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INSTRUCTION CONCERNING RISK FROM OCCUPATIONAL RADIATION EXPOSURE

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A. INTRODUCTION

Section 19.12 of 10 CFR Part 19, "Notices, Instructions and Reports to Workers; Inspections," requires that all individuals working in or frequenting any portion of a restricted area be instructed in the health protection problems associated with exposure to radioactive materials or radiation. This guide describes the instruction that should be provided concerning biological risks to the worker from occupational radiation exposure.

B. DISCUSSION

It is generally accepted by the scientific community that exposure to ionizing radiation may cause biological effects that may be harmful to the exposed organism. These effects are generally classified into two general categories. These categories are Somatic Effects, i.e., effects occurring in the exposed person which, in turn, may be divided into two classes: prompt effects that are observable soon after a large or acute dose (e.g., 25 rems or more in a few hours) and delayed effects such as cancer that may occur years after exposure to radiation; and Genetic Effects,* i.e., abnormalities that may occur in the children of exposed individuals and in subsequent generations. Concerns about these biological effects have resulted in stringent controls on

*Genetic Effects have not been observed in any of the studies of exposed humans.

doses to individual workers and in efforts to control the collective dose (man-rems) to the worker population.

NRC licensee activities result in a significant fraction of the total occupational radiation exposure in the United States. Regulatory action has recently focused more attention on implementing the philosophy of maintaining occupational radiation exposure at levels that are as low as is reasonably achievable (ALARA). Radiation protection training for all workers who may be exposed to ionizing radiation is an essential component of any program designed to maintain exposure levels ALARA. A clear understanding of what is presently known about the biological risks associated with exposure to radiation will result in more effective radiation protection training and should generate more interest on the part of the worker in minimizing both individual and collective doses. In addition, radiation workers have the right to whatever information on radiation risk is available to enable them to make informed decisions regarding the acceptance of these risks.

At the relatively low levels of occupational radiation exposure in the United States, it is difficult to demonstrate correlations between exposure and effect. There is considerable uncertainty and controversy regarding estimates of radiation risk. In the appendix to this guide, a range of risk estimates is provided (see Table 1). Information on radiation risk has been included from such sources as the 1979 National Academy of Sciences Report of the Committee on the Biological Effects of Ionizing Radiation (BEIR 79),* the International Commission on Radiological Protection (ICRP) Publication 27 entitled "Problems in Developing an Index of Harm," the 1979 report of the science work group of the Interagency Task Force on the Health Effects of Ionizing Radiation, the 1977 report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR report), and numerous published articles (see the bibliography to the appendix).

C. REGULATORY POSITION

Instruction to workers performed in compliance with §19.12 of 10 CFR Part 19 should be given prior to assignment to work in a restricted area and

*The 1979 BEIR report, issued in draft form, is currently being revised. A final version is not yet released but the information from the draft used for this guide is not expected to change significantly.

periodically thereafter. In providing instruction concerning health protection problems associated with exposure to radiation, all workers, including those in supervisory roles, should be given specific instruction on the risk of biological effects resulting from exposure to radiation.

The instruction should include the information provided in the appendix to this guide and should be presented to all affected workers and supervisors. The information should be discussed during training sessions. Each individual should be given an opportunity to ask questions and should be asked to acknowledge in writing that the instruction has been received.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants regarding the NRC staff's plans for using this regulatory guide.

This proposed guide has been released to encourage public participation in its development. Except in those cases in which a licensee proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the methods to be described in the active guide reflecting public comments will be used in the evaluation of the instructional program for all individuals working in or frequenting any portion of a restricted area and for all supervisory personnel. Implementation by the staff will in no case be earlier than December 1, 1980.

APPENDIX TO DRAFT REGULATORY GUIDE OH 902-1

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. 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.

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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. The intent of this document is to estimate and explain the possible risk of injury, illness, or death resulting from occupational radiation exposure.

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 children of exposed parents, and cataracts. These effects (with the exception of genetic effects) have been demonstrated in studies of medical radiologists, uranium miners, radium workers, and radiotherapy patients who received excessive doses in the early part of the century. 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.

The studies mentioned, however, involve levels of radiation exposure that are much higher than those permitted occupationally today. Studies have not shown a clear cause-effect relationship between health effects and current levels of occupational radiation exposure.

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

Prompt effects are observable shortly after receiving a very large dose in a short period of time. For example, a dose of 450 rems 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 1 month without medical treatment. Delayed effects such as cancer and cataracts may occur years after exposure to radiation. Genetic effects occur when there is radiation damage to the genetic material. These effects may show up as birth defects or other conditions in the offspring of the exposed individual and succeeding generations, as demonstrated in animal experiments, although this effect has not been observed in human populations.

4. As nuclear industry workers, which effects should concern us most?

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 nuclear industry have been low, and only a few accidents have resulted in overexposures. The probability of serious genetic effects in the children of workers is estimated at about one-third that of other delayed effects. The main concern to industry workers should be the delayed incidence of cancer. The chance of delayed cancer is believed to depend on how much radiation exposure a person gets; therefore, every reasonable effort should be made to keep exposures low.

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

Acute radiation exposure, which causes prompt effects and may cause delayed effects, 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, atomic bomb victims, and accidents that have occurred in nuclear fuel processing. There have been few occupational incidents that have resulted in large acute exposures. 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 mrems (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 interacting factors. One theory is that radiation activates an existing virus in the body which then attacks normal cells causing them to grow rapidly. Another is that radiation reduces the body's normal resistance to existing viruses which can then multiply and damage cells. Radiation can also damage chromosomes in a cell, and the cell is then directed along abnormal growth patterns. What is known is that, in groups of highly exposed people, a higher than normal incidence of cancer is observed. An increased incidence of cancer has not yet been observed at low radiation levels, although human studies are still incomplete. Higher incidence rates of cancer can be produced in laboratory animals by high levels of radiation.

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 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 the human body will repair some of the damage. 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 large radiation doses increase 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. Still, it is prudent to assume that smaller doses also 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 time-honored principle of radiation protection is to do more than merely meet the allowed regulatory 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 radiation dose, but we do have good estimates. The estimates of radiation risks are at least as reliable as estimates for the effects from any other important hazard. Being exposed to typical occupational radiation doses is taking a chance, but that chance is small and 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 individuals 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 statistical chances of eventually developing cancer or some other radiation-related injury. The more radiation exposure you get, the more you increase your chances of cancer.

Clearly, there is no simple answer to this question. The best we can do is provide estimates, for large groups, of the increased chances of cancer or other radiation injury resulting from exposure to radiation.

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. 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 exposed workers may be an increased incidence of cancer over and above the number of cancers that would be expected in that population. 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.

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

The cancer risk estimates (developed by the organizations identified in Question 9) are presented in Table 1.

TABLE 1

CANCER RISK ESTIMATES FROM EXPOSURE TO LOW-LEVEL RADIATION

Source	Number of Additional Cancers Estimated to Occur in 1 Million People After Exposure of Each to 1 Rem of Radiation
BEIR 1979	268-399
ICRP 1977	300*
UNSCEAR 1977	300*

*ICRP and UNSCEAR both estimated 100 excess delayed deaths from these 300 radiation-induced cancers. Only about one-third of cancer cases are fatal. Note that the three independent groups are in close agreement on the risk of radiation-induced cancer.

To put these estimates (of Table 1) into perspective, we will use an average of 300 excess cancer cases per million people, each exposed to 1 rem of ionizing radiation. (Most scientists would agree that 300 is a high estimate of risk and may be considered an upper limit.) This means that if a group of 10,000 workers each receives 1 rem, three would be predicted to develop cancer because of that exposure, although the actual number could be more or less than three (including none).

The American Cancer Society has reported that approximately 25 percent of all adults in the 20-65 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.

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 cancer from an occupational exposure of 1 rem is about equal to your chances of drawing three aces in a row from a deck of cards.

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 from a radiation-induced cancer. Several independent studies have indicated that the average loss of life expectancy from exposure to radiation is about 1 day per rem of exposure. In other words, an individual in a population 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 individual who gets cancer from radiation may lose several years of life expectancy while his more fortunate coworkers suffer no loss. The International Commission on Radiological Protection (ICRP) estimated that the average number of years of life lost from a fatal industrial accident is 30 while the average number of years of life lost from a fatal radiation-induced cancer is 10.

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 incidence due to low exposures to radiation as compared to the normal incidence 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. At low dose levels, it is possible that the risk could be zero. The NRC and other agencies both in the United States and abroad are continuing extensive long-range research programs on radiation risk.

The National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR) and others feel that these risk estimates are higher than would actually occur and represent an upper limit on the risk. However, they are considered by the NRC staff to be the best available estimates that the worker can use to make an informed decision concerning acceptance of the risks associated with exposure to radiation. Although the estimated increased risks of cancer are relatively low, there is a chance that they are not zero. A worker who decides to accept this small increased risk should make every effort to keep exposure to radiation as low as is reasonably achievable to avoid unnecessary risk.

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

Since 1956, the National Academy of Sciences established two 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 1979* BEIR reports). The International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurement (NCRP) are two groups of renowned scientists who have studied radiation effects and published risk estimates (ICRP Publication 26, 1977). 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).

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*The draft publication of the 1979 BEIR report is currently under revision. However, the risk estimates are not expected to change significantly.

10. 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 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 30 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. The whole-body dose required to make someone impotent is also greater than the lethal dose. Thus, exposure to permitted occupational levels of radiation has no observed effect on fertility and should have no physical effect on the ability to function sexually.

11. 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 individuals, 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.

TABLE 2

ESTIMATED LOSS OF LIFE EXPECTANCY FROM HEALTH RISKS

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
Safest jobs (such as teaching)	30
Natural background radiation, calculated	8
Medical X-rays (U.S. average), calculated	6
All catastrophes (earthquake, etc.)	3.5
1 rem occupational radiation dose, calculated (industry average is 0.34 rem/yr)	1
1 rem/yr for 30 years, calculated	30
5 rems/yr for 30 years, calculated	150

These estimates indicate that the health risks from occupational radiation exposure are not greater than the risks associated with many other events or activities we encounter in normal day-to-day activities.

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 possibly related hazards such as exposure to toxic chemicals, dusts, or unusual temperatures. Note also that occupational exposure at the 5 rems per year limit for 50 years, though highly unlikely, may result in a risk comparable to mining and heavy construction, using high-risk estimates.

TABLE 3

ESTIMATED LOSS OF LIFE EXPECTANCY FROM INDUSTRIAL ACCIDENTS*

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 0.5 rem/yr, 50 years, calculated	25
Radiation dose of 5 rems/yr, 50 years	250
Industrial accidents at nuclear facilities (nonradiation)	58

*Adapted from Cohen and Lee, A Catalogue of Risk and Health Implications of Nuclear Power Production, World Health Organization.

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 due perhaps 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 accidental death 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.

TABLE 4

PROBABILITY OF ACCIDENTAL DEATH BY TYPE OF OCCUPATION*

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)	40
Manufacturing	36
Services	28
Wholesale and trade	24

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

12. What are the NRC radiation dose limits?

Federal regulations currently limit occupational radiation dose to 1-1/4 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 where N is the individual'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.

13. What is meant by ALARA?

In addition to providing an upper limit on an individual's permissible radiation exposure, the NRC also requires that its licensees maintain 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 done 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. At low doses the health effects do not seem to be affected by dose rate. The risk of cancer from low doses is considered to be proportional to the amount of exposure, not the rate at which it is received. 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 collective dose is 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 (man-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 man-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 believed 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? 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 (man-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 individuals.

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 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 man-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 large variations in collective doses among licensees. A power reactor could reasonably be expected to have an average annual collective dose of several hundred man-rems. However, a small radiography licensee could very well have a collective dose of only a few man-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 man-rems. However, the smallest collective dose for a radiography licensee was less than 1 man-rem, and the largest was 401 man-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 on NCRP and ICRP recommendations. Scientific reviews of research data on biological effects such as the BEIR report are also considered.

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 terminate 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 according to these reports; 95 percent received less than 2 rems; fewer than 1 percent exceeded 5 rems in any 1 year. The average annual dose of these workers who were monitored and had measurable exposures is 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.

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 necessarily 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 individual during the calendar quarter. The licensee is required to file a 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, paragraph 20.1(c) of the NRC regulations states 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 recently 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 estimated by the BEIR Committee and the ICRP. A few studies have indicated that a given dose of radiation may be more likely to cause biological effects than previously thought. The controversy is focused on studies involving groups of exposed individuals. Opinions differ on the validity of the research methods used and the methods of statistical analysis. The chief problem is that, with small groups, the incidence of effects such as leukemia is small. 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 any observed effects were caused by the exposure to radiation.

The current BEIR committee concluded that claims of higher risk had "no substance," and nearly one-half of the committee members were convinced that the BEIR risk estimates were actually too high. The NRC staff is committed to a continuing review of research on radiation risk and is funding a study to design new research on human effects from exposure to radiation.

23. What are the arguments against lowering the NRC dose limits?

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.

Exposure to 5 rems/yr for 50 years, which virtually never occurs, would increase the estimated risk to levels comparable to risks in mining and heavy construction. 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.

The regulatory standards for dose limits are based on the recommendations of the Federal Radiation Council, the NCRP, and the ICRP. At the time these standards were developed, about 1960, it was considered unlikely that exposure of 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 very 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 through a linear, nonthreshold extrapolation procedure. 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.

Reducing the dose limits, for example, by a factor of 10 (that is, from 5.0 rems/yr to 0.5 rem/yr) has been analyzed by the NRC staff. An estimated 2.6 million man-rems could be saved from 1980 through the year 2000 by nuclear power plant licensees if compliance with the new limit was 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 man-rems would amount to spending $30 to $90 million to prevent each potential radiation-induced cancer death. Society may consider this cost unacceptably high for individual protection.

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

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

a. An independent study has ndicated that a given dose of neutron radiation is more likely to cause biological effects than previously thought. Although the scientific community has not yet agreed with the results of this study, 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 unborn 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 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 unborn child to this additional risk.

c. Also of special interest is the indication that female workers are subject to more risk than male workers. In terms of all types of cancer except leukemia, the 1979 BEIR analysis indicates that female workers have a risk of developing radiation-induced cancer that is approximately one and one-half times that for males. Incidence of radiation-induced leukemia is about the same for both sexes. Female workers should consider carefully 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 radioisotopes in medicine and dentistry adds considerably to our population exposure.

Table 5 shows estimated average individual exposure in millirems from natural background and other sources.

TABLE 5

U.S. GENERAL POPULATION EXPOSURE ESTIMATES (1978)*

Source	Average Individual Dose (mrem/yr)
Natural background	100
Release of radioactive material by mining, milling, etc.	5
Medical	90
Nuclear weapons development (primarily fallout)	5-8
Nuclear energy	0.28
Consumer products	0.03
Total	~ 200 mrem/yr

*Adapted from a report by the Interagency Task Force on the Health Effects of Ionizing Radiation published 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 workers allowed dose?

Equal doses of medical and occupational radiation have equal risks. 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 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 series of X-rays or a radiopharmaceutical in connection with an injury or illness resulting in a dose of 2 rems. This dose and implied risk should be justified on medical grounds. If the worker had also received 2 rems of dose on the job, the combined dose of 4 rems would not incapacitate the worker. Restricting the worker from additional job exposure during 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 inequitable to restrict the individual from employment in restricted areas for the remainder of the quarter.

27. What is meant by internal exposure?

Internal exposure to radiation results when radioactive materials are taken into the body by breathing, ingestion, or absorption through the skin. Different types of material locate for a period of time in different parts of the body or pass through the body, resulting in some dose to the exposed tissues.

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?

Calculations are made to determine the quantity of radioactive material that has been taken into the body and the total organ dose that would result. Then, based on limits established for particular body organs similar to 1-1/4 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. 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 may be used whenever the possibility of contact with loose radioactive material cannot be prevented.

29. Is the dose an individual 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 rems per calendar quarter limit. ICRP recommendations are that the internal and external doses should be summed. This recommendation is under study by the staffs of the NRC and the EPA.

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

A worker may wear two 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 and 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.

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. Thus, your employer is 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:

Your Employer

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

Nuclear Regulatory Commission

Address: Occupational Health Standards Branch
Office of Standards Development
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Phone: 301-443-5970

NRC 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

Department of Health, Education, and Welfare

Address: Office of Public Affairs
Bureau of Radiological Health
Department of Health, Education, and Welfare
Room 15-B-42, HF1-40
5600 Fishers Lane
Rockville, MD 20857

Phone: 301-443-3285

Environmental Protection Agency

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

Phone: 703-557-9710

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DRAFT VALUE/IMPACT STATEMENT

1. PROPOSED ACTION

1.1 Description

All NRC licensees are required to provide appropriate radiation protection training for all permanent and transient personnel who work in restricted areas (§19.12 of 10 CFR Part 19). A clear and reasonable assessment of the biological risks associated with occupational radiation exposure is essential to effective radiation protection training. The proposed action is to provide instructional material in a suitable form describing and estimating the risks from exposure to radiation. The instructional material will be suitable for use in licensee training programs and will represent an acceptable method of complying with part of the existing training requirements.

1.2 Need for Proposed Action

One common element of those occupational areas encompassed by NRC licensing activity is worker exposure to ionizing radiation and the biological risks from exposure. Union representatives have expressed a dissatisfaction with the way in which these risks have been explained to the worker by the licensee. In addition, they feel the NRC has a responsibility to make its position on the controversial issue of radiation risk clear to the worker and the public. A meeting of NRC staff and union representatives was held on November 28, 1978, during which this matter was discussed. A transcript of the meeting is available from the Public Document Room.

The Commission has directed the staff to prepare for and initiate a public hearing concerning the adequacy of present occupational radiation protection standards for exposure of individuals. This hearing should help resolve existing uncertainties in this complex area and the findings should, as a minimum, be published in a form suitable for instruction of the worker. Work on this project began prior to the public hearings so that updated information on risk could be disseminated to the worker shortly after the hearing. Most of the questions of concern to the unions can be disseminated to the worker shortly after the hearing. Most of the questions of concern to the unions can be answered now.

1.3 Value/Impact of Proposed Action

1.3.1 NRC Operations

Instructional material on radiation risk written at a level and scope understandable to the worker should contribute to increased confidence, on the part of the worker, in the NRC in general. A better understanding of the risk should elicit more worker cooperation with NRC-enforced safety programs. Impacts of the development of instructional material on risk are task completion manpower cost, estimated to be 0.2 man-year and printing costs of approximately $400.00.

1.3.2 Other Government Agencies

Agreement States whose licensing regulations include radiation protection training requirements may benefit from the availability of an NRC guide on radiation risk suitable for inclusion in those training programs. Development of the risk guide entails coordination with the Environmental Protection Agency, the Occupational Safety and Health Administration, and the Bureau of Radiological Health to avoid inconsistencies.

1.3.3 Industry

Providing a reasonable and understandable statement on worker risk should facilitate industry efforts to provide effective safety training and to better achieve as low as is reasonably achievable (ALARA) objectives. Minimal impact is expected in the form of additional cost of training programs since training requirements already exist. Input from unions and industry in the development of instructional material on risk will be encouraged, and this implies some additional costs such as staff time for reviewing drafts.

1.3.4 Workers

The proposed action should improve worker protection in that reasonable understanding of radiation risk is essential to the development of safe working practices. The staff believes that an objective discussion of radiation risk may in fact reduce "over concern" on the part of some workers. If improved training results in a wider recognition and respect for radiation as an industrial hazard, more attention will be given to protective procedures and a reduction in individual and collective dose should result.

1.3.5 Public

Nuclear workers are also members of the public and are generally residents of the area where facilities are located. Having a better informed public should result in a wider range of input to local decisionmaking concerning nuclear development. Improved training implies the added benefit of increased plant safety, thereby decreasing the probability of accidents that could involve the public.

1.3.6 Decision on Proposed Action

The NRC should develop and provide instructional material concerning risk from occupational radiation exposure.

2. TECHNICAL APPROACH

The technical approach proposed is to develop instructional material concerning risks to the worker from occupational radiation exposure and to publish the material in a form that will receive the widest dissemination among NRC-licensed facilities. An alternative is to publish the findings of the proposed hearing on dose limits and assume the relevant information will filter down to the worker. It is the feeling of the staff that a direct approach is required here.

3. PROCEDURAL APPROACH

The proposed action, to publish training material concerning risks from occupational radiation exposure, the use of which would be required of all licensees, could be accomplished by several alternative methods. These include an NRC regulation requiring that specific training materials be used, a regulatory guide based on the existing §19.12 that would provide an acceptable method for training on risks, an ANSI standard on training that could be adopted by a regulatory guide, and a NUREG report or a branch position paper.

3.1 Value/Impact of Procedural Alternatives

An NRC regulation establishes general legal requirements, is costly and time consuming to prepare, and is not an appropriate vehicle for the specific and narrow objective proposed here. A regulation would be difficult to modify as new information on radiation risk is developed. One advantage is that a regulation legally requires compliance. In general, this approach is not considered cost effective in view of the objectives of the proposed action.

ANSI standards are generally intended as highly technical and advanced treatments of specialized areas of concern to industry. A comprehensive technical review of risks from radiation would be of value but would not be suitable as instructional material at an introductory level for worker radiation protection training. Completion of an ANSI standard and an endorsing regulatory guide would require several years and would be too costly. This approach is not considered cost effective in view of the proposed objectives.

A NUREG document would be an appropriate vehicle for a comprehensive discussion of radiation risk beyond the scope of what is proposed here. A regulatory position, however, is not established through publication of a NUREG report. Since this proposal includes establishing an acceptable method for compliance with elements of required training programs, a NUREG report is not suitable.

Branch position statements are intended as interim measures to be used when an immediate response is required. They are usually superseded when a more permanent mode of guidance is developed.

A regulatory guide can be prepared at reasonable cost within a reasonable time period. The staff does not consider that revision of any existing regulatory guides could provide the instructional material intended here. Regulatory guides on training requirements are being developed but are specific to types of licensees such as Draft Regulatory Guide OH 717-4 for LWRs. The action proposed here has broad application to all licensees, as does Regulatory Guide 8.13, "Instruction Concerning Prenatal Radiation Exposure."

3.2 Decision on Procedural Approach

The staff concludes that work should begin on a regulatory guide similar to Regulatory Guide 8.13 on the subject of worker instruction concerning risks from occupational radiation exposure. Publication of the active guide should not occur until public hearings on the question of dose limits and risks have been held.

4. STATUTORY CONSIDERATIONS

4.1 NRC Regulatory Authority

Section 19.12 of 10 CFR Part 19 establishes a legal requirement that all NRC licensees provide radiation protection training to personnel and that the training be commensurate with the potential risks from radiation exposure encountered by those personnel. The NRC is thus authorized to provide criteria for acceptable levels of training and to inspect for compliance with training requirements.

4.2 Need for NEPA Statement

The action proposed here is to publish an instructional document on risks. This would occur after, and be in addition to, any major NRC action on retaining or modifying existing dose limits, based on planned public hearings. Since at that time it would not constitute a major addition or change and would entail no effect on the environment, an environmental impact statement is not considered necessary.

5. RELATIONSHIP TO OTHER EXISTING OR PROPOSED REGULATIONS OR POLICIES

Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," will require a commitment to appropriate radiation protection training. When next revised, it should include reference to this proposed action as an acceptable element of a licensee's training program.

This proposed guide is consistent with Regulatory Guide 8.8, "Information Relevant to Ensuring that Occupational Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable." When next revised, it should include cross-reference to this proposed action.

This proposed action directly supplements the Draft Regulatory Guide OH 717-4, "Radiation Protection Training for Light-Water-Cooled Nuclear Power Plant Personnel," and will supplement and be referenced in other planned guides on training at other types of licensed facilities, e.g., uranium fuel fabrication plants, uranium mills, medical institutions.

6. SUMMARY AND CONCLUSIONS

In summary, it is proposed that a regulatory guide be prepared and issued for the purpose of providing instructional material concerning an assessment of risk from occupational radiation exposure.

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