American Board of Health Physics
Examination 31, Part II
July 6, 1987

FUNDAMENTALS (Answer all 6 questions in this section)

QUESTION 1

In some areas there is a developing controversy over calculated risk estimates due to population exposures from radon in residences.

POINTS

1   A.   What is the critical organ and describe the mechanism by which the critical organ is exposed.

1   B.   At a concentration of 1 pCi/L, what number of estimated deaths per 1000 could be attributed to radon exposure in U. S. residences? Use EPA estimates.

           1) <1
           2)   1
           3)   10
           4)   100
           5)   1000

2   C.   Discuss two problems in using uranium mining data to estimate risks to the U. S. population from residential radon exposures.

1   D.   Explain why the "oxygen effect" is or is not significant with radon exposure.

The following statements are related to the biological effects of ionizing radiation. Select the single best answer appropriate to each of the individual parts, A through E. Please use capital letters to mark your selections on the answer sheet; only your letter answer will be graded.

POINTS

1   A.   All of the following statements regarding the ingestion/inhalation of radionuclides are correct except:

           a.   For inhaled radionuclides, tracheobronchial deposition is least dependent upon particle size or mass.

           b.   Phagocytosis and absorption are both clearance mechanisms of the kidney.

           c.   In the multi-compartment model, Class D compounds are cleared most rapidly.

           d.   The attainment of equilibrium within an organ or system is dependent upon the effective half-life of the radionuclide.

           e.   For ingested radionuclides that are poorly absorbed by the gastrointestinal tract, the lower large intestine generally receives the greatest dose.

1   B.   Match each of the following inhaled radionuclides with one of the adult critical organs shown in the adjacent list. (A critical organ may be used more than once.)

a.	Strontium-90		1.	Lung
b.	Cesium-137		2.	Spleen
c.	Plutonium-239 (class Y)		3.	Total Body
d.	Uranium-238 (class W)		4.	Liver
e.	Radon-222		5.	Gonads
			6.	Kidney
			7.	Skin
			8.	Bone

1   C.   Genetic mutations are one possible result of exposure to ionizing radiation. Select the correct response regarding genetic effects.

a.   Within a population, a mutation is usually manifested in the first generation of offspring.

b.   Since many mutations are recessive, a large dose to a small population will cause more genetic damage than a small dose to a larger population.

c.   Hereditary defects are relatively rare, occurring among <0.1% of live-born infants.

d.   Radiation damage is particularly harmful because the body has no mechanism for repairing radiation induced mutations.

e.   For a given dose, the probability of genetic effect is assumed to be proportional to the rate at which the dose is received.

1   D.   Ionizing radiation has been directly associated with cataract formation. Select the statement which is incorrect with respect to this phenomenon.

a.   Occupational exposure to X-rays accounts for approximately 5% of all cataracts observed in X-ray technicians.

b.   The cataractogenic dose to the lens is approximately 500 rad for beta and gamma radiation.

c.   Fast neutrons are more effective at producing cataracts than other forms of radiation.

d.   The cataractogenic effect of radiation is dependent upon the age of the individual.

e.   Radiogenic cataracts are distinct in that they originate on the anterior epithelium of the lens.

1   E.   The expected acute nonstochastic response to a 5 Sv total whole body effective dose equivalent (delivered in a period of one hour or less) from fast neutrons is:

a.   Hematopoietic syndrome

b.   Acute respiratory syndrome

c.   Nausea

d.   Central Nervous System syndrome

e.   Gastrointestinal syndrome

QUESTION 3

The radiochemist at your pressurized water reactor (PWR) informs you that low-level activity considerably in excess of mean normal levels has been found in the plant's sewage effluent. The sewage is directed to a local municipal sewage treatment plant. Samples are taken weekly at the PWR by procedure, and analyzed for gamma emitters. Your sewage system can be isolated from the municipal system and you can hold sewage for twelve hours before capacity is exceeded.

POINTS

2 A. List four initial actions which you would take in this situation.

1 B. Assuming the data from the grab sample were valid and representative, were any daily release limits exceeded? Show calculations.

2 C. The municipal sewage treatment plant provides a seven day composite sample of its influent which was collected since the last previous plant grab sample. Analysis by your lab and an independent laboratory shows a cobalt-60 concentration of

1×10^{-5} μCi/mL.

    (1) Using the composite sample result and assuming all the activity was released by the plant in a single 24 hour period, show by calculation how the maximum daily concentration relates to the release limit for the PWR sewage system.

    (2) Show how the total release relates to the daily release limit.

DATA

Normal Activity Level	Mean = 7×10^{-8} μCi/mL ^{60}Co
	Range = 5×10^{-8} μCi/mL to 1×10^{-7} μCi/mL
Grab sample result	1×10^{-5} μCi/mL ^{60}Co, all other nuclides
	less than LLD (5×10^{-8} μCi/mL)
Plant sewage daily volume	1.5×10^4 gallons
Municipal plant daily volume	1.5×10^6 gallons
Permissible discharge	1×10^{-3} μCi/mL and 10 μCi/day

QUESTION 4

You are asked to evaluate the following situation:

A nurse must enter the room in which a patient is undergoing radiation therapy using sealed sources implanted in the uterus. The total activity of the sources in the implant is 250 mCi of ^{137}Cs. The nurse spends, on average, 10 minutes an hour providing nursing care to the patient. While providing this care, the average distance from the anterior surface of the nurse's abdomen to the implant is 14 inches. The patient is large; assume radiation from the source must pass through 5 inches of the patient's body tissue. In addition, the ovaries are assumed to have 7 cm of overlying tissue (Handbook 59). A lead shield is located on the bedside between the patient and the nurse. The measured attenuation of this shield at 0.662 MeV is 10 for narrow beam conditions.

POINTS

1   A.   Calculate the dose buildup factor for this geometry.

2   B.   Calculate the absorbed dose to the nurse's ovaries if she will have to spend two 8-hour shifts on this service. (Note: For purposes of this problem, assume 1 R will produce 1 rad in tissue.)   -

1   C.   List four (4) directives you would give the nurse regarding her own radiological protection.

1   D.   List four recommendations to reduce exposure from this procedure to other members of the hospital staff and visitors.

DATA

^{137}Cs

Specific gamma ray constant = 3.3 R-cm^2/hr-mCi
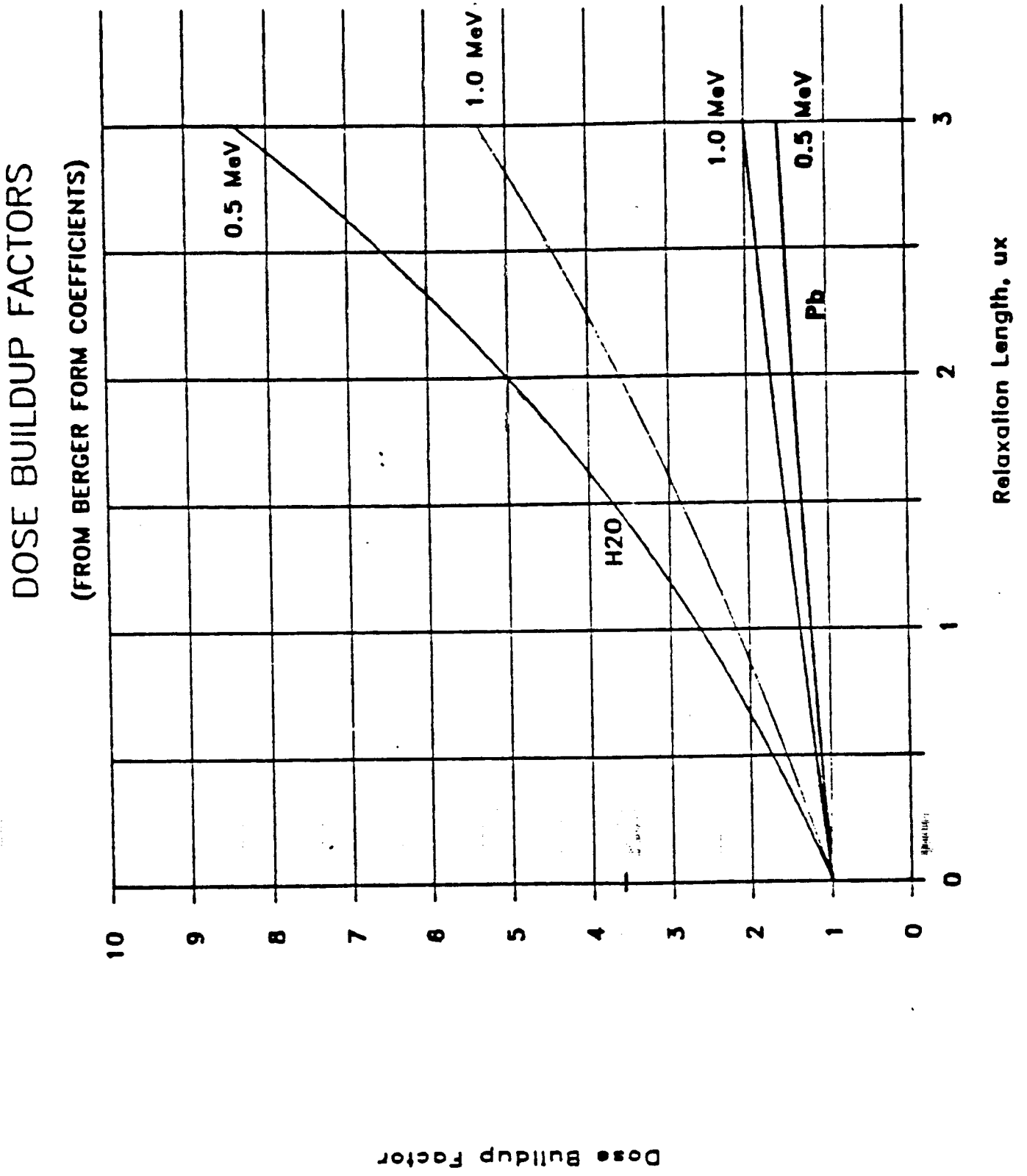
Photon energy = 0.662 MeV

Dose Buildup Curves

Dose buildup factors for point sources in water and lead appear on the next page.

Mass Attenuation Coefficient

Mass attenuation coefficient of tissue at 0.662 MeV = 0.0854 cm^2/g

Mass attenuation coefficient of lead at 0.662 MeV = 0.114 cm^2/g

DOSE BUILDUP FACTORS

(FROM BERGER FORM COEFFICIENTS)

Dose Buildup Factor vs Relaxation Length, ux

Curves labeled: 0.5 MeV, 1.0 MeV (H20); 1.0 MeV, 0.5 MeV (Pb)

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QUESTION 5

A steel light fixture is located in a streaming neutron field adjacent to a research reactor. The reactor operates at steady state for 800 days at which time it is shutdown for routine maintenance. Data for activation calculations are provided below.

POINTS

2	A.	What is the activity of the light fixture one day after reactor shutdown?

1   B.   Three of the radionuclides listed in the data section below account for less than 10% of the total activity present in the light fixture one week after shutdown.

- List these three radionuclides.
- Identify the parameter (or parameters) in the activation equation which limits the activity of each of these radionuclides.

2   C.   Calculate the exposure rate at 6 feet from the light fixture one week after reactor shutdown and the fraction of the exposure rate contributed by the three radionuclides identified in part B?

DATA

Light fixture composition:

       Iron = 60%
       Nickel = 20%
       Manganese = 20%

Mass of light fixture is 1000 gm

ϕth = 4.2 x 10^{12} neutrons/(cm^2-sec)

Avogadro's number = 6.022 x 10^{23}

Nuclide	Half-Life	Gamma Energy (MeV)	Yield %	Parent	Abundance %	Thermal Capture Cross Section (barns)
^{54}Mn	313d	0.84	100	^{54}Fe	5.8	0.01
^{56}Mn	2.58h	2.13	15	^{55}Mn	100	13.4
		1.87	24			
		0.85	99			
^{58}Co	71.4d	0.51	30	^{58}Ni	67.8	0.13
		0.81	99			
^{59}Fe	45.1d	0.29	43	^{58}Fe	0.3	0.9
		1.10	57			

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QUESTION 6

The ICRP Publication 30 provides guidance for weighting organ dose to obtain stochastic whole body dose equivalent limits. This method is used to arrive at the annual limit on intake (ALI) and the derived air concentration (DAC) for radionuclides. The information provided below will be of use in answering the following questions.

Select the best answer appropriate to the individual question. Please use capital letters to mark your selection on the answer sheet; only your letter answer will be graded.

DATA

WEIGHTING FACTORS

Organ or Tissue	W_T
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	0.30

Committed Dose Equivalent in Target Organs or Tissues per Intake of Unit Activity (Sv/Bq) of ^{226}Ra

Organ	Oral	Inhalation
	$f_1=0.2$	(Class W) $f_1=0.2$
Gonads	9.2E-08	-------
Lungs	-------	1.6E-05
Red bone marrow	6.0E-07	-------
Bone surface	6.8E-06	7.6E-06

POINTS

1   A.   What are the appropriate limiting whole body and organ dose equivalents for occupational exposure from 50 year dose equivalent commitments in tissue, $H_{50,T}$?

Stochastic	Nonstochastic
a. $H_{50,T} \leq 0.5$ Sv	$\Sigma_T(w_T H_{50,T}) \leq 0.05$ Sv
b. $H_{50,T} \leq 0.05$ Sv	$\Sigma_T(w_T H_{50,T}) \leq 0.5$ Sv
c. $\Sigma_T(w_T H_{50,T}) \leq 0.5$ Sv	$H_{50,T} \leq 0.05$ Sv
d. $\Sigma_T(w_T H_{50,T}) \leq 0.05$ Sv	$H_{50,T} \leq 0.05$ Sv
e. $\Sigma_T(w_T H_{50,T}) \leq 0.05$ Sv	$H_{50,T} \leq 0.5$ Sv

1   B.   What is the ALI for oral intake of ^{226}Ra?

     a. 7×10^6 Bq
     b. 7×10^4 Bq
     c. 7×10^3 Bq
     d. 2×10^5 Bq
     e. 2×10^6 Bq

1   C.   What is the DAC for inhalation of ^{226}Ra? Assume a worker inhales $2.4 \times 10^3 m^3$ of air per year.

     a. 1×10^2 Bq/m^3
     b. 1×10^1 Bq/m^3
     c. 1×10^0 Bq/m^3
     d. 3×10^1 Bq/m^3
     e. 3×10^0 Bq/m^3

1   D.   What is the committed dose equivalent to the whole body for oral ingestion of the ALI of ^{226}Ra?

     a.   0.015 Sv
     b.   0.06 Sv
     c.   0.05 Sv
     d.   0.2 Sv
     e.   0.02 Sv

1   E.   Suppose a worker, over the course of one year, orally ingests 30% of the ALI and inhales 1,000 DAC hours of ^{226}Ra. What total whole body external exposure can this worker receive without exceeding the ICRP recommended limit?

     a.   0.005 Sv
     b.   0.01 Sv
     c.   0.1 Sv
     d.   0.05 Sv
     e.   0.5 Sv

SPECIALTY (Answer any four of the specialty questions in this section)

QUESTION 7

Average current ionization chambers are used to monitor radiation at accelerator facilities. The radiation to be monitored is usually photons in the energy range of 200 keV to 1 MeV and neutrons with an average energy of a few MeV. Select the best response to each of the following statements concerning ionization chambers. Please use capital letters to mark your selection on the answer sheet; only your letter answer will be graded.

POINTS

1   A.   The term "tissue equivalent" when used to describe ionization chamber construction means that the:

   a.   Effective electron density of the wall is the same as that of tissue.
   b.   Mass stopping power ratio of the wall material to the fill gas is selected to be unity for the energy range of interest.
   c.   Chemical composition of the fill gas only is selected to be "tissue equivalent" so the wall material will not add ion pairs to the detector.
   d.   Chemical composition of the wall material only is selected to be "tissue equivalent" so electron equilibrium in the detector will be the same as it is in tissue.
   e.   Chemical composition of the wall material and gas filling the ionization chamber are selected such that the response of the ionization chamber will be a measure of the absorbed dose in tissue.

1   B.   A polyethylene-walled ionization chamber filled with ethylene gas will:

   a.   Measure the dose equivalent rate of the neutrons plus the photons.
   b.   Measure the total absorbed dose from neutrons and photons.
   c.   Measure the absorbed dose from gamma rays only.
   d.   Measure the absorbed dose from photons and will give an over-estimate of the absorbed dose from neutrons.
   e.   Measure the absorbed dose from gamma rays only.

POINTS

1   C.   The absorbed dose rate measured by a polyethylene-walled, ethylene gas filled ionization chamber in a 5 rem/hr fast neutron field (QF = 5) would most likely be:

           a.   0.2 rad/hr
           b.   1.5 rad/hr
           c.   2.5 rad/hr
           d.   1.0 rad/hr
           e.   3.0 rad/hr

1   D.   Initial recombination of ion pairs produced in an ionization chamber gas is:

           a.   Independent of dose rate.
           b.   Dependent on dose rate.
           c.   Reduced by addition of a halogen quench gas.
           d.   Independent of electrode spacing.
           e.   Independent of collecting potential.

1   E.   Volume recombination in the ionization chamber gas is:

           a.   Dependent on dose rate.
           b.   Reduced by addition of a halogen quench gas.
           c.   Independent of collecting potential.
           d.   Independent of dose rate.
           e.   Independent of electrode spacing.

1   F.   Initial recombination in a high pressure tissue equivalent ionization chamber can be used to:

           a.   Determine the absorbed dose rate in a muon field.
           b.   Determine the exposure rate from photons only in a mixed neutron and photon field.
           c.   Determine the average quality factor in a mixed neutron and photon field.
           d.   Determine the fluence rate in extremely high fluence rate fast neutron fields.
           e.   Determine the dose equivalent rate from photons only.

1   G.   The number of ion pairs collected in an air-filled aluminum walled ionization chamber depends primarily on:

           a.   Collecting electrode separation.
           b.   Electrode geometry (i.e., parallel plate, cylindrical, or spherical).
           c.   Applied voltage.
           d.   Ion mobility in air.
           e.   Absorbed dose rate.

POINTS

1   H.   Ion pair collection in ionization chambers used to monitor pulsed
            radiation depends on:

            a.   Chemical composition of the fill gas.
            b.   Average number of ion pairs produced per second.
            c.   Energy to produce an ion pair in the gas.
            d.   Ion pairs produced during the pulse.
            e.   Chemical composition of the wall material.

1   I.   An aluminum ion chamber filled with CO_2 will best:

            a.   Measure the absorbed dose from high energy neutrons.
            b.   Measure the high energy neutron fluence in mixed radiation
                  fields.
            c.   Measure the dose equivalent from high energy neutrons and
                  photons from 0.2 MeV to 1.0 MeV at an accelerator.
            d.   Measure the absorbed dose from muons from an accelerator.
            e.   Measure the dose equivalent from high energy neutrons at
                  an accelerator.

1   J.   The efficiency for collecting ion pairs produced in an ionization
            chamber is greater using:

            a.   Parallel plate electrodes.
            b.   Negative feedback.
            c.   Cylindrical-shaped collecting electrodes.
            d.   A guard ring.
            e.   Spherical-shaped collecting electrodes.

QUESTION 8

You are the Health Physicist at a pressurized water reactor (PWR) power station. Management is considering the installation of a new spray system which is intended to reduce the airborne iodine after a loss of coolant accident (LOCA). You have been asked to calculate the reduction in the two hour exclusion area boundary (EAB) dose that can be expected if such a system is installed.

POINTS

3	A.	How much iodine remains airborne after two hours with and without the spray?
3	B.	What is the total amount of I-131 released with and without the spray during the same time period in Question A?
3	C.	What is the thyroid dose commitment to the receptor with and without the use of the spray during the same time period?
1	D.	What is the 10CFR100 limit for the 2-hour thyroid dose?

DATA

- ·The spray system has an iodine removal rate of 10.0 per hour, but it affects only 90% of the airborne iodine that is in the elemental state. The other 10% of the airborne iodine is unaffected by the spray.

- The iodine released to the containment instantaneously at the initiation of the accident can be represented as 1E+8 Ci of I-131 which has a half-life=8.03 days; thyroid dose conversion=1.5E+6 Rem/Ci.

- The chi/Q at the EAB can be taken to be 1.0E-3 s/m^3. The breathing rate of the receptor is 3.5E-4 m^3/s.

- The leakage from containment is 0.025% per day.

The ICRP Publication 37 describes methods for optimizing the cost of radiation protection programs with the benefit derived from those programs. In the following situations select the <u>best</u> response for each question. Please use <u>capital letters</u> to mark your selection on the answer sheet; only your letter answer will be graded.

DATA

The following symbols are used in this series of situations/questions:

V = gross benefit of the introduction of a practice involving ionizing radiation.

P = basic production cost, exclusive of the cost of radiation protection.

X = cost of achieving a selected level of radiation protection.

Y = cost of the detriment resulting from the selected level of radiation protection.

B = the net benefit of introducing a practice.

T = time interval in days for tritium bioassays.

Number of workers to receive bioassays for tritium in urine = 40.

Cost per bioassay sample analysis = $50.00.

POINTS

1   A. Optimization techniques can be used to assure that:

    a. A radiation protection practice is an low as reasonably achievable (ALARA).
    b. The dose and resultant radiation detriment are minimized.
    c. The gross monetary benefit of a practice involving ionizing radiation is maximized.
    d. A cost of achieving a selected level of radiation protection is minimized.
    e. The basic production cost is minimized.

1   B. The relationship of the net benefit, B, to the other variables is:

    a.   B = V - (P+X-Y)
    b.   B = V - (P+X+Y)
    c.   B = V + (P-X+Y)
    d.   B = V - (P-X-Y)
    e.   B = V + (P+X-Y)

POINTS

1 C. Optimization techniques are to be used to determine the period between bioassay samples of the 40 radiation workers in this facility in which exposure to tritium is of primary concern. Which two variables are assumed to be independent of the sampling period T?

    a. V and X
    b. P and Y
    c. V and Y
    d. P and X
    e. V and P

1 D. Which relationship maximizes the net benefit, B, where T_0 is the optimum sampling period?

    a. $(dV/dT)_{T_0} = +(dY/dT)_{T_0}$

    b. $(dX/dT)_{T_0} = -(dY/dT)_{T_0}$

    c. $(dX/dT)_{T_0} = +(dY/dT)_{T_0}$

    d. $(dV/dT)_{T_0} = +(dX/dT)_{T_0}$

    e. $X = Y$

1 E. The annual cost, X, of achieving the selected bioassay interval, T, is

    a. $X = [40 \times (365/T) \times 50 \times T]$
    b. $X = [(40/50) \times 365 \times T]$
    c. $X = [40 \times 50 \times 365 \times T]$
    d. $X = [(40/50) \times (365/T)]$
    e. $X = [40 \times 50 \times (365/T)]$

1 F. The primary purpose of the bioassay analysis of tritium in urine is to

    a. Assess the adequacy of tritium control systems.
    b. Assess the effectiveness of administrative controls that limit exposure of personnel to tritium.
    c. Assess the adequacy of the radiation protection program for tritium exposure.
    d. Estimate time averaged concentrations of tritium in the breathing zone of the workers.
    e. Assess doses to workers from the intake of tritium.

1   G.   The <u>principal</u> detriment of long bioassay sampling periods for tritium is

         a.   The reduced ability to estimate actual doses received by workers.
         b.   The potential for an intake to escape detection.
         c.   The increased cost of the detriment.
         d.   The loss of prompt detection of tritium contamination in the work area.
         e.   The reduced cost of the required bioassays.

1   H.   Assuming an effective half-life of tritium in the body of 10 days and a dose commitment of 1.2×10^{-7} Sv at the detection limit of tritium in urine (10 dpm/ml), what is the maximum committed dose equivalent from an undetectable intake for a bioassay sampling period of T days?

         a. $1.2 \times 10^{-7}[\exp(-0.693 \times T/10)]$

         b. $1.2 \times 10^{-7}[\exp(+0.693 \times T/10)]$

         c. $40 \times (365/T) \times 1.2 \times 10^{-7}[\exp(-0.693 \times T/10)]$

         d. $40 \times (365/T) \times 1.2 \times 10^{-7}[\exp(+0.693 \times T/10)]$

         e. $1.2 \times 10^{-7} \times T[\exp(+0.693 \times T/10)]$

1   I.   The optimum sampling period based on the above conditions is approximately 87 days. What maximum dose equivalent commitment would result if a worker were to receive an intake of tritium of such an activity that it would be undetectable at the next scheduled sampling date. Assume the intake occurred just after the previous bioassay sample was taken.

         a. 5×10^{-4} Sv

         b. 1×10^{-5} Sv

         c. 5×10^{-6} Sv

         d. 1×10^{-6} Sv

         e. 5×10^{-5} Sv

1   J.   For a sampling period less than the optimum the costs X and Y are changed from their respective values at the optimum condition as follows:

         a.   X and Y each remain the same.
         b.   X decreases and Y decreases
         c.   X decreases and Y increases
         d.   X increases and Y increases.
         e.   X increases and Y decreases.

QUESTION 10

Respiratory protection is widely used in nuclear facilities to limit internal depositions of radionuclides. In some cases worker effectiveness is reduced by the requirements for respiratory protection. You are to make an ALARA evaluation based on the conditions listed in the DATA section.

POINTS

2   A.   What is the 50 year committed dose equivalent that a maintenance worker would be exposed to <u>without</u> respiratory protection from each year of work? Neglect accident and upset conditions and assume the same crew members are used for each entry.

2   B.   What is the 50 year committed dose equivalent that a maintenance worker would be exposed to <u>with</u> respiratory protection from each year of work? Neglect accident and upset conditions and assume the same crew members are used for each entry.

2   C.   It costs $50 to refurbish a respirator after each usage. What is the annual cost of respirator usage, and is it ALARA to require respiratory protection at $200,000 per person-Sv?

2   D.   Redesign of the facility HVAC could reduce the radionuclide concentrations listed in the DATA section by 40% for an additional $1,000,000. At what fraction of the annual 50 year committed dose equivalent would a maintenance worker be exposed in this situation if no respiratory protection were used?

2   E.   Is the incorporation of the improved HVAC system in the facility at a cost of $1,000,000 ALARA based on $200,000 per person-Sv saved? Show total cost comparisons for the "mask on" and no HVAC improvement with "mask off" and the HVAC improvement in place to substantiate your answer.

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QUESTION 10 (concluded)

DATA

- New facility with a design life of 20 years.
- Maintenance activities will require 125 entries per year with an 8 person crew for an average stay time of 2 hours <u>with respirators</u>. The external radiation field is 0.1 mGy/hr (gamma) in the areas where maintenance is performed.
- Respirators supply a protection factor of 50 for particulates and iodine.
- Time and motion studies indicate the time for each entry into a radiation area can be reduced by 25% if respirators are not used.
- The following airborne radionuclide concentration data are to be used:

| Radionuclide | Inhalation | | Airborne Concentration |
	ALI	DAC	(in work area)
	Bq	Bq/m^3	Bq/m^3
^3H	3×10^9	8×10^5	4×10^5
$^{90}Sr/^{90}Y$ (Class W)	1×10^5	6×10^1	3×10^1
^{129}I (Class D)	3×10^5	1×10^2	4×10^1
^{239}Pu (Class W)	2×10^2	8×10^{-2}	5×10^{-2}

QUESTION 11

To eliminate a chemical precipitant problem in the offgas stack, a nuclear facility has separated the dissolver offgas effluent from the remainder of the main ventilation discharge. The retrofit stack will discharge 5 Ci/sec of krypton-85.

POINTS

3   **A.**   The maximum ground level concentrations of ^{85}Kr must not exceed 1E-05 μCi/mL under adverse meteorology. Utilize the attached graphs to determine the necessary stack height, h, to reduce the concentration under these adverse conditions to the limit specified previously. State all assumptions, and neglect plume rise.

Note: $h = [(2\sigma_z^2)]^{1/2}$ (approximately) and

$$\sigma_y\sigma_z = 0.117\ Q/(\bar{X}u)$$

1   **B.**   Discuss the usefulness of stack height to control noble gas environmental exposures.

3   **C.**   Calculate the maximum ground level concentration in μCi/mL of krypton-85 for a 200 ft release height. State all assumptions.

3   **D.**   The nearest residence is 20 km away from this nuclear facility. The wind carries the krypton-85 towards this residence 25% of the time at an average velocity of 2.5 m/sec in the direction sector of 45 degrees in size. The year-long average release rate of krypton-85 is 1.25 Ci/sec that is discharged from a 200 ft stack. A beta-sensitive environmental TLD located in this sector at a distance of 10 km recorded an absorbed dose of 40 mrad above background for the one year period. What is the estimated annual absorbed dose at this residence? What is the annual average value of σ_z in this sector?
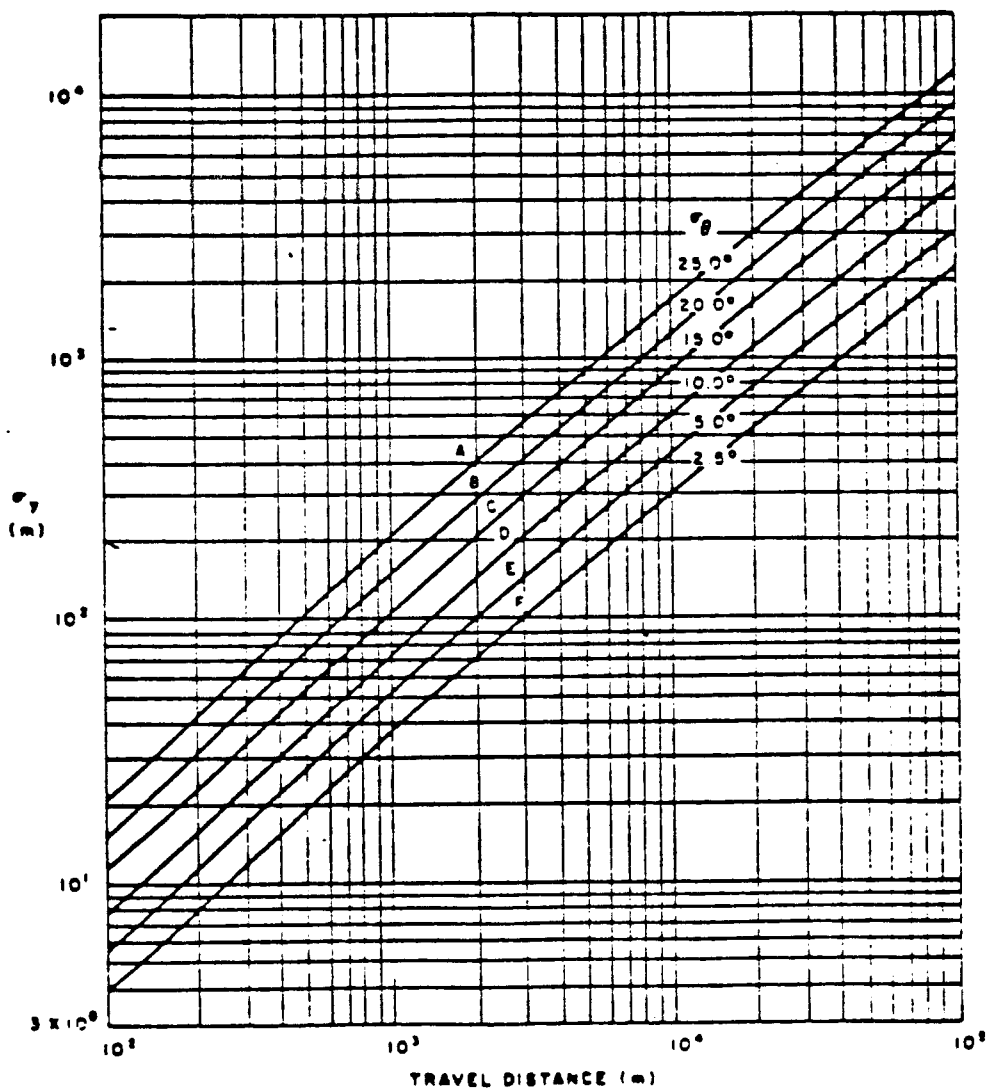
DATA

- Attached graphs of $\sigma_y\sigma_z$ and σ_y.

- Note: $\bar{X}_{\text{long-term avg}} = \left(\dfrac{2}{\pi}\right)^{1/2}\ \dfrac{fQ'}{\sigma_z\mu(2\pi x/n)}$

  $\times\ \exp(-h^2/2\sigma_z^2)$

- $(\bar{X}_{\text{max-z}}/\bar{X}_{\text{max-h}}) = (H_1/h_2)^2$
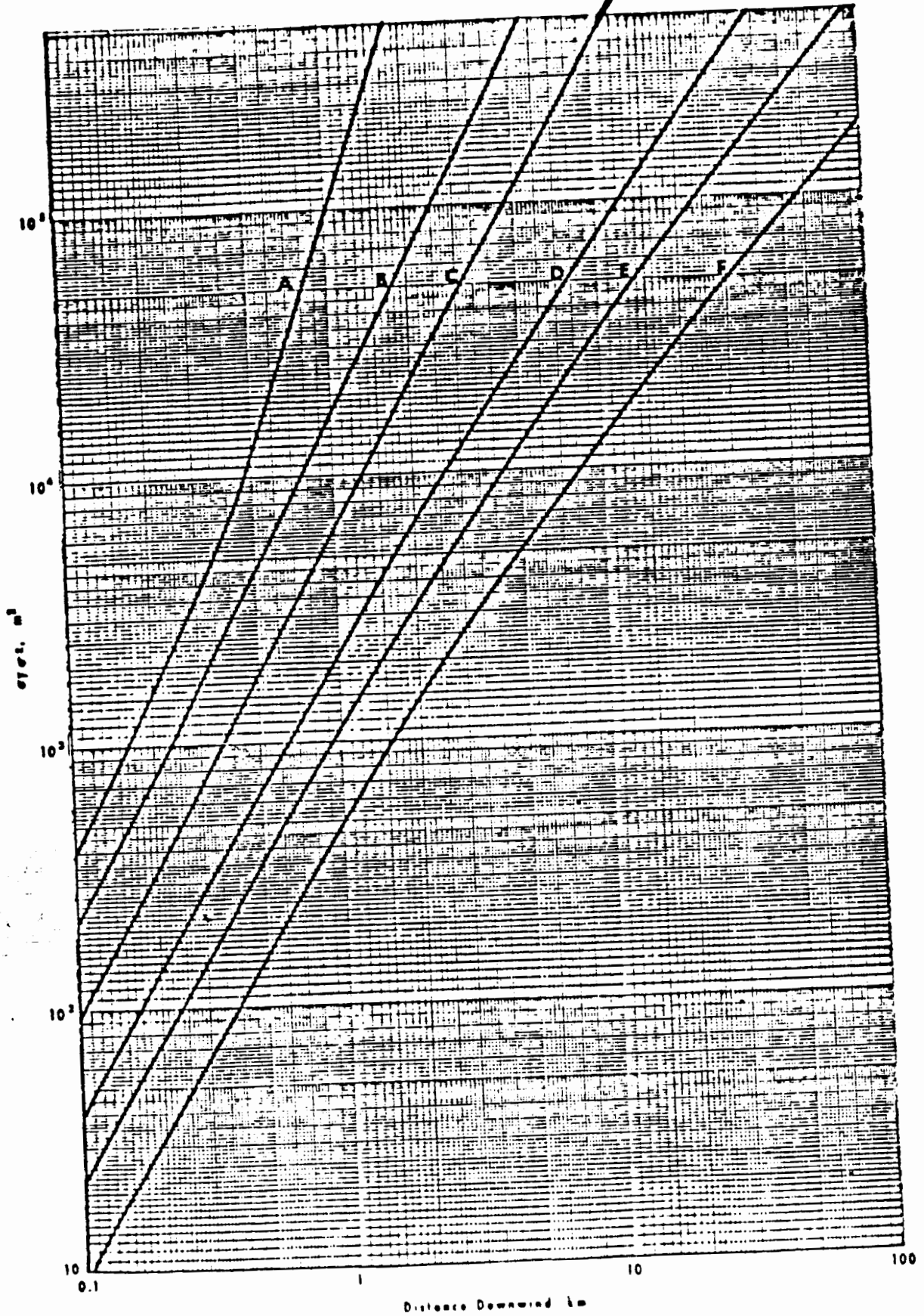
QUESTION 12

A pregnant nurse who has recently been involved with a cardiac pacemaker placement procedure using a C-arm fluoro unit comes to you and asks you to estimate the dose to her baby. She is 12 weeks pregnant. She was next to the patient for 20 minutes while fluoro was on. According to her estimates, you place the embryo-fetus 1.8 feet from the tube and 2.0 feet from the patient. The nurse was wearing a standard lead apron during the entire procedure. The unit was operating at 25% of the maximum legal output. The average kVp was 80. There was no drape or side-shield present on the unit.
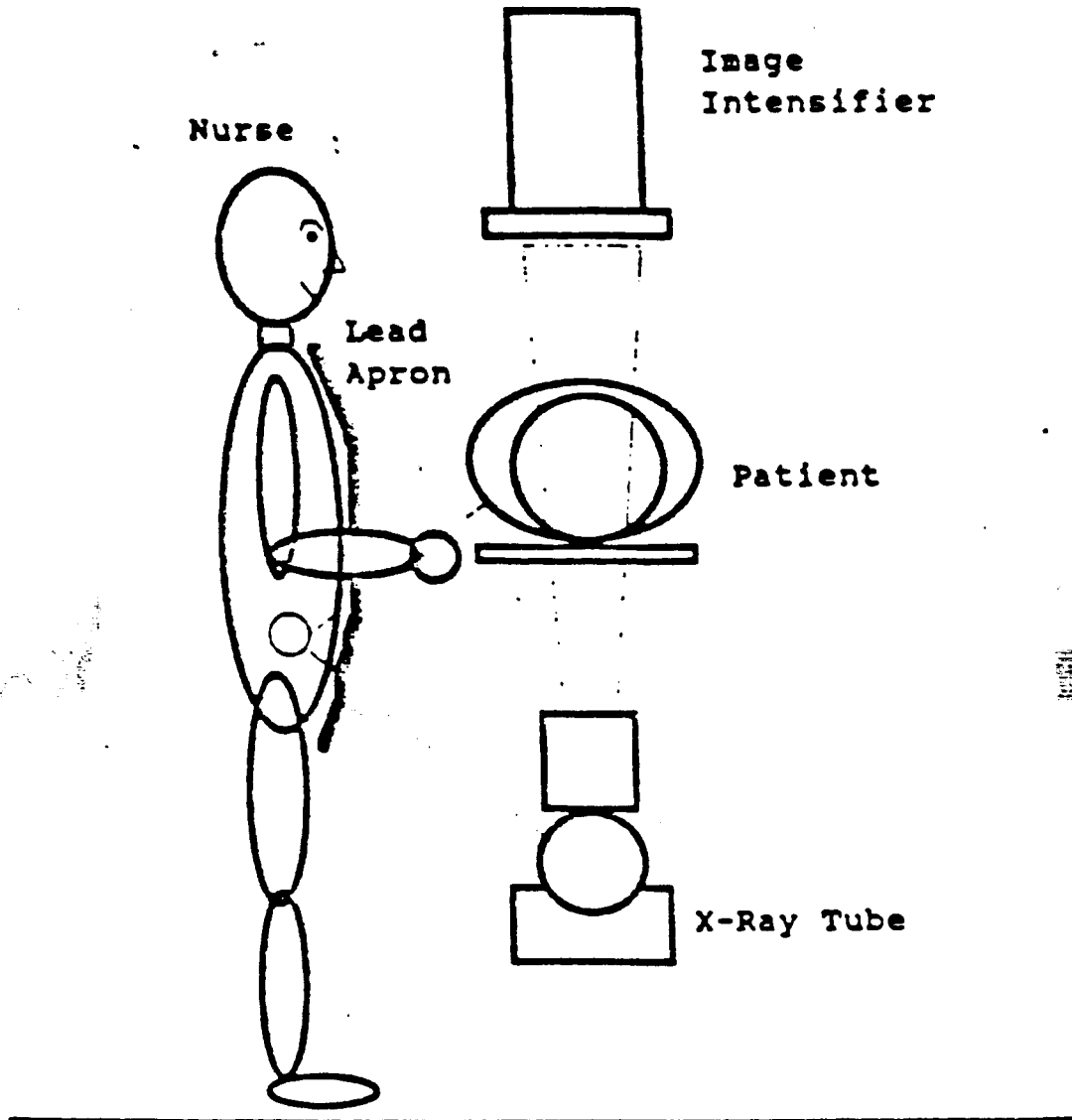
You are the Health Physics Supervisor overseeing an LSA radwaste shipment. One
HP Technician is assisting you. You have 1 liner to ship containing 150 cubic
feet of resin, solidified in cement, 21,000 pounds net weight. The radiation
level at 1 ft from the unshielded liner is 6 R/hr.

You must place the liner inside one of two available casks: Cask A or Cask B.
Cask A is a DOT-certified Type A cask and has 5 cm of lead shielding. Cask B
is a DOT-certified Type B cask and has 10 cm of lead shielding. The cask selected
will be shipped on an exclusive use, unenclosed, flatbed trailer.

Before the liner is placed inside the selected cask, the HP Technician spends 2
minutes at a distance of 1 ft from the unshielded liner taking final measurements.
He then reads his 200 mR self-reading pocket dosimeter (SRD) and reports it is
off-scale high. Checking his dosimeter card, he tells you that his SRD was
reading 190 when you and he began this job.

POINTS

1	A.	Calculate the activity, in curies, of each radionuclide to be shipped.
2	B.	Can this be made as an LSA shipment? Justify your answer with calculations.
2	C.	Calculate the transmitted gamma exposure rate, in mR/hr, at the exterior wall of each cask if used for the resin. Show all calculations.
2	D.	Based on DOT radiation level restrictions, can Cask A be used for this LSA shipment? State your reason(s) .
1	E.	Why was the HP Technician's SRD off-scale high? Show all calculations.
2	F.	List 2 good HP practices which were violated to result in the off-scale SRD reading.

DATA

The results from radiochemical analysis of the resins, and the concentration
limits for LSA shipments, are shown below:

Radionuclide	Concentration $\mu Ci/cm^3$)	LSA Concentration Limit ($\mu Ci/g$)
^{51}Cr	15	0.3
^{60}Co	5	0.3
^{90}Sr	10	0.005

1 ft^3 = 2.8 x 10^4 cm^3

QUESTION 13 (concluded)

1 lb = 454 g

Density of lead = 11.34 g/cm^3

Mass attenuation coefficient for 1 MeV gamma in lead = 0.0708 cm^2/g

Radiation level at 1 ft from the unshielded liner = 6 R/hr

Assume 1 gamma per disintegration with 1 MeV average energy

Assume buildup factor, B, for 5 cm of lead at 1 MeV gamma = 2

Assume buildup factor, B, for 10 cm of lead at 1 MeV gamma = 3.

Assume distance from outside of resin liner to outside of shipping cask (through the shielding) to be 1 ft.