NORTHWESTERN UNIVERSITY
EVANSTON – CHICAGO

OFFICE OF RESEARCH SAFETY

B - 106 WARD BUILDING
303 EAST CHICAGO AVENUE
CHICAGO, ILLINOIS 60611

January 23, 1984

1/30/84
Jan 23 III
Brown
2/1/84

12-00382-03
030-01372
40-4826

US Nuclear Regulatory Commission
Material Licensing Branch
Division of Fuel Cycle &
Material Safety
799 Roosevelt Road
Glen Ellyn, Illinois 60137

RE: Renewal SUD-556

Attention: Ms. B.J.Holt

Dear Ms. Holt:

Northwestern University has five separate licenses with the US NRC to cover the use of radioactive materials in our educational and research programs. Two of these licenses, 12-00382-05 and 12-00094-06, are for the possession of large sealed Cesium-137 sources which are housed in animal irradiators. I understand that gamma irradiator licenses are still licensed by NRC headquarters in Bethesda, Maryland. The other three licenses, however, are reviewed through the Region III office. Since we spend a great deal of time in reviewing these licenses, it seems appropriate to consolidate them and thus, to go through the renewal process once every five years rather than on three separate occasions. I would like to propose that this be done and offer the following justification.

1) One license would be inclusive for the use of all NRC regulated material at Northwestern University with the exception of the gamma irradiators.
2) The radiation safety program is under the auspices of one committee at Northwestern University regardless of the type of radioactive material being used.
3) Inspection of the licenses at Northwestern by the NRC would be a complete inspection of the entire program rather that just certain aspects.
4) Discrepancies could not occur between licenses.
5) Less time would be required in renewing these licenses.

I request, therefore, that the radioactive material licensed under SUD-556 be transferred to 12-00382-03, the broad material license, and that SUD-556 be discontinued.

In reviewing license SUD-556 for renewal, I found certain statements in previous correspondence and amendments that needed to be corrected. I have addressed these below.

FEE EXEMPT

JAN 26 1984

RECEIVED
JAN 26 1984
REGION III

Control No. 76231

LICENSE APPLICATION dated 6/25/73

Information included in this license application should be deleted and the following information substituted.

1) Use and storage of source material is in a Nuclear Chicago Model 9000 subcritical reactor. Source material is inventoried annually. The reactor is housed in Room B970, Technological Institute, a building primarily of masonry construction. Access to the area is restricted during experimentation and the equipment and area are surveyed on a regular basis. Surveys are performed for both gamma and neutron radiation. Calculations and an "Approach to Criticality" experiment have shown criticality is impossible to achieve.

2) The source material will be bombarded with neutrons from either Plutonium/Berylium sources or a Californium-252 source. The Van de Graff generator is no longer operational because of an inadequate vacuum system.

3) Dosimetry service is provided by R.S.Landauer, Jr. & Co. on a monthly basis.

LETTER dated 7/19/74

This letter should be deleted from the file since the information is no longer correct.

LICENSE APPLICATION dated 6/30/78

1) Handbook of Radiological Operations has been replaced by the Radiation Safety Handbook. (copy enclosed)

2) Current Radiation Safety Committee on file.
   - Dr. Tom Lund, D.D.S., Chairman
   - Dr. Allen Samarel, M.D.
   - Dr. Joseph Culotti
   - Dr. Fred Turek
   - Dr. Barbara-Ann Lewis
   - Dr. Alan Epstein, M.D.
   - Dr. Paul Hollenberg
   - Dr. Ed Rozhon
   - Dr. David Miller, RSO

3) Radiation safety training expanded and included the following:
   - °Two 15-minute video tapes which are required for all new radiation workers on the use of radioactive materials in the laboratory.
   - °Radiation safety seminar in the "Safe Use of Radioactive Materials". Offerred quarterly for those with little or no previous experience.
   - °New Radiation Workers packet containing information on biological effects of radiation.

4) Name change of waste disposal company to ADCO Services, Inc.

5) Appendix B: New instrument list and calibration procedures enclosed.

6) Appropriate rooms where material is used.

Th/Ni alloy: stored in B046, Technological Institute
U/Th salts: Rooms 2864 and 2867, Technological Institute
U fuel rods: Room B970, Technological Institute
U mill tailings: Rooms 2786 and 2787, Technological Institute

AMENDMENT REQUEST dated 1/13/81

Information correct except for Radiation Safety Committee composition and waste disposal company. Both of these corrections are referred to above. A copy of the revised charter is enclosed.

AMENDMENT REQUEST dated 6/15/83

The information included in this request is correct except the uranium mill tailings were obtained from Wyoming instead of Colorado.

If additional information is needed, please contact me at 312-649-8300. Northwestern University is a non-profit educational institution and is exempt from fee payment as stated in 10CFR170.11.4. Thank you for your assistance in this license review and renewal.

Sincerely,

David R. Miller

David R. Miller, Ph.D.
Radiation Safety Officer
Director, Office of Research Safety

Control No. 76231

CHARTER FOR THE RADIATION SAFETY COMMITTEE

Need: Pursuant to the provisions of Section 33-13 of Title 10, Code of Federal Regulations, Part 33 governing the issuance of specific licenses of broad scope for byproduct material, a Radiation Safety Committee is established at Northwestern University.

Convening Authority and Composition: The President of Northwestern University, upon recommendation of the Vice President for Research, will appoint a University Radiation Safety Committee. This committee will consist of at least eight members, plus ex-officio representatives. The membership shall include the Radiation Safety Officer (ex-officio), representatives of the University administration (ex-officio), and University faculty members trained or experienced in the same use of radioactive materials and radiation sources. In addition, those affiliated institutions who are receiving, acquiring, using, possessing or transferring radioisotopes or radiation producing instruments under the terms and requirements of any University held licenses or who are using the services of the Radiation Safety Office may request that a representative of their institution be appointed to serve on the Radiation Safety Committee. The Chairman of the Radiation Safety Committee shall be appointed by the President of the University.

General Purposes: The Radiation Safety Committee has three major purposes:

(1) Formulate and recommend to the Vice President for Research, policies governing the safe use of radioactive materials and radiation sources.

(2) Regulate the use of radioactive material and radiation sources by reviewing and approving proposals and qualifications of individuals desiring to use such materials or sources for educational or research purposes.

(3) Review and evaluate the performance and actions of the Radiation Safety Office.

Specific Responsibilities:

(1) The Radiation Safety Committee shall be responsible for reviewing

and either approving or disapproving, on the basis of radiological safety or factors related to radiological health, all applications to use radioactive materials or radiation sources.

(2) The Committee shall recommend the procedures for reviewing and approving requests by individuals either to become authorized users or to change their type of authorization.

(3) The Committee shall assure that records are maintained by the Radiation Safety Office to document all actions taken by the Committee on reviewing requests by individuals either to become authorized users or to change their type of authorization.

(4) The Committee shall be responsible for recommending policies and procedures for a radiation safety program including, but not limited to, recommendations on educational programs relating to the radiation safety program, survey frequencies, size and responsibilities of the Radiation Safety Office, and requirements necessary for an individual to become an authorized user of radioactive materials or radiation sources.

(5) The Committee shall be responsible for reviewing the radiation safety program on an annual basis or more frequently if requested to do so by the Vice President for Research.

(6) The Committee shall be responsible for recommending corrective procedures or policy revisions when deficiencies in the radiation safety program are noted.

(7) The Committee shall, when deemed appropriate, review and evaluate survey reports of facilities and laboratories using radioactive materials or radiation sources.

(8) The Committee shall be responsible for establishing those subcommittees or ad-hoc committees necessary to carry out its overall responsibilities.

(9) A written record of actions taken by the Committee shall be maintained.

Administrative Procedures: The administrative procedures of the Committee may change as the requirements necessary to assure compliance with existing regulations and responsible radiation protection are altered. The following current procedures may be modified accordingly:

(1) The policies and procedures recommended by the Committee and approved by the Vice President for Research shall be carried out by individuals and offices designated by the Vice President.

(2) All members of the Radiation Safety Committee plus two ex-officio representatives, the Radiation Safety Officer and the Research Services Administrator, shall have voting rights. When issues come to the Radiation Safety Committee concerning a voting member that member shall withdraw from voting.

(3) The Radiation Safety Officer shall answer all questions regarding the routine operation of the radiation safety program on behalf of the Committee. In addition, he shall receive and initially review all requests and proposals from individuals who desire to become authorized users and will forward these requests to the Committee as a whole with his recommendation. Requests and proposals to become an authorized user will require approval by all members voting. At least two-thirds of the voting members of the Radiation Safety Committee must vote.

(4) The Radiation Safety Officer will report the results of surveys or other information pertaining to radiation safety to the Committee upon request of the Chairman.

(5) The Radiation Safety Committee shall meet at least quarterly. A meeting must be called by the Chairman at the earliest opportunity if requested by any three (3) members of the Committee, by the Radiation Safety Officer, or by the Vice President for Research.

(6) The Radiation Safety Committee shall review the recommendations of the Radiation Safety Officer, provide final approvals or disapprovals of proposals and render final decisions on all matters raised by any other subcommittees.

(7) The Radiation Safety Officer will inform the appropriate parties of the decisions of the Radiation Safety Committee regarding requests for authorization, approval or modification of proposed uses of radioisotopes and radiation sources or any other decisions within the purview of the Committee's authority.

(8) Appeal of the decisions of the Radiation Safety Committee will be to the Vice President for Research of Northwestern University.

(9) A quorum shall consist of at least four voting members of the committee.

(1) Approval of motions shall require a majority of those present.

Amendments to the Charter:

This Charter may be amended upon three-fourths vote by the members of the Radiation Safety Committee when amendments are required to comply with Federal, State or local laws and regulations or when they will improve the operation of the radiation safety program of the University. All recommended amendments become effective upon approval by the Vice President for Research of Northwestern University.

APPENDIX B

INSTRUMENT LIST: EVANSTON CAMPUS

I.D.Number	Instrument	Model Number	Available	Rad.Detected	Range	Use
SN 843	Victoreen Ion chamber	440	1		0-3 mR/hr to 0-300 mR/hr, 2 mg/cm²	Survey of sealed source areas
SN 2050		740F	1		0-25 mR/hr to 0-25K mR/hr, 0.00025" mylar	Survey of sealed source areas
SN1856	Eberline gas prop. counter	PAC-4G-3 TP-1, AC-21 and AC- 1B	1		0-500X10³ cpm, 0.85 mg/cm²	Lab surveys H^3wipes
RS 058	Nuclear Chicago Prop	8700	1		$0\text{-}10^6$ cpm Qgas	Wipe tests
	Spectroshield		1		$0\text{-}10^6$ cpm	Wipe tests
RS100	Eberline:geiger	E-120G	1		0-700 cpm to $0\text{-}7X10^4$ cpm: 1.7 mg/cm²,end window	Lab surveys: X-ray diffraction leakage
RS019	Eberline	PRM-5-3 with SPA-3 (NaI)	1		0-500X10³ cpm	I^{125},I^{131},Te^{123m}, Co^{57} surveys
297	Eberline	PRS-2P/NRD	1	neutrons	ratemeter: 10cpm to 999,999 cpm dose ratemeter: 0.00001 to 99,900	Surveys of Nuc. Eng. labs
	Victoreen					
	Dosimeter charger	906	1			
	Dosimeter	541R	3		0-200 mR	Varied
	Dosimeter	541F	1		0-200 mR	
	Dosimeter	883	1		0-500 mR	
	Dosimeter	050	1		0-5 R	

Northwestern University

Calibration Procedure, Evanston campus

A. Ion chambers, geiger counters, portable gas flow proportional counters:

1. Pertinent information (instrument type, manufacturer, model numbers and serial numbers of both meter and probe, and calibration date), is recorded on the calibration data form.

2. Physical inspection of the instrument for mechanical damage. Instrument is cleaned if necessary.

3. Battery check, using "battery check" switch on the instrument. In cases where the batteries are low, they are checked with the Triplett Model 630A volt-ohmmeter (20 000 ohms/volt) or equivalent. Low voltage batteries are replaced as needed.

4. Where applicable (as stated in specific instrument manuals) circuit bias and/or tube voltages are checked using the volt meter.

5. The input voltage threshold sensitivity is determined using the Eberline MP-1 Mini Pulser, which has a continuously variable voltage output for this purpose.

6. The instrument is placed in the 137Cs radiation field, at distances appropriate for a "two-points-per-scale" calibration. The two points on each scale are separated by at least 50% of the scale. For example, on a 0-100mR/hr scale, 80mR/hr and 20mR/hr are calibration points. If nonlinearity of the meter is found, the two points are adjusted such that the average fractional deviation is equal for both high and low ends of the scale. If the measured exposure rate differs at any point by greater than or equal to 10% but less than 20%, a calibration graph, chart, or correction factor is attached to the instrument. Instruments are removed from service for repair and recalibration when measured exposure rates deviate by greater than or equal to 20% from the true exposure rate.

7. For G.M. and other pulse counting meters the Eberline Pulser, MP-1, is used to calibrate the electronics. This instrument has a range of from 1.0c/min to $1.6x10^6$c/min at an accuracy of +/-0.1%. The output pulse has a 0.2 u-sec rise time, a 0.2 usec window width and a 3 usec fall. This is not the sole means of calibration; the survey meters are also exposed to the radiation field.

8. The portable gas flow proportional counters (PAC4G3/AC21B) are calibrated with ^{99}Tc plated sources at 280+/-10, 3460+/-100, 33 900+/-1000, and 283 500+/-8 500 cpm (ea), as certified by the manufacturer, Eberline Instrument Corp. These sources are NBS traceable and the total estimated error is +/-3%. The activities correspond to count rates which lie approximately in the midpoint of each range on the Lin-Log scales.

Calibration Procedure, Evanston Campus

B. Nuclear Chicago Gas Flow Proportional Counter

1. The counter is checked for voltage plateau using the Nuclear Chicago Ra(D+E) source, or other appropriate source.

2. The counter is checked for reproducibility by means of a Chi-square statistical analysis. At least 20 repeated measurements are made for this analysis.

3. Counting efficiencies are determined using the NEN Beta source set #NES200 A (NBS traceable) reference sources.

C. An appropriate check source is counted in specified geometry for each instrument. This information is recorded on the calibration form.

D. Calibration frequency is semi-annually.

E. Calibration Sources:

1. NEN Beta Source Set #NES200 A

2. 137Cs, Nuclear Associates Model 726, 99.2 mCi(3/30/78) serial number 158.

3. 99Tc Electroplated Beta Source Set, Eberline serial numbers 7644, 7645, 7646, and 7647, calibration date 3/14/77.

F. Health Physics: The 137Cs source is constructed with a built-in timer which returns the source automatically into the source housing at the end of the specified duration of exposure. The field is limited such that an operator behind the source is not exposed to the direct beam. Doors to the calibration facility are locked if possible and are posted with the correct radiation warning signs. Personal dosimetry is used (film badge). An accessory survey meter is kept on hand during the calibration procedure. Protective clothing is worn.

No handling of the 99Tc electroplated beta sources is necessary.

Beta reference sources are used in planchets and are not handled with bare hands.

CALIBRATION OF 2PRS-2P/NRD

1. The instrument is splashproof but should be inspected to be as clean and dry as possible.
2. Battery check is performed by connecting a well-regulated power supply supplying an adjustable voltage between 5 volts and 7 volts, at 150mA, to the battery connector on chassis. Range switch is in the OFF position.
3. Adjust power supply to 5.75 volts and turn range switch to position A; battery legend should indicate BATT OK. Adjust power supply to 5.6 volts; battery legend should indicate ERROR.
4. Adjust BATT OK ADJ potentiometer R520 if necessary to give above indications.
5. To adjust high voltage connect an electrostatic voltmeter or any other instrument with an extremely high impedance, to capacitor C601 and place range switch in the HV position.
6. Adjust HV ADJ (front panel) for 1500 volts. If display does not indicate 1500 volts ± 5%, adjust VCO frequency, R515, potentiometer.
7. Adjust HV ADJ to 500 volts. If display does not indicate 500 ± 5% adjust VCO OFFSET, R516, potentiometer. Repeat as often as necessary for complete adjustment.
8. Next the calibration boards and their control switches are adjusted and programmed.
9. For the calibration function to operate, the CALIB switch of the calibration board must be in the IN position and the function switch on the front panel must be in the RATE mode.
10. The SCALAR switch is not part of the calibration function. It provides a choice of readout for the scalar functions. In the STORE position the counts are stored and the display readout is updated at the completion of the timed cycle or when the range switch is placed in the STOP position. In the increment position the display is updated with each count.
11. Connect a pulse generator (Eberline MP-1) and set it at a rate of 100K cpm. Vary the time switch on the front panel from 0.5 min. to 5 min. and record instrument reading.
12. Set selector switch on RATE mode starting with A,B,C,D, as the input signal from the MP-1 is varied from 800 cpm, 8K cpm, 80K cpm and 800K cpm respectively.
13. Expose instrument to ^{252}Cf (NE 116) with a source strength of 8.31×10^{6} n/sec (3.685 ugm) on 1-26-78 and apply the inverse square law. Record instrument reading and distances.

OFFICE OF RESEARCH SAFETY
SURVEY INSTRUMENT CALIBRATION

Instrument ______________________________

	model no.	serial no.
meter		
probe		

Calibration Date ____________________
Next Calibration ____________________
Investigator ____________________
Department/Lab ____________________
Calibrated by ____________________

A. Function
Batteries ____________________
Drift ____________________
Input Voltage ____________________

Check Source ____________________
Zero ____________________
Misc. ____________________
Test Instrument ____________________

B. Pulse Generator: Eberline Mini-Pulser, MP-1

scale	$pulse \cdot min^{-1}$	$c \cdot min^{-1}$	$pulse \cdot min^{-1}$	$c \cdot min^{-1}$

C. Calibration Source: ______________________________

scale	m*	field $mR \cdot hr^{-1}$	read $mR \cdot hr^{-1}$	field $mR \cdot hr^{-1}$	read $mR \cdot hr^{-1}$				

*source to detector midline distance

D.

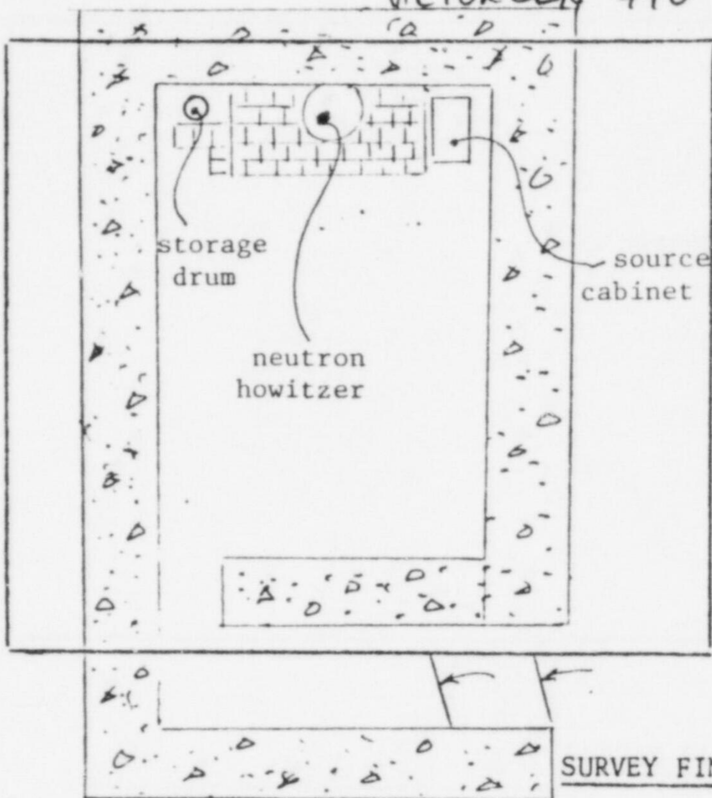
RADIOLOGICAL SAFETY SURVEY REPORT SHEET

BUILDING TECH ROOM B959 DATE 1-20-84 BY C Smith

Routine [✓] Spot Check [ ] Special [ ] Equipment [ ]

Survey Instrument PRS 2P/NRD
VICTOREEN 440

Sources of Ionizing Radiation



TYPE		FORM	ACTIVITY
Cf- 252	(2)	neutron howitzer / source cabinet	
Pu-Be	(6)	storage drum	
Co-60	(1)	source cabinet	

Ventilation:

Comments:

^{137}Cs : 2.5 mR/hr

SURVEY FINDINGS (operational)

		VICT 440 mr/hr	NRD mrem/hr	
252Cf source in howitzer in raised position	1	—	—	
at surface	2	12.0	2.7	
at post	3	4.0	0.1	
levels in rest of room	4	≤0.1	≤0.1	
252Cf source in storage position	5	—	—	
surface	6	9.5	2.0	
post	7	0.1	0.1	
levels in rest of room	8	≤0.1	≤0.1	
Pu-Be storage drum: surface	9	1.4	60	
normally with shielding	0	≤0.1	≤0.1	
Background		≤0.1	≤0.1	

RECOMMENDATIONS:

Control No. 76231

NORTHWESTERN UNIVERSITY
EVANSTON – CHICAGO

OFFICE OF RESEARCH SAFETY

B - 106 WARD BUILDING
303 EAST CHICAGO AVENUE
CHICAGO, ILLINOIS 60611

TO: ALL RADIATION WORKERS OF CHILD BEARING AGE

As a radiation worker you are in a profession which has one of the best safety histories of all occupations. It is important, however, that you be aware that any exposure to radiation involves some degree of risk. The Office of Research Safety staff recommends that radiation exposures be kept as low as reasonably achievable and that any unnecessary exposure be avoided.

A special situation arises when an occupationally exposed woman is pregnant. Exposure of the body of such a woman to penetrating radiation would also involve exposure of the embryo or fetus. Because a number of studies have indicated that the embryo or fetus is more sensitive than an adult, particularly during the first three months after conception when a woman may not be aware that she is pregnant, the Nuclear Regulatory Commission (NRC) requires that instruction be given to all occupationally exposed women with regard to potential problems associated with prenatal radiation exposure.

If you are pregnant, or are planning to become pregnant, please contact this office so that we can discuss your radiation exposure history with you and suggest procedures to follow to minimize the exposure risk during pregnancy. If you have questions, please feel free to discuss them with your supervisor or the research safety staff.

David R. Miller, Director
Office of Research Safety

POSSIBLE HEALTH RISKS TO CHILDREN OF WOMEN WHO ARE EXPOSED TO RADIATION DURING PREGNANCY

Summary

Occupational exposures to radiation are being kept low. However, qualified scientists have recommended that the radiation dose to a pregnant woman should not exceed 0.5 rem because of possible risks to her unborn child. Since this 0.5 rem is lower than the dose generally permitted to adult workers, women may want to take special actions to avoid receiving higher exposures, just as they might stop smoking during pregnancy or might climb stairs more carefully to reduce possible risks to their unborn children.

All Nuclear Regulatory Commission licensees are now required* to inform all individuals who work in a restricted area of the health protection problems associated with radiation exposure. This instruction would in many cases include information on the possible risks to unborn babies. The regulations also state** that licensees should keep radiation exposures as low as practicable. According to the National Council on Radiation Protection and Measurements, particular efforts should be made to keep the radiation exposure of an embryo or fetus at the very lowest practicable level during the entire period of pregnancy.

Some recent studies have shown that the risk of leukemia and other cancers in children increases if the mother is exposed to a significant amount of radiation during pregnancy. According to a report by the National Academy of Sciences, the incidence of leukemia among children under 10 years of age in the United States could rise from 3.7 cases in 10,000 children to 5.6 cases in 10,000 children if the children were exposed to 1 rem of radiation before birth (a "rem" is a measure of radiation). The Academy has also estimated that an equal number of other types of cancers could result from this level of radiation. Although other scientific studies have shown a much smaller effect from radiation, the Nuclear Regulatory Commission wants women employees of its licensees to be aware of any possible risk so that the women can take steps they think appropriate to protect their offspring.

As an employee of a Nuclear Regulatory Commission licensee, you may be exposed to more radiation than the general public. However, the Nuclear Regulatory Commission has established a basic exposure limit for all occupationally exposed adults of 1.25 rems per calendar quarter, or 5 rems per year. No clinical evidence of harm would be expected in an adult working within these levels for a lifetime. Because the risks of undesirable effects may be greater for young people, persons under 18 years of age are permitted to be exposed to only 10 percent of the adult occupational limits. (This lower limit is also applied to members of the general public.)

The scientific organization called the National Council on Radiation Protection and Measurements has recommended that because unborn babies may be more sensitive to radiation than adults, their radiation dose as a result of occupational exposure of the mother should not exceed 0.5 rem. Other scientific groups, including the International Commission on Radiation Protection, have also stressed the need to keep radiation doses to unborn children as low as practicable.

Thus it is the responsibility of your employer to take all practicable steps to reduce your radiation exposure. Then it is your responsibility to decide whether the exposure you are receiving is sufficiently low to protect your unborn child. The advice of your employer's health physicist or radiation protection officer should be obtained to determine whether radiation levels in your working areas are high enough that a baby could receive 0.5 rem or more before birth. If so, the alternatives that you might want to consider are:

(a) If you are now pregnant or expect to be soon, you could decide not to accept or continue assignments in these areas.

(b) You could reduce your exposure, where possible, by decreasing the amount of time you spend in the radiation area, increasing your distance from the radiation source, and using shielding.

(c) If you do become pregnant, you could ask your employer to reassign you to areas involving less exposure to radiation. If this is not possible, you might consider leaving your job. If you decide to take such steps, do so without delay. The unborn child is most sensitive to radiation during the first three months of your pregnancy.

(d) You could delay having children until you are no longer working in an area where the radiation dose to your unborn baby could exceed 0.5 rem.

You may also, of course, choose to:

(e) Continue working in the higher radiation areas, but with full awareness that you are doing so at some small increased risk for your unborn child.

The following facts should be noted to help you make a decision:

1. The first three months of pregnancy are the most important, so you should make your decision quickly.

2. At the present occupational exposure limit, the actual risk to the unborn baby is small, but experts disagree on the exact amount of risk.

3. There is no need to be concerned about sterility or loss of your ability to bear children. The radiation dose required to produce such effects is more than 100 times larger than the Nuclear Regulatory Commission's dose limits for adults.

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*By Title 10, Part 19 of the Code of Federal Regulations.

**In Title 10, Part 20.

4. Even if you work in an area where you receive only 0.5 rem per three-month period, in nine months you could receive 1.5 rems, which exceeds the full-term limit suggested by the NCRP. Therefore, if you decide to restrict your unborn baby's exposure as recommended by the NCRP, be aware that the 0.5 rem limit applies to the full nine-month pregnancy.

The remainder of this document contains a brief explanation of radiation and its effects on humans. As you will see, some radiation is present everywhere and the levels of radiation most employees of Nuclear Regulatory Commission licensees receive are not much larger than these natural levels. Because the radiation levels in the facility where you will be working are required by law to be kept quite low, there is not considered to be a significant health risk to individual adult employees.

Discussion of Radiation

The amount of radiation a person receives is called the "dose" and is measured in "rems." The average person in the United States gets a dose of one rem from natural sources every 12 years. The dose from natural radiation is higher in some states, such as Colorado, Wyoming, and South Dakota, primarily because of cosmic radiation. There the average person gets one rem every 8 years.

Natural background radiation levels are also much higher in certain local areas. A dose of one rem may be received in some areas on the beach at Guarapari, Brazil, in only about 9 days, and some people in Kerala, India, get a dose of one rem every 5 months.

Many people receive additional radiation for medical reasons. The annual radiation dose averaged over the United States population from diagnostic X-rays is 0.072 rem per year. The average dose from one chest X-ray is 0.045 rem.

Radiation can also be received from natural sources such as rock or brick structures, from consumer products such as television and glow-in-the-dark watches, and from air travel. The possible annual dose from working 8 hours a day near a granite wall at the Redcap Stand in Grand Central Station, New York City, is 0.2 rem, and the average annual dose in the United States from TV, consumer products, and air travel is 0.0026 rem.

Radiation, like many things, can be harmful. A large dose to the whole body (such as 600 rems in one day) would probably cause death in about 30 days, but such large doses result only from rare accidents. Control of exposure to radiation is based on the assumption that any exposure, no matter how small, involves some risk. The occupational exposure limits are set so low, however, that medical evidence gathered over the past 50 years indicates no clinically observable injuries to individuals due to radiation exposures when the established radiation limits are not exceeded. This was true even for exposures received under the early occupational exposure limits, which were many times higher than the present limits. Thus the risk to individuals at the occupational exposure levels is considered to be very low. However, it is impossible to say that the risk is zero. To decrease the risk still further, licensees are expected to keep actual exposures as far below the limits as practicable.

The current exposure limits for people working with radiation have been developed and carefully reviewed by nationally and internationally recognized groups of scientists. It must be remembered, however, that these limits are for adults. Special consideration is appropriate when the person being exposed is, or may be, an expectant mother, because the exposure of an unborn child may also be involved.

Prenatal Irradiation

The prediction that an unborn child would be more sensitive to radiation than an adult is supported by observations for relatively large doses. Large doses delivered before birth alter both physical development and behavior in experimentally exposed animals. A report of the National Academy of Sciences states that short-term doses in the range of 10 to 20 rems cause subtle changes in the nerve cells of unborn and infant rats. The report also states, however, that no radiation-induced changes in development have been demonstrated to result in experimental animals from doses up to about 1 rem per day extended over a large part of the period before birth.

The National Academy of Sciences also noted that doses of 25 to 50 rems to a pregnant human may cause growth disturbances in her offspring. Such doses substantially exceed, of course, the maximum permissible occupational exposure limits.

Concern about prenatal exposure (i.e., exposure of a child while in its mother's uterus) at the permissible occupational levels is primarily based on the possibility that cancer (especially leukemia) may develop during the first 10 years of the child's life. Several studies have been performed to evaluate this risk. One study involved the followup of 77,000 children exposed to radiation before birth (because of diagnostic abdominal X-rays made for medical purposes during their mother's pregnancy). Another study involved the followup of 20,000 such children. In addition, 1292 children who received prenatal exposure during the bombing of Hiroshima and Nagasaki were studied. Although contradictory results have been obtained, most of the evidence suggests a relationship between prenatal exposure and an increased risk of childhood cancer.

Bibliography

1. Donald G. Pizzarello and Richard L. Witcofski, *Basic Radiation Biology*, Philadelphia. Lea and Febizer, 1967.

2. National Academy of Sciences – National Research Council, *The Effects on Populations of Exposure to Low Levels of Ionizing Radiation*, Washington, D.C., November 1972.

3. National Council on Radiation Protection and Measurements, *Basic Radiation Protection Criteria*, NCRP Report No. 39, Washington, D.C., January 15, 1971.

4. United Nations, *Ionizing Radiation: Levels and Effects*, 2 vol., Reports of the United Nations Scientific Committee on the Effects of Atomic Radiation, Report No. A/8725, United Nations, New York, 1972.

5. U.S. Atomic Energy Commission, Division of Technical Information, Understanding the Atom Series:

   Atoms, Nature and Man

   The Genetic Effects of Radiation

   The Natural Radiation Environment

   Your Body and Radiation

APPENDIX TO REGULATORY GUIDE 8.13

INSTRUCTION CONCERNING PRENATAL RADIATION EXPOSURE

Basic Radiation Exposure Limits

As a worker in an activity licensed by the Nuclear Regulatory Commission (NRC), you may be exposed to more radiation than the general public. The amount of radiation an individual receives is called the "dose" and it is measured in "rems."[1] The average individual in the United States accumulates a dose of 1 rem from natural radiation sources[2] every 12 years. The NRC has established a basic radiation exposure limit[3] for all occupationally exposed adults of 1.25 rems per calendar quarter, which is 5 rems per year. If a licensee has records of your previous radiation exposure history and your total radiation exposure does not exceed an average of 5 rems per year, the regulations currently allow a maximum of 3 rems per calendar quarter (a total annual dose of 12 rems per year).[4] Individuals under 18 years of age and members of the general public are permitted to be exposed to only 0.125 rem per calendar quarter or one-tenth of the occupational limits.

It must be remembered, however, that these limits are for adults. Internationally recognized groups of scientists have considered the special situation that exists when an unborn child may be exposed to radiation as a result of occupational exposure of the mother.

[1]Note: a rem is a measure of radiation dose just as the mile is a measure of distance and the pound is a measure of weight.

[2]Exposure to natural or background radiation comes from cosmic rays (from outer space), from radioactive materials that occur naturally in rock or brick structures, and from radioactive elements present naturally in the food and water we eat and drink.

[3]In the Code of Federal Regulations, Title 10, Part 20, "Standards for Protection Against Radiation," Section 20.101, "Radiation Dose Standards for Individuals in Restricted Areas."

[4]Recent guidance from the Environmental Protection Agency recommends a maximum allowed dose of 5 rems per year rather than 12. This recommendation is included in a proposed rule change by the NRC, which was published for public comment in the Federal Register (44 FR 10388, February 20, 1979).

Recommendations of Scientific Organizations

The scientific organization called the National Council on Radiation Protection and Measurements (NCRP) has recommended that because the unborn[5] are more sensitive to radiation than adults, their radiation dose from occupational radiation exposure of the mother should not exceed 0.5 rem (Ref. 1). The International Commission on Radiological Protection (ICRP) recommends that occupational radiation exposure of women of reproductive capacity be received gradually in small increments so that it would be unlikely for an unborn baby to receive more than 0.5 rem in the first 2 months when a woman may not be aware that she is pregnant (Ref. 2). After a woman knows she is pregnant, the ICRP recommends that she not work in areas where the annual exposure would probably exceed 1.5 rems.

NRC Requirements

All Nuclear Regulatory Commission licensees are required[6] to inform all individuals who work in a restricted radiation area of the risks associated with radiation exposure. This instruction should include information on the risks to the unborn. The regulations also require[7] licensees to keep radiation exposures as low as is reasonably achievable. For radiation protection purposes, the NRC assumes that there is some risk associated with any amount of radiation exposure (down to zero). According to the NCRP, vigorous efforts should be made to keep the radiation exposure of the unborn at the very lowest practicable level during the entire pregnancy.

Therefore, it is the responsibility of your employer to take all practicable steps to reduce your radiation exposure and to keep you informed of the exposures you are receiving.

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[5] Scientifically, from conception to about 15 days an unborn child is referred to as a zygote; from 15 days until 2 months as an embryo; and from 2 months until birth as a fetus. In this appendix, the term unborn is used to include all three stages.

[6] By the Code of Federal Regulations, Title 10, Part 19, "Notices, Instructions and Reports to Workers; Inspections."

[7] In the Code of Federal Regulations, Title 10, Part 20, "Standards for Protection Against Radiation," Section 20.1, "Purpose."

Your Responsibility

It is your responsibility to decide whether the risks to you or to a known or potential unborn child are acceptable. The following facts will help you make your decision:

1. The first 3 months of pregnancy are the most important, so you should make your decision early.

2. In most work situations, the actual dose received by an unborn child would be less than the dose you would receive yourself because some of the dose would be absorbed by your body.

3. The dose to the unborn child can be reduced, where possible, (a) by decreasing the amount of time you spend in an area where you will be exposed to radiation, (b) by increasing the distance between youself and the source of radiation, and (c) by shielding your abdominal area.

4. If you do become pregnant, you could ask your employer to reassign you to areas involving less exposure to radiation.

5. When your occupational exposure is below the 5 rems-per-year limit, the risk to an unborn child may be small in relation to other day-to-day risks to the unborn during pregnancy. Experts disagree on the exact amount.

6. There is no need to be concerned about sterility, that is, loss of your ability to bear children. The radiation dose required to produce this effect is more than 100 times greater than the Nuclear Regulatory Commission's basic dose limits for adults of 5 rems per year, 1.25 rems per calendar quarter.

7. Even if you work in an area where you receive only 0.5 rem per 3-month period, in 9 months you could receive 1.5 rems, and your unborn baby could receive more than 0.5 rem (the full-term limit recommended by the NCRP). Therefore, if you decide to restrict your unborn baby's radiation exposure as recommended by the NCRP, be aware that the 0.5-rem limit to the unborn applies to the full 9-month pregnancy.

Your Additional Rights as a Worker

It is up to you to compare the benefits of your employment against the possible risks involving occupational radiation exposure to a known or potential unborn child. You should know that the Pregnancy Discrimination Act, an amendment of Title VII of the Civil Rights Act of 1964, states that "...women affected by pregnancy, childbirth, or related medical conditions; shall be treated the same for all employment-related purposes, including receipt of benefits under fringe benefit programs, as other persons not so affected but similar in their ability or inability to work..." (Ref. 3). In addition, the Equal Employment Opportunity Commission (a Federal agency) is responsible for examining cases for compliance with this Act.

Why the Unborn are More Sensitive

The remainder of this appendix contains a brief explanation of prenatal[8] exposure to radiation in relation to other risks to the unborn during pregnancy.

The unborn baby is more sensitive to radiation than the adult because of its rapid rate of development. At certain times during development, those cells forming a specific organ or body function are dividing very rapidly and therefore are most likely to be damaged. In addition, the unborn's organs and systems for fighting infections and harmful substances are not yet developed (Ref. 4).

Four to six percent of the live births show some birth defect. Most often it is not possible to say what caused a particular birth defect. Out of 100 children born with birth defects, 2 to 3 can be attributed to drugs and chemicals. Defects in the genetic material[9] of the parents are thought to cause another 25 out of 100 birth defects (Ref. 5). About 1 out of 3 naturally aborted fetuses show abnormal genetic material (Ref. 6). Other factors in the mother's life (including the exposure of the unborn to naturally occurring radiation) are thought to cause another 6 out of 100 birth defects. However, it is not known what causes the remaining birth defects, that is, about 65 out of 100 (Ref. 5). It is estimated that 70 out of 100 fertilized eggs will not result in the birth of a living infant (Ref. 7).

Prenatal Radiation Risk Compared to Other Risks

Some common activities once considered safe have now been shown to be harmful during pregnancy (see Table 1). Alcohol has been said to be the most

[8]Prenatal means prior to birth, while the unborn child is in the mother's uterus.
[9]Substance involved in reproduction or the passing down of traits from parents to their children.

TABLE 1

EFFECT AND FREQUENCY OF CERTAIN MATERNAL FACTORS ON PREGNANCY OUTCOME

Maternal Factor	Pregnancy Outcome	Rate of Occurrence
German Measles[a]	Defects of: heart, lens of the eye, skeletal muscles, inner ear, teeth.	2 in 3
Cigarette Smoking[b]	In general, babies weigh 5 to 9 ounces less than average babies.	
Less than 1 pack per day	Infant death	1 in 5
Pack or more per day	Infant death	1 in 3
Alcohol Consumption[c]		
2 drinks per day	Babies weigh 2 to 6 ounces less than average babies	
2 to 4 drinks per day	Signs of fetal alcohol syndrome (growth deficiency, brain dysfunction, characteristic facial signs)	1 in 10
4 or more drinks per day		1 in 5
Chronically alcoholic		1 in 3 to 1 in 2
Maternal Age[d]		
20 years	Down's Syndrome (mental and physical growth retardation)	1 in 2300
35 to 39 years		1 in 64
40 to 44 years		1 in 39
Aspirin[e] (Salicylates)	Clubfoot	1 in 13
High Altitude[f]		
Mean altitude:		
263 feet	Low birth weight (higher risk); babies weigh less than 5½ pounds	1 in 15
5000 feet		1 in 10
10,500 feet		1 in 4

Radiation[g]

Childhood Cancer:

1 rem	Childhood leukemia deaths before the age of 12 years	1 in 3333
1 rem	Deaths from other childhood cancers before the age of 10	1 in 3571

Bomb exposure at 4-13 weeks gestation:

From 15 to greater than 100 rads[h] (Hiroshima) Greater than 150 rads (Nagasaki)	Small head size with severe mental retardation at exposures greater than 25 rads	1 in 4

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a. G. Tondury, "The Virus as a Danger to Human Embryos," Teratology Symposium, Como, Italy, October 1967, edited by A. Bertelli, L. Donati, Excerpta Medica Foundation, Amsterdam, 1969.

b. M. B. Meyer and J. A. Tonascia, "Maternal Smoking, Pregnancy Complications, and Perinatal Mortality," American Journal of Obstetrics and Gynecology, Vol. 128, no. 5, pp. 494-502, July 1, 1977.

c. D. W. Smith, "Alcohol Effects on the Fetus," Progress in Clinical and Biological Research, Vol. 36, pp. 73-82, 1980.

d. "Preventability of Perinatal Injury," Progress in Clinical and Biological Research, edited by K. Adamson and H. A. Fox, Alan R. Liss, Inc., New York, 1975.

e. I. D. Richards, "A Retrospective Inquiry into Possible Teratogenic Effects of Drugs in Pregnancy," Advances in Experimental Medical Biology, Vol. 27, p. 441, 1972.

f. D. Grahn and J. Kratchman, "Variation in Neonatal Death Rate and Birth Weight in the United States and Possible Relations to Environmental Radiation, Geology and Altitude," American Journal of Human Genetics, Vol. 15, pp. 329-351, 1963.

g. National Academy of Sciences, Report of the Committee on the Biological Effects of Ionizing Radiation (BEIR-80 Report), "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," Washington, D.C., November 1980.

h. Rads and rems are measurements of radiation dose. For some types of radiation, such as those present at the bombings, a given dose of rads might equal a larger dose of rems. The experts are not sure.

common chemical causing infant malformation and mental retardation (Ref. 8). The full "fetal alcohol syndrome" seen in 30 to 50 out of 100 mothers who were heavy drinkers (8 or more drinks per day) shows growth problems, brain dysfunction, and subtle facial signs. Symptoms of the fetal alcohol syndrome were seen in the children of 11 out of 100 women who drank 2 to 4 drinks a day during their pregnancies, and in the children of 19 out of 100 women who drank 4 or more drinks a day during their pregnancies.

Babies born to women who smoked cigarettes while they were pregnant weighed less than average babies, which contributes to a higher risk of early death. In addition, higher numbers of natural abortions were seen with these mothers and lower school performance and physical well being were seen in their children when tested at age 7 (Ref. 9). Aspirin, antihistamines, cold remedies, barbiturates, and amphetamines are a few drugs suspected of having harmful effects on the developing baby (Ref. 10). The Food and Drug Administration has warned pregnant women to avoid or reduce their intake of caffeine (found in coffee, tea, and cola drinks) because of animal studies showing related birth defects (Ref. 11).

Radiation also can be harmful to an unborn baby at doses that would have little or no effect on adults.[10] Large doses of radiation (greater than 100 rems) to unborn babies can cause growth retardation, severe birth defects, and even death. Which organ is most seriously affected by radiation depends on the stage of growth at the time of the exposure. For growth defects, the period of greatest sensitivity is between weeks 2 and 12 of a woman's pregnancy. During a large part of this time, a woman may not be aware that she is pregnant.

The BEIR-80[11] report (Ref. 12) discusses the effects of radiation on the growing baby. Small head size was seen in studies of Japanese children who were in the womb when their mothers received doses of atomic bomb radiation

[10]For a general discussion of risks to adults from occupational radiation exposure, see Regulatory Guide 8.29, "Instruction Concerning Risks from Occupational Radiation Exposure." A list of additional publications on the biological risks of radiation exposure can be found in the bibliography of this appendix.

[11]The Committee on the Biological Effects of Ionizing Radiation (BEIR) was established by the National Academy of Sciences to report on the effects on populations from exposure to low levels of radiation.

over a very short period of time, greater than 10 rads at Hiroshima and greater than 150 rads at Nagasaki.[12] The reason for the different degree of effect at the two cities is not known. At higher doses, greater than 25 rads, mental retardation was associated with the small head size.

The BEIR-80 report also discussed several studies performed to evaluate an increased risk of cancer (especially leukemia) in children whose mothers had received medical x-ray examinations while pregnant. The BEIR committee concluded that if 100,000 unborn babies were each exposed to 1 rem, up to 62 of the children could get leukemia before reaching 10 years of age. Of these, 37 cases would occur normally regardless of radiation exposure. Therefore, the number of cases assumed to be caused by radiation would be 25. An equal number of other cancers could result from this level of radiation. Other scientific studies have shown a much smaller or zero cancer effect from this level of radiation. Hence, it is not certain that the low doses of radiation actually caused the childhood cancers or if the babies that later developed cancer were for some reason more likely to be x-rayed while in the womb.

The National Council on Radiation Protection and Measurements (NCRP Report No. 53, Ref. 13) questions whether a dose of 5 to 10 rems, received at critical stages in the baby's development (2 to 12 weeks), can cause birth defects or an increased risk of childhood cancer. Therefore, the NCRP recommends that a radiation exposure limit of 0.5 rem to the unborn during the entire pregnancy be set to ensure a reasonable safety factor. The International Commission on Radiation Protection (ICRP) in their report No. 26 gives a similar recommendation (Ref. 2).

<u>Some Radioactive Material Can Be Inhaled or Swallowed</u>

Special care should be taken when a potentially pregnant woman is working with radioactive material that can be inhaled or swallowed. If you are pregnant, this type of radioactive material may enter your body and cross into your baby's body.[13] If you are working with such material, you should talk to the

[12]A rad is a measure of radiation dose similar to the rem. The radiation dose in rads may be converted to the dose in rems. For example, 10 rads at Hiroshima may have been more than 10 rems; the experts are not sure, but the matter is under study.

[13]Much of this information was presented by Steven A. Book in "Health Physics Education for the Pregnant Worker" at the 1980 Health Physics Society Meeting in Honolulu, Hawaii, December 1979.

person responsible for radiation protection at your place of work (such as the radiation safety officer or health physicist, if available) about the following questions:

1. Will the radioactive material be retained in my body?
2. Will the radioactive material cross from my body to my baby's body?
3. How can I avoid breathing or swallowing this radioactive material?
4. How can I get rid of this radioactive material if I get it into my body?

Radioiodine, a radioactive medicine widely used in hospitals for diagnostic and therapeutic purposes and in research laboratories, is a good example of the type of radioactive material that can enter your body. Radioiodine is important in this regard because it easily crosses into the unborn baby's body and may affect its thyroid gland, which starts to function at about the tenth week of pregnancy (Ref. 14). By the time of birth, the amount of radioiodine in each ounce of the baby's thyroid would be higher than that in the mother's thyroid (Ref. 14). In addition, the baby's thyroid is more sensitive than the adult thyroid (Ref. 15). Radioiodine as a gas easily mixes with the air and has been reported to be present in nuclear medicine workers in concentrations several times higher than workers who did not usually work directly with radioiodine (Ref. 16).

Summary of Risks

Occupational exposures to radiation are, for most workers in NRC-licensed activities, well below the established limits. However, qualified scientists have recommended that the radiation dose to the unborn as a result of occupational exposure of the expectant mother should not exceed 0.5 rem because of possible effects on development of the unborn child and an increased risk of childhood leukemia and cancer. Since 0.5 rem per 9 months is lower than the dose generally permitted for adult radiation workers, women workers may want to take special actions to avoid receiving exposures higher than 0.5 rem per 9 months. Similarly, women may stop smoking and drinking during pregnancy or may restrict their intake of drugs and caffeinated beverages -- all to reduce risks to their developing babies.

APPENDIX REFERENCES

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11. Marjorie Sun, "Briefing: FDA Caffeine Decision Too Early, Some Say," Science, Vol. 209, p. 1500, September 29, 1980.

12. National Academy of Sciences, Report of the Committee on the Biological Effects of Ionizing Radiation (BEIR-80 Report), "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," November 1980.

13. NCRP, "Review of NCRP Radiation Dose Limit for Embryo and Fetus in Occupationally-Exposed Women; Recommendations of the National Council on Radiation Protection and Measurements," NCRP Report No. 53, NCRP Publications, Washington, DC, March 1977.

14. S. A. Book and M. Goldman, "Thyroidal Radioiodine Exposure of the Fetus," Health Physics, Vol. 29, ~~No. 1, July 1975.~~ No. 6, December 1975.

15. S. A. Book, D. A. McNeill, and W. L. Spangler, "Age and Its Influence on Effects of Iodine-131 in Guinea Pigs' Thyroid Glands," Radiation Research, Vol. 81, No. 2, February 1980.

16. M. Blum and A. Tuizzi, "Thyroidal I-131 Burdens in Medical and Paramedical Personnel," Journal of the American Medical Association, Vol. 200, p. 184, 1967.

APPENDIX TO REGULATORY GUIDE 8.29

INSTRUCTION CONCERNING RISKS FROM OCCUPATIONAL RADIATION EXPOSURE

This instructional material is intended to provide the user with the best available information concerning what is currently known about the health risks from exposure to ionizing radiation.[1] A question and answer format has been used. The questions were developed by the NRC staff in consultation with workers, union representatives, and licensee representatives experienced in radiation protection training. Risk estimates have been compiled from numerous sources generally recognized as reliable. A bibliography is included for the user interested in further study.

The biological effects that are known to occur after exposure to high doses (hundreds of rems[2]) of radiation are discussed early in the document; discussions of the estimated risks from the low occupational dose (<5 rems per year) follow. It is intended that this information will help develop an attitude of healthy respect for the risks associated with radiation, rather than unnecessary fear or lack of concern. Additional guidance is being or will be developed concerning other topics in radiation protection training.

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1. *What is meant by risk?*

Risk can be defined in general as the probability (chance) of injury, illness, or death resulting from some activity. However, the perception of risk is affected by how the individual views its probability and its severity. The intent of this document is to provide estimates of and explain the basis for possible risk of injury, illness, or death resulting from occupational radiation exposure. (See Questions 9 and 10 for estimates of radiation risk and comparisons with other types of risk.)

2. *What are the possible health effects of exposure to radiation?*

Some of the health effects that exposure to radiation may cause are cancer (including leukemia), birth defects in the future children of exposed parents, and cataracts.[3] These effects (with the exception of genetic effects) have been observed in studies of medical radiologists, uranium miners, radium workers, and radiotherapy patients who have received large doses of radiation. Studies of people exposed to radiation from atomic weapons have also provided data on radiation effects. In addition, radiation effects studies with laboratory animals have provided a large body of data on radiation-induced health effects, including genetic effects.

The observations and studies mentioned above, however, involve levels of radiation exposure that are much higher (hundreds of rems) than those permitted occupationally today (<5 rems per year). Although studies have not shown a cause-effect relationship between health effects and current levels of occupational radiation exposure, it is prudent to assume that some health effects do occur at the lower exposure levels.

3. *What is meant by prompt effects, delayed effects, and genetic effects?*

a. Prompt effects are observable shortly after receiving a very large dose in a short period of time. For example, a whole-body[4] dose of 450 rems (90 times the annual dose limit for routine occupational exposure) in an hour to an average adult will cause vomiting and diarrhea within a few hours; loss of hair, fever, and weight loss within a few weeks; and about a 50 percent chance of death within 60 days without medical treatment.

b. Delayed effects such as cancer may occur years after exposure to radiation.

c. Genetic effects can occur when there is radiation damage to the genetic material. These effects may show up as birth defects or other conditions in the future children of the exposed individual and succeeding generations, as demonstrated in animal experiments. However, excess genetic effects clearly caused by radiation have not been observed in human populations exposed to radiation. It has been observed, however, that radiation can change the genes in cells of the human body. Thus, the possibility exists that genetic effects can be caused in humans by low doses even though no direct evidence exists as yet.

4. *In worker protection, which effects are of most concern to the NRC?*

The main concern to the NRC is the delayed incidence of cancer. The chance of delayed cancer is believed to depend

[1] Ionizing radiation consists of energy or small particles such as gamma, beta, or alpha radiation emitted from radioactive materials which, when absorbed by living tissue, can cause chemical and physical damage.

[2] The rem is the unit of measure for radiation dose and relates to the biological effect of the absorbed radiation.

[3] Cataracts differ from other radiation effects in that a certain level of dose to the lens of the eye (~200 rems) is required before they are observed.

[4] It is important to distinguish between whole-body and partial-body exposure. 100 rems to the whole body will have more effect than 100 to a hand. For example, exposure of a hand would affect a small fraction of the bone marrow and a limited portion of the skin.

on how much radiation exposure a person gets; therefore, every reasonable effort should be made to keep exposures low.

Immediate or prompt effects are very unlikely since large exposures would normally occur only if there were a serious radiation accident. Accident rates in the radiation industry have been low, and only a few accidents have resulted in exposures exceeding the legal limits. The probability of serious genetic effects in the future children of workers is estimated in the BEIR[5] report, based on animal studies, at less than one-third that of delayed cancer (5-65 genetic effects per million rems compared to 160-450 cancer cases). A clearer understanding of the cause-effect relationship between radiation and human genetic effects will not be possible until additional research studies are completed.

5. ***What is the difference between acute and chronic exposure?***

Acute radiation exposure, which causes prompt effects and may also cause delayed effects, usually refers to a large dose of radiation received in a short period of time; for example, 450 rems received within a few hours or less. The effects of acute exposures are well known from studies of radiotherapy patients, some of whom received whole-body doses; atomic bomb victims; and the few accidents that have occurred in the early days of atomic weapons and reactor development, industrial radiography, and nuclear fuel processing. There have been few occupational incidents that have resulted in large exposures. NRC data indicate that, on the average, 1 accidental overexposure in which any acute symptoms are observed occurs each year. Most of these occur in industrial radiography and involve exposures of the hands rather than the whole body.

Chronic exposure, which may cause delayed effects but not prompt effects, refers to small doses received repeatedly over long time periods; for example, 20-100 mrem (a mrem is one-thousandth of a rem) per week every week for several years. Concern with occupational radiation risk is primarily focused on chronic exposure to low levels of radiation over long time periods.

6. ***How does radiation cause cancer?***

How radiation causes cancer is not well understood. It is impossible to tell whether a given cancer was caused by radiation or by some other of the many apparent causes. However, most diseases are caused by the interaction of several factors. General physical condition, inherited traits, age, sex, and exposure to other cancer-causing agents such as cigarette smoke are a few possible contributing factors. One theory is that radiation can damage chromosomes in a cell, and the cell is then directed along abnormal growth patterns. Another is that radiation reduces the body's normal resistance to existing viruses which can then multiply and damage cells. A third is that radiation activates an existing virus in the body which then attacks normal cells causing them to grow rapidly.

What is known is that, in groups of highly exposed people, a higher than normal incidence of cancer is observed. Higher than normal rates of cancer can also be produced in laboratory animals by high levels of radiation. An increased incidence of cancer has not been demonstrated at radiation levels below the NRC limits.

7. ***If I receive a radiation dose, does that mean I am certain to get cancer?***

Not at all. Everyone gets a radiation dose every day (see Question 25), but most people do not get cancer. Even with doses of radiation far above legal limits, most individuals will experience no delayed consequences. There is evidence that some radiation damage can be repaired. The danger from radiation is much like the danger from cigarette smoke. Only a fraction of the people who breathe cigarette smoke get lung cancer, but there is good evidence that smoking increases a person's chances of getting lung cancer. Similarly, there is evidence that the larger the radiation dose, the larger the increase in a person's chances of getting cancer.

Radiation is like most substances that cause cancer in that the effects can be seen clearly only at high doses. Estimates of the risks of cancer at low levels of exposure are derived from data available for exposures at high dose levels and high dose rates. Generally, for radiation protection purposes these estimates are made using the linear model (Curve 1 in Figure 1). We have data on health effects at high doses as shown by the solid line in Figure 1. Below about 100 rems, studies have not been able to accurately measure the risk, primarily because of the small numbers of exposed people and because the effect is small compared to differences in the normal incidence from year to year and place to place. Most scientists believe that there is some degree of risk no matter how small the dose (Curves 1 and 2). Some scientists believe that the risk drops off to zero at some low dose (Curve 3), the threshold effect. A few believe that risk levels off so that even very small doses imply a significant risk (Curve 4). The majority of scientists today endorse either the linear model (Curve 1) or the linear-quadratic model (Curve 2). The NRC endorses the linear model (Curve 1), which shows the number of effects decreasing as the dose decreases, for radiation protection purposes.

It is prudent to assume that smaller doses have some chance of causing cancer. This is as true for natural cancer-causers such as sunlight and natural radiation as it is for those that are man made such as cigarette smoke, smog, and man-made radiation. As even very small doses may entail some small risk, it follows that no dose should be taken without a reason. Thus, a principle of radiation protection is to do more than merely meet the allowed regulatory

[5]The National Academy of Sciences established a committee on the Biological Effects of Ionizing Radiation (BEIR) whose 1980 report on the effects on populations of exposure to low levels of ionizing radiation provides much of the background for this guide.

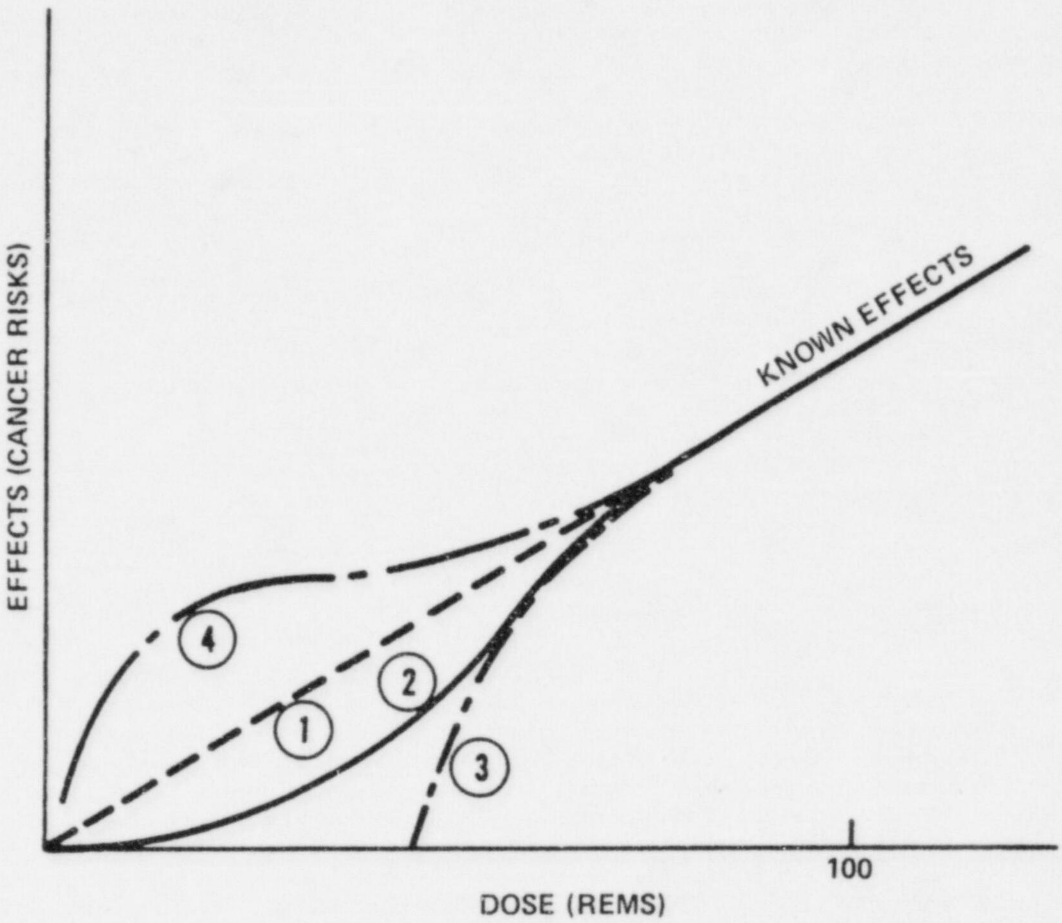

Figure 1. Some proposed models for how the effects of radiation vary with doses at low levels.

limits; doses should be kept as low as is reasonably achievable (ALARA).

We don't know exactly what the chances are of getting cancer from a low-level radiation dose, but we can make estimates based on extensive scientific knowledge. The estimates of radiation risks are at least as reliable as estimates for the effects from any chemical hazard. Being exposed to typical occupational radiation doses is taking a chance, but that chance is reasonably well understood.

It is important to understand the probability factors here. A similar question would be: If you select one card from a full deck, will you get the ace of spades? This question cannot be answered with a simple yes or no. The best answer is that your chances are 1 in 52. However, if 1000 people each select one card from full decks, we can predict that about 20 of them will get an ace of spades. Each person will have 1 chance in 52 of drawing the ace of spades, but there is no way that we can predict which persons will get the right card. The issue is further complicated by the fact that in 1 drawing by 1000 people, we might get only 15 successes and in another perhaps 25 correct cards in 1000 draws. We can say that if you receive a radiation dose, you will have increased your chances of eventually developing cancer. It is assumed that the more radiation exposure you get, the more you increase your chances of cancer.

Not all workers incur the same level of risk. The radiation risk incurred by a worker depends on the amount of dose received. Under the linear model explained above, a worker who receives 5 rems in a year incurs 10 times as much risk as another worker (the same age) who receives only 0.5 rem. The risk depends not only on the amount of dose, but also on the age of the worker at the time the dose is received. This age difference is due, in part, to the fact that a young worker has more time to live than an older worker, and the risk is believed to depend on the number of years of life following the dose. The more years left, the larger the risk. It should be clear that, even within the regulatory dose limits, the risk may vary a great deal from one worker to another. Fortunately, only a very few workers receive doses near 5 rems per year; as pointed out in the answer to Question 19, the average annual dose for all radiation workers is less than 0.5 rem.

A reasonable comparison involves exposure to the sun's rays. Frequent short exposures provide time for the skin to repair. An acute exposure to the sun can result in painful burning, and excessive exposure has been shown to cause skin cancer. However, whether exposure to the sun's rays is short term or spread over time, some of the injury is not repaired and may eventually result in skin cancer.

The effect upon a group of workers occupationally exposed to radiation may be an increased incidence of cancer over and above the number of cancers that would normally be expected in that group. Each exposed individual has an increased probability of incurring subsequent cancer. We can say that if 10,000 workers each receive an additional 1 rem in a year, that group is more likely to have a larger incidence of cancer than 10,000 people who do not receive the additional radiation. An estimate of the increased probability of cancer from low radiation doses delivered to large groups is one measure of occupational risk and is discussed in Question 9.

8. ***What groups of expert scientists have studied the risk from exposure to radiation?***

In 1956, the National Academy of Sciences established advisory committees to consider radiation risks. The first of these was the Advisory Committee on the Biological Effects of Atomic Radiations (BEAR) and more recently it was renamed the Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR). These committees have periodically reviewed the extensive research being done on the health effects of ionizing radiation and have published estimates of the risk of cancer from exposure to radiation (1972 and 1980 BEIR reports). The International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurement (NCRP) are two other groups of scientists who have studied radiation effects and published risk estimates (ICRP Publication 26, 1977). These two groups have no government affiliation. In addition, the United Nations established an independent study group that published an extensive report in 1977, including estimates of cancer risk from ionizing radiation (UNSCEAR, 1977).

Several individual research groups or scientists such as Alice Stewart, E.S. Gilbert, T.F. Mancuso, T.W. Anderson, to name a few, have published studies concerning low-level radiation effects. The bibliography to this appendix includes several articles for the reader who wishes to do further study. The BEIR-80 report includes analysis of the work of many independent researchers.

9. ***What are the estimates of the risk of cancer from radiation exposure?***

The cancer risk estimates (developed by the organizations identified in Question 8) are presented in Table 1.

In an effort to explain the significance of these estimates, we will use an approximate average of 300 excess cancer cases per million people, each exposed to 1 rem of ionizing radiation. If in a group of 10,000 workers each receives 1 rem, we could estimate that three would develop cancer because of that exposure, although the actual number could be more or less than three.

TABLE 1

Estimates of Excess Cancer Incidence from Exposure to Low-Level Radiation

Source	Number of Additional[a] Cancers Estimated to Occur in 1 Million People After Exposure of Each to 1 Rem of Radiation
BEIR, 1980	160-450[b]
ICRP, 1977	200
UNSCEAR, 1977	150-350

[a] Additional means above the normal incidence of cancer.

[b] All three groups estimated premature deaths from radiation-induced cancers. The American Cancer Society has recently stated that only about one-half of all cancer cases are fatal. Thus, to estimate incidence of cancer, the published numbers were multiplied by 2. Note that the three groups are in close agreement on the risk of radiation-induced cancer.

The American Cancer Society has reported that approximately 25 percent of all adults in the 20- to 65-year age bracket will develop cancer at some time from all possible causes such as smoking, food, alcohol, drugs, air pollutants, and natural background radiation. Thus in any group of 10,000 workers not exposed to radiation on the job, we can expect about 2,500 to develop cancer. If this entire group of 10,000 workers were to receive an occupational radiation dose of 1 rem each, we could estimate that three additional cases might occur which would give a total of about 2,503. This means that a 1-rem dose to each of 10,000 workers might increase the cancer rate from 25 percent to 25.03 percent, an increase of about 3 hundredths of one percent.

As an individual, if your cumulative occupational radiation dose is 1 rem, your chances of eventually developing cancer during your entire lifetime may have increased from 25 percent to 25.03 percent. If your lifetime occupational dose is 10 rems, we could estimate a 25.3 percent chance of developing cancer. Using a simple linear model, a lifetime dose of 100 rems may have increased your chances of cancer from 25 to 28 percent.

The normal chance of developing cancer if you receive no occupational radiation dose is about equal to your chance of getting any spade on a single draw from a full deck of playing cards, which is one chance out of four. The additional chance of developing cancer from an occupational exposure of 1 rem is less than your chances of drawing an ace from a full deck of cards three times in a row.

Since cancer resulting from exposure to radiation usually occurs 5 to 25 years after the exposure and since not all cancers are fatal, another useful measure of risk is years of life expectancy lost on the average from a radiation-induced cancer. It has been estimated in several studies that the average loss of life expectancy from exposure to radiation is about 1 day per rem of exposure. In other words, a person exposed to 1 rem of radiation may, on the average, lose 1 day of life. The words "on the average" are important, however, because the person who gets cancer from radiation may lose several years of life expectancy while his coworkers suffer no loss. The ICRP estimated that the average number of years of life lost from fatal industrial accidents is 30 while the average number of years of life lost from a fatal radiation-induced cancer is 10. The shorter loss of life expectancy is due to the delayed onset of cancer.

It is important to realize that these risk numbers are only estimates. Many difficulties are involved in designing research studies that can accurately measure the small increases in cancer cases due to low exposures to radiation as compared to the normal rate of cancer. There is still uncertainty and a great deal of controversy with regard to estimates of radiation risk. The numbers used here result from studies involving high doses and high dose rates, and they may not apply to doses at the lower occupational levels of exposure. The NRC and other agencies both in the United States and abroad are continuing extensive long-range research programs on radiation risk.

Some members of the National Academy of Sciences BEIR Advisory Committee and others feel that risk estimates in Table 1 are higher than would actually occur and represent an upper limit on the risk. Other scientists believe that the estimates are low and that the risk could be higher. However, these estimates are considered by the NRC staff to be the best available that the worker can use to make an informed decision concerning acceptance of the risks associated with exposure to radiation. A worker who decides to accept this risk should make every effort to keep exposure to radiation ALARA to avoid unnecessary risk. The worker, after all, has the first line responsibility for protecting himself from radiation hazards.

10. How can we compare radiation risk to other kinds of health risks?

Perhaps the most useful unit for comparison among health risks is the average number of days of life expectancy lost per unit of exposure to each particular health risk. Estimates are calculated by looking at a large number of persons, recording the age when death occurs from apparent causes, and estimating the number of days of life lost as a result of these early deaths. The total number of days of life lost is then averaged over the total group observed.

Several studies have compared the projected loss of life expectancy resulting from exposure to radiation with other health risks. Some representative numbers are presented in Table 2.

These estimates indicate that the health risks from occupational radiation exposure are smaller than the risks associated with many other events or activities we encounter and accept in normal day-to-day activities.

TABLE 2

Estimated Loss of Life Expectancy from Health Risks[a]

Health Risk	Estimates of Days of Life Expectancy Lost, Average
Smoking 20 cigarettes/day	2370 (6.5 years)
Overweight (by 20%)	985 (2.7 years)
All accidents combined	435 (1.2 years)
Auto accidents	200
Alcohol consumption (U.S. average)	130
Home accidents	95
Drowning	41
Natural background radiation, calculated	8
Medical diagnostic x-rays (U.S. average), calculated	6
All catastrophes (earthquake, etc.)	3.5
1 rem occupational radiation dose, calculated (industry average for the higher-dose job categories is 0.65 rem/yr)	1
1 rem/yr for 30 years, calculated	30

[a]Adapted from Cohen and Lee, "A Catalogue of Risks," *Health Physics*, Vol. 36, June 1979.

A second useful comparison is to look at estimates of the average number of days of life expectancy lost from exposure to radiation and from common industrial accidents at radiation-related facilities and to compare this number with days lost from other occupational accidents. Table 3 shows average days of life expectancy lost as a result of fatal work-related accidents. Note that the data for occupations other than radiation related do not include death risks from other possible hazards such as exposure to toxic chemicals, dusts, or unusual temperatures. Note also that the unlikely occupational exposure at 5 rems per year for 50 years, the maximum allowable risk level, may result in a risk comparable to the average risks in mining and heavy construction.

Industrial accident rates in the nuclear industry and related occupational areas have been relatively low during the entire history of the industry (see Table 4). This is believed to be due to the early and continuing emphasis on tight safety controls. The relative safety of various occupational areas can be seen by comparing the probability of death by accident per 10,000 workers over a 40-year working lifetime. These figures do not include death from possible causes such as exposure to toxic chemicals or radiation.

11. Can a worker become sterile or impotent from occupational radiation exposure?

Observation of radiation therapy patients who receive localized exposures, usually spread over a few weeks, has

TABLE 3

Estimated Loss of Life Expectancy from Industrial Hazards[a]

Industry Type	Estimates of Days of Life Expectancy Lost, Average
All industry	74
Trade	30
Manufacturing	43
Service	47
Government	55
Transportation and utilities	164
Agriculture	277
Construction	302
Mining and quarrying	328
Radiation accidents, death from exposure	<1
Radiation dose of 0.65 rem/yr (industry average) for 30 years, calculated	20
Radiation dose of 5 rems/yr for 50 years	250
Industrial accidents at nuclear facilities (nonradiation)	58

[a]Adapted from Cohen and Lee, "A Catalogue of Risk," *Health Physics*, Vol. 36, June 1979; and World Health Organization, *Health Implications of Nuclear Power Production*, December 1975.

TABLE 4

Probability of Accidental Death by Type of Occupation[a]

Occupation	Number of Accidental Deaths for 10,000 Workers for 40 Years
Mining	252
Construction	228
Agriculture	216
Transportation and public utilities	116
All industries	56
Government	44
Nuclear industry (1975 data excluding construction)	40
Manufacturing	36
Services	28
Wholesale and trade	24

[a]Adapted from National Safety Council, *Accident Facts*, 1979; and Atomic Energy Commission, *Operational Accidents and Radiation Exposure Experience*, WASH-1192, 1975.

shown that a dose of 500-800 rems to the gonads can produce permanent sterility in males or females (an acute whole-body dose of this magnitude would probably result in death within 60 days). An acute dose of 20 rems to the testes can result in a measurable but temporary reduction in sperm count. Such high exposures on the job could result only from serious and unlikely radiation accidents. Although high doses of radiation can affect fertility, they have no effect on the ability to function sexually. Likewise, exposure to permitted occupational levels of radiation has no observed effect on fertility and also has no effect on the ability to function sexually.

12. What are the NRC external radiation dose limits?

Federal regulations currently limit occupational external whole-body radiation dose to 1¼ rems in any calendar quarter or specified 3-month period. However, when there is documented evidence that a worker's previous occupational dose is low enough, a licensee may permit a dose of up to 3 rems per quarter or 12 rems per year. The accumulated dose may not exceed 5(N - 18) rems[6] where N is the person's age in years, i.e., the lifetime occupational dose may not exceed an average of 5 rems for each year above the age of 18.

An additional whole-body dose of approximately 5 rems per year is permitted from internal exposure. (See Question 28.)

13. What is meant by ALARA?

In addition to providing an upper limit on a person's permissible radiation exposure, the NRC also requires that its licensees maintain occupational exposures as far below the limit as is reasonably achievable (ALARA). This means that every activity at a nuclear facility involving exposure to radiation should be planned so as to minimize unnecessary exposure to individual workers and also to the worker population. A job that involves exposure to radiation should be scheduled only when it is clear that the benefit justifies the risks assumed. All design, construction, and operating procedures should be reviewed with the objective of reducing unnecessary exposures.

14. Has the ALARA concept been applied if, instead of reaching dose limits during the first week of a quarter, the worker's dose is spread out over the whole quarter?

No. For radiation protection purposes, the risk of cancer from low doses is assumed to be proportional to the amount of exposure, not the rate at which it is received. Thus it is assumed that spreading the dose out over time or over larger numbers of people does not reduce the overall risk. The ALARA concept has been followed only when the individual and collective doses are reduced by reducing the time of exposure or decreasing radiation levels in the

[6]The NRC has published a proposed rule change for public comment that would eliminate the 5(N-18) formula. This proposal is currently under consideration by a task force reviewing all of 10 CFR Part 20. Recent EPA guidance recommends eliminating the 5(N-18) formula. If adopted, the maximum allowed annual dose will be 5 rems rather than 12.

individual and collective doses are reduced by reducing the time of exposure or decreasing radiation levels in the working environment.

15. What is meant by collective dose and why should it be maintained ALARA?

Nuclear industry activities expose an increasing number of people to occupational radiation in addition to the radiation doses they receive from natural background radiation and medical radiation exposures. The collective occupational dose (person-rems) is the sum of all occupational radiation exposure received by all the workers in an entire worker population. For example, if 100 workers each receive 2 rems, the individual dose is 2 rems and the collective dose is 200 person-rems. The total additional risk of cancer and genetic effects in an exposed population is assumed to depend on the collective dose.

It should be noted that, from the viewpoint of risk to a total population, it is the collective dose that must be controlled. For a given collective dose, the number of health effects is assumed to be the same even if a larger number of people share the dose. Therefore, spreading the dose out may reduce the individual risk, but not that of the population.

Efforts should be made to maintain the collective dose ALARA so as not to unnecessarily increase the overall population incidence of cancer and genetic effects.

16. Is the use of extra workers a good way to reduce risks?

There is a "yes" answer to this question and a "no" answer. For a given job involving exposure to radiation, the more people who share the work, the lower the average dose to an individual. The lower the dose, the lower the risk. So, for you as an individual, the answer is "yes."

But how about the risk to the entire group of workers? Under assumptions used by the NRC for purposes of protection, the risk of cancer depends on the total amount of radiation energy absorbed by human tissue, not on the number of people to whom this tissue belongs. Therefore, if 30 workers are used to do a job instead of 10, and if both groups get the same collective dose (person-rems), the total cancer risk is the same, and nothing was gained for the group by using 30 workers. From this viewpoint the answer is "no." The risk was not reduced but simply spread around among a larger number of persons.

Unfortunately, spreading the risk around often results in a larger collective dose for the job. Workers are exposed as they approach a job, while they are getting oriented to do the job, and as they withdraw from the job. The dose received during these actions is called nonproductive. If several crew changes are required, the nonproductive dose can become very large. Thus it can be seen that the use of extra workers may actually increase the total occupational dose and the resulting collective risks.

The use of extra workers to comply with NRC dose limits is not the way to reduce the risk of radiation-induced cancer for the worker population. At best, the total risk remains the same, and it may even be increased. The only way to reduce the risk is to reduce the collective dose; that can be done only by reducing the radiation levels, the working times, or both.

17. Why doesn't the NRC impose collective dose limits?

Compliance with individual dose limits can be achieved simply by using extra workers. However, compliance with a collective dose limit (such as 100 person-rems per year for a licensee) would require reduction of radiation levels, working times, or both. But there are many problems associated with setting appropriate collective dose limits.

For example, we might consider applying a single collective dose limit to all licensees. The selection of such a collective dose limit would be almost impossible because of the wide variations in collective doses among licensees. A power reactor could reasonably be expected to have an average annual collective dose of several hundred person-rems. However, a small industrial radiography licensee could very well have a collective dose of only a few person-rems in a year.

Even choosing a collective dose limit for a group of similar licensees would be almost as difficult. Radiography licensees as a group had an average collective dose in 1977 of 9 person-rems. However, the smallest collective dose for a radiography licensee was less than 1 person-rem, and the largest was 401 person-rems.

Setting a reasonable collective dose limit for each individual licensee would also be very difficult. It would require a record of all past collective doses on which to base such limits. Setting an annual collective dose limit would then amount to an attempt to predict a reasonable collective dose for each future year. In order to do this, it would be necessary to be able to predict changes in each licensed activity that would increase or decrease the collective dose. In addition, annual collective doses vary significantly from year to year according to the kind and amount of maintenance required, which cannot generally be predicted in advance. Following all such changes and revising limits up and down would be very difficult if not impossible. However, these efforts would be necessary if a collective dose limit were to be reasonable and help minimize doses and risks.

18. How are radiation dose limits established?

The NRC establishes occupational radiation dose limits based on guidance to Federal agencies from the Environmental Protection Agency (EPA) and, in addition, considers NCRP and ICRP recommendations. Scientific reviews of research data on biological effects such as the BEIR report are also considered.

For example, recent EPA guidance recommended that the annual whole-body dose limit be established at 5 rems per year and indicated that exposure, year after year, to 5 rems would involve a risk to a worker comparable to the average risks incurred by workers in the higher risk jobs such as mining. In fact, few workers ever reach such a limit, much less year after year, and the risks associated with actual exposures are considered by the EPA to be comparable to the safer job categories. A 5-rem-per-year limit would allow occasional high dose jobs to be done without excessive risk.

19. What are the typical radiation doses received by workers?

The NRC requires that certain categories of licensees report data on annual worker doses and doses for all workers who leave employment with licensees. Data were received on the occupational doses in 1977 of approximately 100,000 workers in power reactors, industrial radiography, fuel processing and fabrication facilities, and manufacturing and distribution facilities. Of this total group, 85 percent received an annual dose of less than 1 rem; 95 percent received less than 2 rems; fewer than 1 percent exceeded 5 rems in 1 year. The average annual dose of those workers who were monitored and had measurable exposures was about 0.65 rem. A study completed by the EPA, using 1975 exposure data for 1,260,000 workers, indicated that the average annual dose for all workers who received a measurable dose was 0.34 rem.

Table 5 lists average occupational exposures for workers (persons who had measurable exposure above background levels) in various occupations, based on the 1975 data.

TABLE 5

U.S. Occupational Exposure Estimates[a]

Occupational Subgroup	Average Whole-Body Dose (millirems)	Collective Dose (person-rems)
Medicine	320	51,400
Industrial Radiography	580	5,700
Source Manufacturing	630	2,500
Power Reactors	760	21,400
Fuel Fabrication and Reprocessing	560	3,100
Uranium Enrichment	70	400
Nuclear Waste Disposal	920	100
Uranium Mills	380	760
Department of Energy Facilities	300	11,800
Department of Defense Facilities	180	10,100
Educational Institutions	206	1,500
Transportation	200	2,300

[a]Adapted from Cook and Nelson, *Occupational Exposures to Ionizing Radiation in the United States: A Comprehensive Summary for 1975*. Draft, Environmental Protection Agency.

20. What happens if a worker exceeds the quarterly exposure limit?

Radiation protection limits, such as 3 rems in 3 months, are not absolute limits below which it is safe and above which there is danger. Exceeding a limit does not imply that you have suffered an injury. A good comparison is with the highway speed limit, which is selected to limit accident risk and still allow you to get somewhere. If you drive at 75 mph, you increase your risk of an auto accident to levels that are not considered acceptable by the people who set speed limits, even though you may not actually have an accident. If a worker's radiation dose repeatedly exceeds 3 rems in a quarter, the risk of health effects could eventually increase to a level that is not considered acceptable to the NRC. Exceeding an NRC protection limit does not mean that any adverse health effects are going to occur. It does mean that a licensee's safety program has failed in some respect and that the NRC and the licensee should investigate to make sure the problems are corrected.

If an overexposure occurs, the regulations prohibit any additional occupational exposure to that person during the remainder of the calendar quarter in which the overexposure occurred. The licensee is required to file an overexposure report to the NRC and may possibly be subject to a fine, just as you are subject to a traffic fine for exceeding the speed limit. In both cases, the fines and, in some serious or repetitive cases, suspension of license are intended to encourage efforts to operate within the limits. The safest limits would be 0 mph and 0 rem per quarter. But then we wouldn't get anywhere.

21. Why do some facilities establish administrative limits that are below the NRC limits?

There are two reasons. First, the NRC regulations state that licensees should keep exposures to radiation ALARA. By requiring specific approval for worker doses in excess of set levels, more careful risk-benefit analysis can be made as each additional increment of dose is approved for a worker. Secondly, a facility administrative limit that is set lower than the quarterly NRC limit provides a safety margin designed to help the licensee avoid overexposures.

22. Several scientists have suggested that NRC limits are too high and should be lowered. What are the arguments for lowering the limits?

In general, those critical of present dose limits say that the individual risk is higher than is estimated by the BEIR Committee, the ICRP, and UNSCEAR. Based on studies of low-level exposures to large groups, some researchers have concluded that a given dose of radiation may be more likely to cause biological effects than previously thought. Some of these studies are listed in the bibliography (Mancuso, Archer) and the BEIR-80 report includes a section analyzing the findings of these and other studies. Scientific opinion differs on the validity of the research methods used and the methods of statistical analysis. The problem is that the expected additional incidence of radiation-caused effects such as cancer is difficult to detect in comparison with the much larger normal incidence. It cannot be shown without question that these effects were more frequent in the exposed study group than in the unexposed group used for comparison, or that the observed effects were caused by radiation. The BEIR committee concluded that claims of higher risk had "no substance."

The NRC staff continually reviews the results of research on radiation risks. With respect to large-scale studies of radiation-induced health effects in human populations exposed to low-level ionizing radiation, the NRC and EPA have recently concluded that there is no one population group available for which such a study could be expected to provide a more meaningful estimate of the low-level radiation risk. This is due, in large part, to the observed and estimated low incidence of radiation health effects from low doses. However, the results of ongoing studies, such as that on nuclear shipyard workers, will be carefully reviewed and the development of a radiation-worker registry is being considered as a possible data base for future studies.

23. *What are the reasons for not lowering the NRC dose limits?*

Assuming that the 5-rem-per-year limit is adopted, there are three reasons:

a. Health risks are already low.

The estimated health risks associated with current average occupational radiation doses (e.g., 0.5 rem/yr for 50 years) are comparable to or less than risk levels in other occupational areas considered to be among the safest. If a person were exposed to the maximum of 5 rems per year for 50 years, which virtually never occurs, he or she might incur a risk comparable to the average risks in mining and heavy construction. An occasional 5-rem annual dose might be necessary to allow some jobs to be done without a significant increase in the collective dose. If the dose limits were lowered significantly, the number of people required to complete many jobs would increase. The collective dose would then increase since more individuals would be receiving nonproductive exposure while entering and leaving the work area and preparing for the job. The total number of health effects might go up as the collective dose increased.

b. The current regulations are considered sound.

The regulatory standards for dose limits are based on the recommendations of the Federal Radiation Council. At the time these standards were developed, about 1960, it was considered unlikely that exposure to these levels during a working lifetime would result in clinical evidence of injury or disease different from that occurring in the unexposed population. The scientific data base for the standards consisted primarily of human experience (x-ray exposures to medical practitioners and patients, ingestion of radium by watch dial painters, early effects observed in Japanese atomic bomb survivors, radon exposures of uranium miners, occupational radiation accidents) involving very large doses delivered at high dose rates. The data base also included the results of a large number of animal experiments involving high doses and dose rates. The animal experiments were particularly useful in the evaluation of genetic effects. The observed effects were related to low-level radiation according to the linear model explained in Question 7. Based on this approach, the regulations in 10 CFR Part 20, "Standards for Protection Against Radiation," also state that licensees should maintain all radiation exposures, and releases of radioactive materials in effluents, as low as is reasonably achievable. More recent scientific reviews of the large body of experimental data, such as the BEIR-80 and the recent EPA guidance, continue to support the view that use of a 5-rem-per-year limit is acceptable in practice. Experience has shown that, under this limit, the average dose to workers is near 0.5 rem/yr with very few workers consistently approaching the limit.

c. There is little to gain.

Reducing the dose limits, for example, to 0.5 rem/yr has been analyzed by the NRC staff. An estimated 2.6 million person-rems could be saved from 1980 through the year 2000 by nuclear power plant licensees if compliance with the new limit were achieved by lowering the radiation levels, working times, or both, rather than by using extra workers. It is estimated that something like $23 billion would be spent toward this purpose. Spending $23 billion to save 2.6 million person-rems would amount to spending $30 to $90 million to prevent each potential radiation-induced premature cancer death. Society considers this cost unacceptably high for individual protection.

24. *Are there any areas of concern about radiation risks that might result in changing the NRC dose limits?*

Yes. Three areas of concern to the NRC staff are specifically identified below:

a. An independent study by Rossi and Mays and other biological research have indicated that a given dose of neutron radiation may be more likely to cause biological effects than was previously thought. Other recent studies cast doubt on the issue. The NCRP is currently studying the data related to the neutron radiation question and is expected to make recommendations as to whether neutron dose limits should be changed. Although the scientific community has not yet come to agreement on this question, workers should be advised of the possibility of higher risk when entering areas where exposure to neutrons will occur.

b. It has been known for some time that rapidly growing living tissue is more sensitive to injury from radiation than tissue in which the cells are not reproducing rapidly. Thus the embryo or fetus is more sensitive to radiation injury than an adult. The NCRP recommended in Report No. 39 that special precautions be taken when an occupationally exposed woman could be pregnant in order to protect the embryo or fetus. In 1975, the NRC issued Regulatory Guide 8.13, "Instruction Concerning Prenatal Radiation Exposure," in which it is recommended that licensees instruct all workers concerning this special risk. The guide recommends that all workers be advised that the NCRP recommended that the maximum permissible dose to the embryo or fetus from occupational exposure of the mother should not exceed 0.5 rem for the full 9-month pregnancy period. In addition, the guide suggests options available to the female employee who chooses not to expose her embryo or fetus to this additional risk.

The United States Department of Health and Human Services is similarly concerned about prenatal exposure from medical x-rays. In 1979 they published proposed guidelines for physicians concerning abdominal x-rays for possibly pregnant women. The guidelines in effect encourage the x-ray staff to make efforts to determine whether a female patient is pregnant and to defer x-rays if possible until after the child is born.

c. Also of special interest is the indication that female workers are subject to more risk of cancer incidence than male workers. In terms of all types of cancer except leukemia, the BEIR-80 analysis indicates that female workers have a risk of developing radiation-induced cancer that is approximately one and one-half times that for males. This increased risk is primarily due to the incidence of breast and thyroid cancer in women. These types of cancer, however, have a high cure rate. Thus the difference between men and women in cancer mortality is not great. Incidence of radiation-induced leukemia is about the same for both sexes. Female workers should be aware of this difference in the risks of radiation-induced cancer in deciding whether or not to seek work involving exposure to radiation.

25. How much radiation does the average person who does not work in the nuclear industry receive?

We are all exposed from the moment of conception to ionizing radiation from several sources. Our environment, and even the human body, contains naturally occurring radioactive materials that contribute some of the background radiation we receive. Cosmic radiation originating in space and in the sun contributes additional exposure. The use of x-rays and radioactive materials in medicine and dentistry adds considerably to our population exposure.

Table 6 shows estimated average individual exposure in millirems from natural background and other sources.

TABLE 6

U.S. General Population Exposure Estimates (1978)[a]

Source	Average Individual Dose (mrem/yr)
Natural background (average in U.S.)	100
Release of radioactive material in natural gas, mining, milling, etc.	5
Medical (whole-body equivalent)	90
Nuclear weapons (primarily fallout)	5-8
Nuclear energy	0.28
Consumer products	0.03
Total	~200 mrem/yr

[a]Adapted from a report by the Interagency Task Force on the Health Effects of Ionizing Radiation pubished by the Department of Health, Education, and Welfare.

Thus, the average individual in the general population receives about 0.2 rem of radiation exposure each year from sources that are a part of our natural and man-made environment. By the age of 20 years, an individual has accumulated about 4 rems. The most likely target for reduction of population exposure is medical uses.

26. Why aren't medical exposures considered as part of a worker's allowed dose?

Equal doses of medical and occupational radiation have equal risks.[7] Medical exposure to radiation should be justified for reasons quite different, however, from those applicable to occupational exposure. A physician prescribing an x-ray should be convinced that the benefit to the patient of the resulting medical information justifies the risk associated with the radiation. Each worker must decide on the acceptance of occupational radiation risk just as each worker must decide on the acceptability of any other occupational hazard.

For another point of view, consider a worker who receives a dose of 2 rems from a series of x-rays or a radioactive medicine in connection with an injury or illness. This dose and the implied risk should be justified on medical grounds. If the worker had also received a dose of 2 rems on the job, the combined dose of 4 rems would not incapacitate the worker. A dose of 4 rems is not especially dangerous and is not large compared to the cumulative lifetime dose. Restricting the worker from additional job exposure during the remainder of the quarter would have no effect one way or the other on the risk from the 2 rems already received from medical exposure. If the individual worker accepts the risks associated with the x-rays on the basis of the medical benefits and the risks associated with job-related exposure on the basis of employment benefits, it would be unfair to restrict the individual from employment in radiation areas for the remainder of the quarter.

Some therapeutic medical doses such as those received from cobalt-60 treatment can range as high as 6000 rems to a small part of the body, spread over a period of several weeks or months.

27. What is meant by internal exposure?

The total radiation dose to the worker is the external dose (measured by the film badge and reported as "whole-body dose") plus the dose from internal emitters. The monitoring of the additional internal dose is difficult. Because there is the possibility of internal doses occurring, a good air-monitoring program should be established when warranted.

The uptake of radioactive materials by workers is generally due to breathing contaminated air. Radioactive materials may be present as fine dust or gases in the workplace atmosphere. The surfaces of equipment and workbenches

[7]It is likely that a significant portion of reported medical x-ray exposure is to parts of the body only. An exposure of 100 mrem to the whole body is more significant than a 100-mrem chest x-ray.

may be contaminated. Radioactive materials may enter the body by being breathed in, taken in with food or drink, or being absorbed through the skin, particularly if the skin is broken.

After entering the body, the radioactive material will migrate to particular organs or particular parts of the body depending on the biochemistry of the material. For example, uranium will tend to deposit in the bones where it will remain for a long time. It is slowly eliminated from the body, mostly by way of the kidneys. Radium will also tend to deposit in the bones. Radioactive iodine will seek out the thyroid glands (located in the neck) and deposit there.

The dose from these internal emitters cannot be measured either by the film badge or by other ordinary dosimeters carried by the worker. This means that the internal radiation dose must be separately monitored using other detection methods.

Internal exposure can be estimated by measuring the radiation emitted from the body or by measuring the radioactive materials contained in biological samples such as urine or feces. Dose estimates can also be made if one knows how much radioactive material is in the air and the length of time during which the air was breathed.

28. How are the limits for internal exposure set?

Standards have been established for the maximum permissible amount of each radionuclide that may be accumulated in the critical organs[8] of the worker's body.

Calculations are made to determine the quantity of radioactive material that has been taken into the body and the total dose that would result. Then, based on limits established for particular body organs similar to 1¼ rems in a calendar quarter for whole-body exposure, the regulations specify maximum permissible concentrations of radioactive material in the air to which a worker can be exposed for 40 hours per week over 13 weeks or 1 calendar quarter. The regulations also require that efforts be made to keep internal exposure ALARA.

Internal exposure is controlled by limiting the release of radioactive material into the air and by carefully monitoring the work area for airborne radioactivity and surface contamination. Protective clothing and respiratory (breathing) protection should be used whenever the possibility of contact with loose radioactive material cannot be prevented.

29. Is the dose a person received from internal exposure added to that received from external exposure?

Exposure to radiation that results from radioactive materials taken into the body is measured, recorded, and reported to the worker separately from external dose. The internal dose to the whole body or to specific organs does not at this time count against the 3-rem-per-calendar-quarter limit. ICRP recommends that the internal and external doses should be appropriately added. This recommendation is currently under study by the staffs of the NRC, the EPA, and the Occupational Safety and Health Administration (OSHA).

30. How is a worker's external radiation dose determined?

A worker may wear three types of radiation-measuring devices. A self-reading pocket dosimeter records the exposure to incident radiation and can be read out immediately upon finishing a job involving external exposure to radiation. A film badge or TLD badge records radiation dose, either by the amount of darkening of the film or by storing energy in the TLD crystal. Both these devices require processing to determine the dose but are considered more reliable than the pocket dosimeter. A worker's official report of dose received is normally based on film or TLD badge readings, which provide a cumulative total and are more accurate.

31. What are my options if I decide not to accept the risks associated with occupational radiation exposure?

If the risks from exposure to radiation that may be expected to occur during your work are unacceptable to you, you could request a transfer to a job that does not involve exposure to radiation. However, the risks associated with exposure to radiation that workers, on the average, actually receive are considered acceptable, compared to other occupational risks, by virtually all the scientific groups that have studied them. Your employer is probably not obligated to guarantee you a transfer if you decide not to accept an assignment requiring exposure to radiation.

You also have the option of seeking other employment in a nonradiation occupation. However, the studies that have compared occupational risks in the nuclear industry to those in other job areas indicate that nuclear work is relatively safe. Thus, you will not necessarily find significantly lower risks in another job.

A third option would be to practice the most effective work procedures so as to keep your exposure ALARA. Be aware that reducing time of exposure, maintaining distance from radiation sources, and using shielding can all lower your exposure. Plan radiation jobs carefully to increase efficiency while in the radiation area. Learn the most effective methods of using protective clothing to avoid contamination. Discuss your job with the radiation protection personnel who can suggest additional ways to reduce your exposure.

32. Where can I get additional information on radiation risk?

The following list suggests sources of useful information on radiation risk:

a. Your Employer

The radiation protection or health physics office in the facility where you are employed.

[8] Critical organ refers to those parts of the body vulnerable to radiation damage such as bone, lungs, thyroid, and other systems where certain radioactive materials will concentrate if taken into the body.

b. Nuclear Regulatory Commission

Regional Offices

King of Prussia, PA 19406	215-337-5000
Atlanta, GA 30303	404-221-4503
Glen Ellyn, IL 60137	312-932-2500
Arlington, TX 76012	817-334-2841
Walnut Creek, CA 94596	415-943-3700

Headquarters

Occupational Radiation Protection Branch
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Telephone: 301-443-5970

c. Department of Health and Human Services

Office of the Director
Bureau of Radiological Health (HFX-1)
Department of Health and Human Services
5600 Fishers Lane
Rockville, MD 20857

Telephone: 301-443-4690

d. Environmental Protection Agency

Office of Radiation Programs
U.S. Environmental Protection Agency
401 M Street, SW
Washington, D.C. 20460

Telephone: 703-557-9710