorporate this information into our training program.	C. Filer	Group meeting of 11-27-85
• Establish as a lab rule that all rubber septa will be wired for syringe use or a crimp cap septum be used instead.	C. Filer	Immediately

Investigated by:

C. Filer (chairman), J. Krieger, C. Wright, T. Labone, E. Heath

ATTACHMENT 6: REPORT 30-28407/85-01

DOSE ASSESSMENT
12/16/85

1. To calculate the absorbed dose to the skin we must:

   a. select a model for the anatomy of the skin,

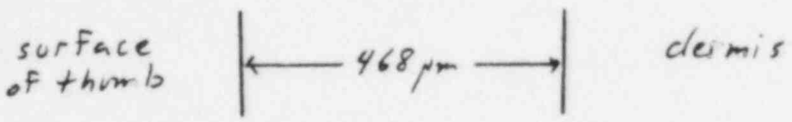
   b. select a model for the distribution of the C-14 in the skin as a function of depth and time,

   c. relate the contamination measurements to this model to determine the activity present in the skin,

   d. calculate the absorbed dose to the basal layer with an appropriate dose function.

ANATOMY OF SKIN

2. The primary area of contamination is approximately 1 cm^2 on the thumbprint area of the left thumb. Konishi and Yoshizawa (1985, pg. 31) reported a mean epidermal thickness of 468μm for this area, which coincides with the range of 384-539μm reported in ICRP 23 (1975, pg. 49) for females. The model used for subsequent dose calculations is:



CONTAMINATION SURVEY MEASUREMENTS

3. The contamination measurements for the 1 cm^2 area of highest activity on the thumb is given below:

DATE	TIME	ΔT (Hours)	COUNT RATE ($c.m^{-1}$)
11-18	13:30	0	-
11-20	13:00	47.5	99000
11-21	13:00	71.5	48000
11-22	9:00	91.5	22000
11-25	11:00	165.5	2020
11-26	12:00	190.5	1000
12-2	9:00	331.5	700
12-3	9:00	355.5	1510
12-4	9:00	379.5	2420
12-5	8:00	402.5	3040
12-6	8:00	426.5	3760
12-9	8:00	498.5	3040
12-10	8:00	522.5	2530
12-11	8:00	546.5	1810
12-12	8:00	570.5	1510
12-13	8:00	594.5	1210
12-16	8:00	666.5	400

4. The measurements were made with an end-window GM (2 mg.cm^{-2} window) through a collimator consisting of a 12 mm thick sheet of Lucite with a 1.27 cm^2 hole. All count rates are corrected for dead time.

5. A plot of the measurements versus time is shown in Figure 1.

KINETICS OF C-14 IN SKIN

6. The compound that contaminated the skin was C-14 acetic anhydride. This compound can be expected to:

   a. chemically react with proteins in the skin to form stable products, and

   b. react with water to form acetate.

8. Any C-14 present after the initial decontamination efforts is assumed to be firmly bound to the protein in the skin. This assumption is consistant with the observation that all subsequent decontamination efforts were ineffective.

9. The GM detector can "see" a certain depth into the skin because of the range of the C-14 beta particles. The maximum range is 280μm in water, but the contribution to the overall count rate from the activity at a given depth is not constant because of the attenuation of the beta particles. The apparent mass absorption coefficient for tissue is given by Loevinger et.al. (1956, pg. 712) as:

$$\frac{\mu}{\rho} = 18.6\,(E_0 - 0.036)^{-1.37} \quad cm^2 \cdot g^{-1}$$

For C-14, with E_0 = 0.156 MeV, with = 1.0 g.cm^{-3}, μ= 340 cm^{-1}.

10. The depth X in tissue where 95% of the maximum count rate is achieved is:

$$0.95 = K \int_0^X e^{-340x}\, dx, \quad \text{where } K = 340\ cm^{-1};$$

$$0.95 = \frac{340}{340}\left(1 - e^{-340x}\right)$$

$$X = 88 \times 10^{-4}\ cm$$

The window of the GM tube accounts for approximately 20×10^{-4} of tissue equivalent material, which means that the GM tube can "see" 68×10^{-4}cm into the epidermis.

11. If one assumes that:

 a. the C-14 present is tightly bound to the skin,

 b. the basal layer generates a certain thickness of new cells each day, and

 c. an equal thickness of dead skin is sloughed off each day,

 then Figure 1 can be viewed as a cross section of the contamination levels in the skin at the time of the incident.

12. The decrease in count rate after 450 hours is assumed to indicate that the edge of the slug-flow contaminated skin is within 68×10^{-4}cm, i.e., the basal layer is within 68×10^{-4}cm.

13. The skin renewal rate R is thus:

$$R = \frac{68\ \mu m}{(666.5\ h - 450.0\ h)} = 0.31\ \mu m \cdot h^{-1}.$$

 The rate calculated from the assumed depth and the elapsed time is:

$$R = \left(\frac{468\ \mu m}{666.5\ h}\right) = 0.70\ \mu m \cdot h^{-1}.$$

14. The first value of R=0.31 is deemed to be too low because it predicts a turnover time of 63 days, which is considerably longer than ICRP 23 values. This underestimation may be due to a drop in the concentration causing the reduction in count rate rather than the edge effect that was assumed. For these reasons the second value of R=0.70 will be used for the dose calculation.

15. In summary, the epidermis is assumed to be 468 m thick and is renewed at a rate of $0.70 \mu m.h^{-1}$. This slug flow pushes the contaminated skin away from the basal layer.

ACTIVITY PRESENT IN SKIN

16. The activity in the skin measured from time zero to 400 hours after the incident is greater than 280µm from the basal layer and thus contributes no dose. The activity present in the remaining epidermis will be assumed to be uniformly labeled such that the surface count rate is equal to the peak count rate interpolated at t=450 hours, i.e., 4000 cm^{-1}. Thus:

$$dn = a e c\, dx\, e^{-340x} \quad c \cdot m^{-1},$$

where:

dn = count rate from activity in volume element a dx,
a = area, 1 cm^2.
c = concentration, $d.m^{-1}.cm^{-3}$.
e = efficiency, 0.017 $c.d^{-1}$.

$$n = aec \int_0^{280\times10^{-4}} e^{-340x}\,dx$$

$$c = (340 \cdot n)/(a \cdot e) = (340)(4000)/(0.017) = 8.000\times10^{7}\ d \cdot m^{-1} \cdot cm^{-3}$$

$$c = 36\ \mu Ci \cdot cm^{-3}.$$

17. The total activity A present is:

$$A = (36\ \mu Ci \cdot cm^{-3})(1\ cm^{2})(280\times10^{-4}\ cm) = 1.0\ \mu Ci.$$

18. Bremsstrahlung measurements performed 426.5 hours after the contamination showed that not more than 0.7μCi was present at the 95% confidence level, which supports the activity calculated above.

ABSORBED DOSE FUNCTION

19. The function used to calculate the absorbed dose to the skin is similar to that used by Chamberlain (Newberry 1964, pg. 67). An infinite plane covered by 1 $d.s^{-1}cm^{-2}$ of C-14 will deliver the following absorbed dose to the surface of the plane:

$$\dot{D} = \frac{(1\ d \cdot s^{-1} \cdot cm^{-2})(0.5\ beta \cdot d^{-1})(6.6\ MeV \cdot cm^{2} \cdot g^{-1})(3600\ s \cdot h^{-1})}{(6.242\times10^{7}\ MeV \cdot g^{-1} \cdot rad^{-1})}$$

$$\dot{D} = 1.903\times10^{-4}\ rad \cdot h^{-1} \cdot d^{-1} \cdot s.$$

Where 6.6 $MeV.cm^2.g^{-1}$ is the mass stopping power for a 0.050 MeV electron (Mean C-14 beta energy) in water (ICRU 1985, pg. 206).

20. For 1μCi the absorbed due rate will be:

$$\dot{D} = 7.0\ rad \cdot h^{-1} \cdot \mu Ci^{-1}.$$

21. Using Loevinger's absorption coefficient, the complete absorbed dose function becomes:

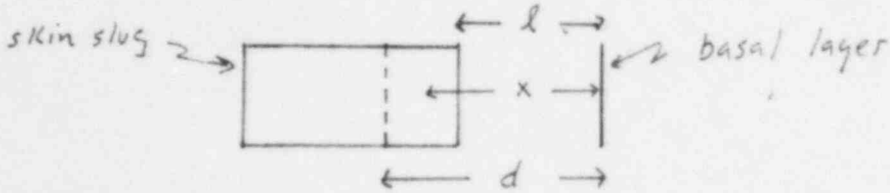
$$\dot{D}(x) = 7.0\ e^{-340x}\ rad \cdot h^{-1} \cdot \mu Ci^{-1}.$$

22. This function is simple, converges to a finite value on the surface of the plane, and is within a factor of 3 of the absorbed doses given by Cross (1982, pg. 27) The dose function will be adjusted upward by a factor of 3 to compensate for any underestimation of dose, thus:

$$\dot{D}(x) = 21\ e^{-340x}\ rad \cdot h^{-1} \cdot \mu Ci^{-1}.$$

ABSORBED DOSE TO BASAL LAYER

23. The slug-flow skin model is shown below:



As the skin grows l will increase, pushing the slug past the dotted line, which denotes the 280μm range of the C-14 beta.

24. Thus, the absorbed dose rate $\dot{D}_s$ at the basal layer is:

$$\dot{D}_s(x,t) \int_l^d a \cdot \dot{D}(x) \cdot c \cdot dx \quad rad \cdot h^{-1},$$

where:

t = time after contamination in hours
$l = 0.7 \mu m.h^{-1}.t = 7 \times 10^{-5}\ cm.h^{-1}.t$
$a = 1\ cm^2$
$c = 36 \mu Ci.cm^{-3}$
$\dot{D}(x) = 21\ e^{-kx}\ rad\ h^{-1} \mu Ci^{-1}$
$d = 280 \times 10^{-4} cm.$
$k = 340\ cm^{-1}$

$$\dot{D}_s(x,t) = 756 \int_l^d e^{-kx}\, dx$$

$$\dot{D}_s(t) = \left(\frac{756}{340}\right)\left(e^{-kl} - e^{-kd}\right)$$

$$\dot{D}_s(t) = 2.224\ e^{-kl} - 1.631 \times 10^{-4}$$

$$D_s = \int_0^T (2.224\, e^{-K\ell} - 1.631\times10^{-4})\, dt \quad \text{rads.}$$

where

$$T = (280\ \mu m)/(0.7\ \mu m \cdot h^{-1}) = 400\ h.$$

$$K\ell = (340\ cm^{-1})(7\times10^{-5}\ cm \cdot h^{-1} \cdot t) = 2.380\times10^{-2} \cdot t.$$

$$D_s = 93.45\, e^{-(2.380\times10^{-2})t} \Big|_{400}^{0} + (1.631\times10^{-4})t \Big|_{400}^{0}$$

$$D_s = 93\ \text{rad}.$$

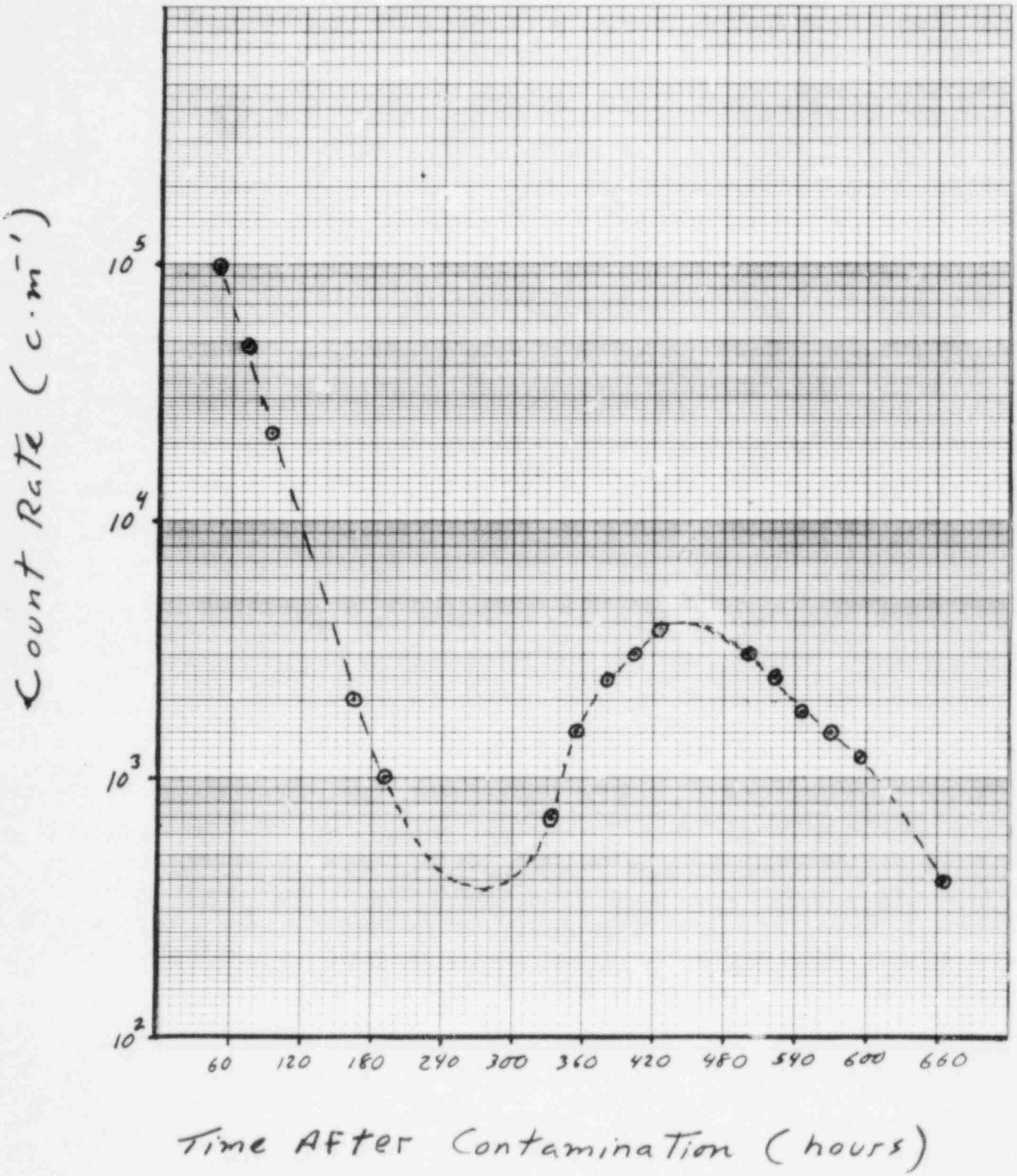


Figure 1. Count rate of thumb versus time.

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