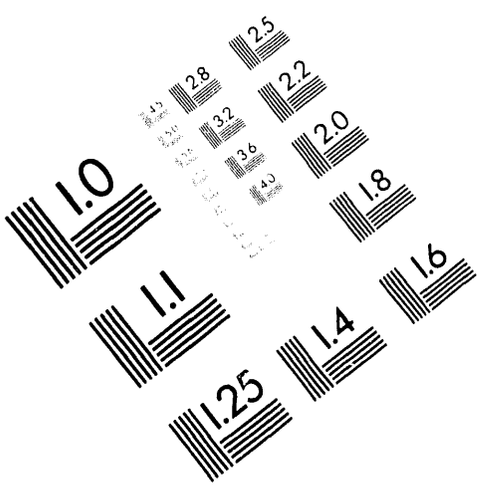

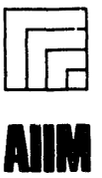

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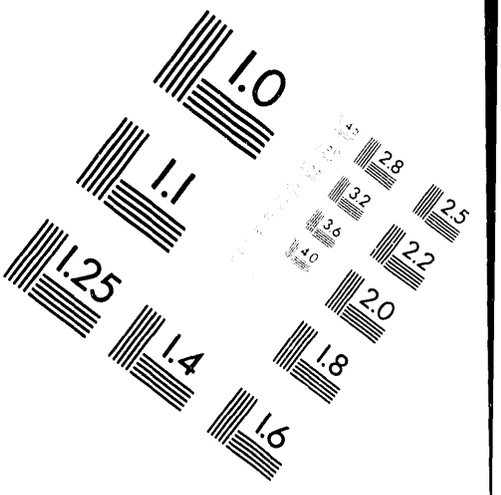

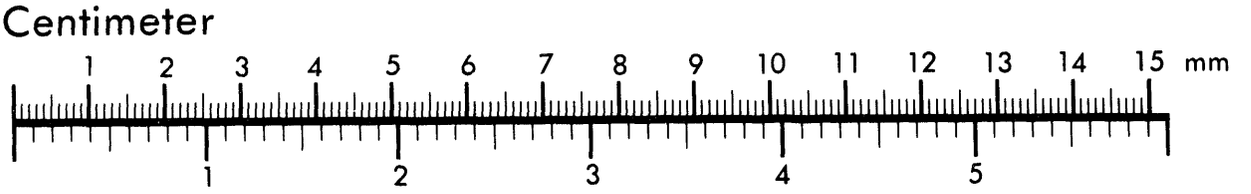

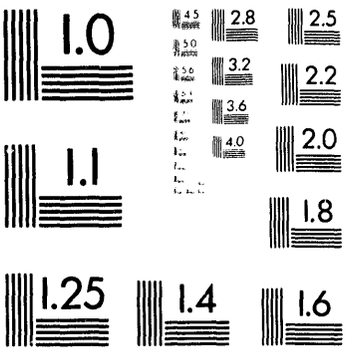

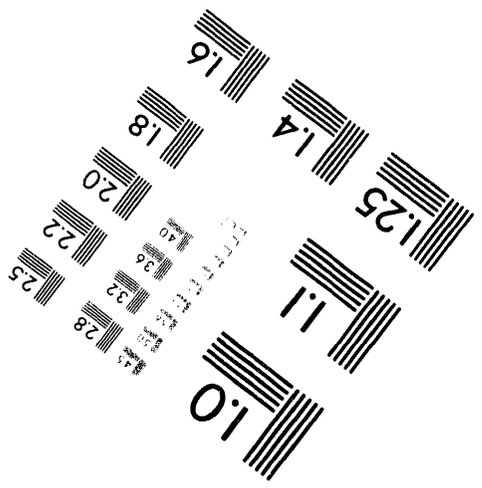

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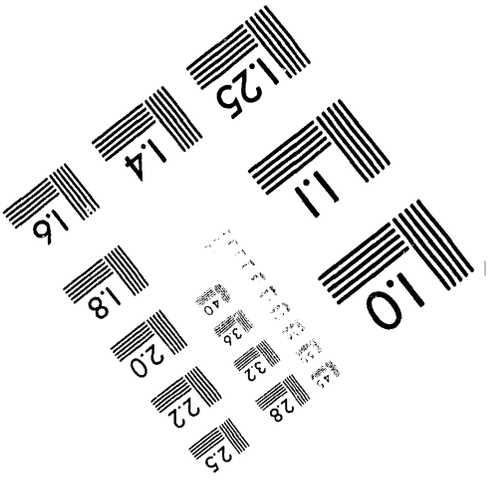

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RADIOLOGICAL RISK GUIDELINES FOR NONREACTOR NUCLEAR FACILITIES AT THE PACIFIC NORTHWEST LABORATORY

D. E. Lucas
T. A. Ikenberry

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Pacific Northwest Laboratory
Richland, Washington 99352

INTRODUCTION

Radiological risk evaluation guidelines for the public and workers have been developed at the Pacific Northwest Laboratory (PNL) based upon the Nuclear Safety Policy of the U.S. Department of Energy (DOE) established in Secretary of Energy Notice SEN-35-91 (DOE 1991). The DOE nuclear safety policy states that the general public be protected such that no individual bears significant additional risk to health and safety from the operation of a DOE nuclear facility above the risks to which members of the general population are normally exposed.

The radiological risk evaluation guidelines developed at PNL are unique in that they are 1) based upon quantitative risk goals and 2) provide a consistent level of risk management. These guidelines are used to evaluate the risk from radiological accidents that may occur during research and development activities at PNL. A safety analyst uses the frequency of the potential accident and the radiological dose to a given receptor to determine if the accident consequences meet the objectives of the Nuclear Safety Policy.

DEVELOPMENT OF RISK EVALUATION GUIDELINES

The two nuclear safety goals stated in SEN-35-91 for protection of the public were used as the starting point in developing the guidelines. A third nuclear safety goal, for protection of workers, was developed by PNL using the philosophy implicit in SEN-35-91. From each nuclear safety goal a quantitative risk goal was defined. Finally, these risk goals were used to derive the risk evaluation guidelines for the public and worker. The development process is illustrated in Figure 1.

Both DOE nuclear safety goals address limiting risk to the general public from DOE operations. Nuclear Safety Goal 1 limits the risk to the public from prompt fatalities to 0.1% of the sum of the risk from all other accidents. Nuclear Safety Goal 2 limits the risk to the public from cancer fatalities to 0.1% of the risk from all other causes of death.

Risk Evaluation Guideline 1. The objective of Nuclear Safety Goal 1 is to limit immediate fatalities in the general population. However, the risk (R) to any individual from prompt, radiation-induced fatality should be low. Therefore, PNL extended the application of this goal to the theoretical maximally exposed individual (MEI) at or beyond the site boundary (i.e., the Public MEI) and on-site but outside the facility (i.e., the Worker MEI).

Death rate statistics from the National Safety Council (NSC) were used to quantify this goal. Annually there are approximately 40 fatalities per 100,000 individuals in the general population due to accidents (NSC 1991). This death rate and the objective of 0.1% of normal risk included in Nuclear Safety Goal 1 were used to quantify Risk Goal 1 for prompt fatalities:

$$R \leq 4 \times 10^{-7} \text{ fatalities} \cdot \text{yr}^{-1} \quad (1)$$

This is a very low risk of prompt fatalities. The consequence (C) in this goal is any prompt fatality, so the limiting case is one prompt fatality per event. Solving for event frequency (F), this goal becomes:

$$F = \frac{R}{C} = 4 \times 10^{-7} \text{ yr}^{-1} \quad (2)$$

which is just into the incredible region for event frequencies ($F < 10^{-6}$ yr^{-1}). Therefore, the quantitative interpretation of this goal is that prompt, radiation-induced fatalities are not allowed for credible events ($F \geq 10^{-6}$ yr^{-1}).

The condition of "no prompt fatalities allowed for credible events" required that a strict maximum allowed dose be established. This constraint was met by limiting the maximum dose (D) allowed to a 100-rem effective dose equivalent (EDE) for both MEIs. No prompt fatalities are expected at doses of 100 rad (ICRP 1991), or by extension, at 100 rem. Thus, Nuclear Safety Goal 1 is met by:

Risk Evaluation Guideline 1
$D_{event} \leq 100$ rem EDE for $F_{event} \geq 10^{-6}$ yr^{-1}
Application: general public and workers

Nuclear Safety Goal 1 sets the limiting dose for the risk evaluation guidelines.

Risk Evaluation Guideline 2. The concern of Nuclear Safety Goal 2 is latent cancer fatalities. Death rate statistics were used to quantify risk goals for this nuclear safety goal. There are approximately 200 fatalities annually per 100,000 individuals in the general population due to cancer (NSC 1991). This annual death rate and the objective of 0.1% provided in Nuclear Safety Goal 2 were used to quantify Risk Goal 2 for a cancer fatalities in a public MEI, as follows:

$$R \leq 2 \times 10^{-6} \text{ fatalities} \cdot yr^{-1} \quad (3)$$

The risk relationship is a function of event frequency (F), dose (D), and cancer induction rate (I):

$$R = F \cdot (D \cdot I) \quad (4)$$

The value of R is set in Risk Goal 2. The value of I for fatal cancer induction rates in the general population was taken from recommendations of the International Commission of Radiological Protection (ICRP 1991). The risk guideline, therefore, can be expressed in terms of the maximum acceptable dose (D) for a given event frequency (F):

$$D_{max} = \frac{R}{(F \cdot I)} \quad (5)$$

The fatal cancer induction rate for the general population (all ages) is 5 x

10^{-4} fatalities·rem^{-1} (ICRP 1991). Using this value (for I in Equation 5), the Risk Evaluation Guideline 2, to limit cancer fatalities in the general public, is as follows:

Risk Evaluation Guideline 2
$D_{event} \leq 4 \times 10^{-3} / F$
Application: general public

Risk Evaluation Guideline 3. The Nuclear Safety Policy of DOE is concerned with limiting the risk to the general public surrounding DOE facilities. PNL used the Nuclear Safety Policy as the cornerstone of a broader PNL policy, expanding it to cover PNL workers as well as the general public. Nuclear Safety Goal 3 was developed using the implicit DOE nuclear safety philosophy, stating that risk to a worker from fatalities due to accidents should not exceed the risk to workers in other, relatively safe industries.

Nuclear Safety Goal 3 is quantified in Risk Goal 3 using fatal accident rate statistics as a basis for limiting risk from latent cancer fatalities. It therefore somewhat combines the approaches used in Risk Goals 1 and 2. Similar to Nuclear Safety Goal 2, the concern of Nuclear Safety Goal 3 is latent cancer fatalities. As was done for Nuclear Safety Goal 1, death rate statistics (fatal accidents) from the NSC (1991) were used to quantify risk goals for this nuclear safety goal.

Annually there are approximately 4 accidental deaths per 100,000 workers in the relatively safe industries of trades and services. Using this annual death rate and the objective of Nuclear Safety Goal 3, the risk of latent cancer fatalities to the worker MEI from cancer fatalities is quantified in Risk Goal 3 as follows:

$$R \leq 4 \times 10^{-5} \text{ fatalities} \cdot \text{yr}^{-1} \quad (6)$$

The fatal cancer induction rate for the work force (20 to 64 years of age) is 4×10^{-4} fatalities·rem^{-1} (ICRP 1991). Using the value for I, and the Equation 6 for R in Equation 5, Risk Evaluation Guideline 3, to limit cancer fatalities in the work force, is as follows:

Risk Evaluation Guideline 3
$D_{event} \leq 1 \times 10^{-1} / F$
Application: Workers

APPLICATION OF RISK EVALUATION GUIDELINES

In safety analyses, the frequencies and consequences of postulated events are determined. Events determined to have a frequency of less than 10^{-6} yr^{-1} are considered incredible and need not be further evaluated. Selected credible events are further analyzed to determine potential dose consequences to the Public MEI and the Worker MEI in order to make a determination if an undue risk exists.

The three risk evaluation guidelines are used to assist in making these judgements. Using the event frequency, the risk evaluation guidelines are used to determine the doses against which the consequences of that event are evaluated. If the doses from the event meet Risk Evaluation Guidelines 1 and 2 for the Public MEI and Risk Evaluation Guidelines 1 and 3 for the Worker MEI, the risk from that event is considered acceptable. Conversely, if any of the guidelines are not met, then additional analyses or controls may be needed to reduce the dose and/or frequency of the event.

Each event is evaluated on a case-by-case basis. The risk evaluation guidelines are used as tools to assist in making the final determination if an

undue risk exists. These guidelines are not to be treated as rigid criteria for accepting risk.

Alternate approaches for using the guidelines are provided to give the analyst flexibility and encourage the use of cost-effective techniques in the performance of accident analyses. In going from one approach to the next, the required level of analysis gets progressively easier (i.e., F need not be well defined). However, the risk evaluation guideline becomes more restrictive to account for increased uncertainty. The analyst may choose the method most appropriate for his needs, limitations, and resources.

CONCLUSION

To achieve their purpose, risk evaluation guidelines should provide a consistent risk level for a range of accident frequencies and a range of dose consequence. The risk should be based upon comparison with other types of risk to which the public and worker are exposed. For the public, accidents at DOE nuclear facilities represent an involuntary risk. Therefore, the public guideline risk level should be small compared to other risks the public commonly encounters. For workers, the risk guideline should represent a level of risk comparable to the risk to workers in other, relatively safe industries.

DOE's Nuclear Safety Policy and published death rate statistics for the public and workers were used to develop risk evaluation guidelines. The methodology developed here was used to calculate and plot risk values (fatalities$\cdot yr^{-1}$) shown in Figure 2 based on various causes of death as a function of event frequency and dose equivalent. From this graph four regions of risk may be defined as shown in Figure 3: unacceptable risk, normal risk, very low risk, and insignificant risk. These data and the resulting regions of risk provide perspective for comparing the radiological risk evaluation guidelines to actual risks the public and workers experience in normal day-to-day living. The risk guideline for the public falls within the very low risk region. The risk guideline for the worker falls within the lower portion of the normal

risk region.

The radiological risk evaluation guidelines are an effective tool for assisting in the management of risk at DOE nonreactor nuclear facilities. These guidelines 1) meet the nuclear safety policy of DOE, 2) establish a tool for managing risk at a consistent level within the defined constraints, and 3) set risk at an appropriate level, as compared with other risks encountered by the public and worker.

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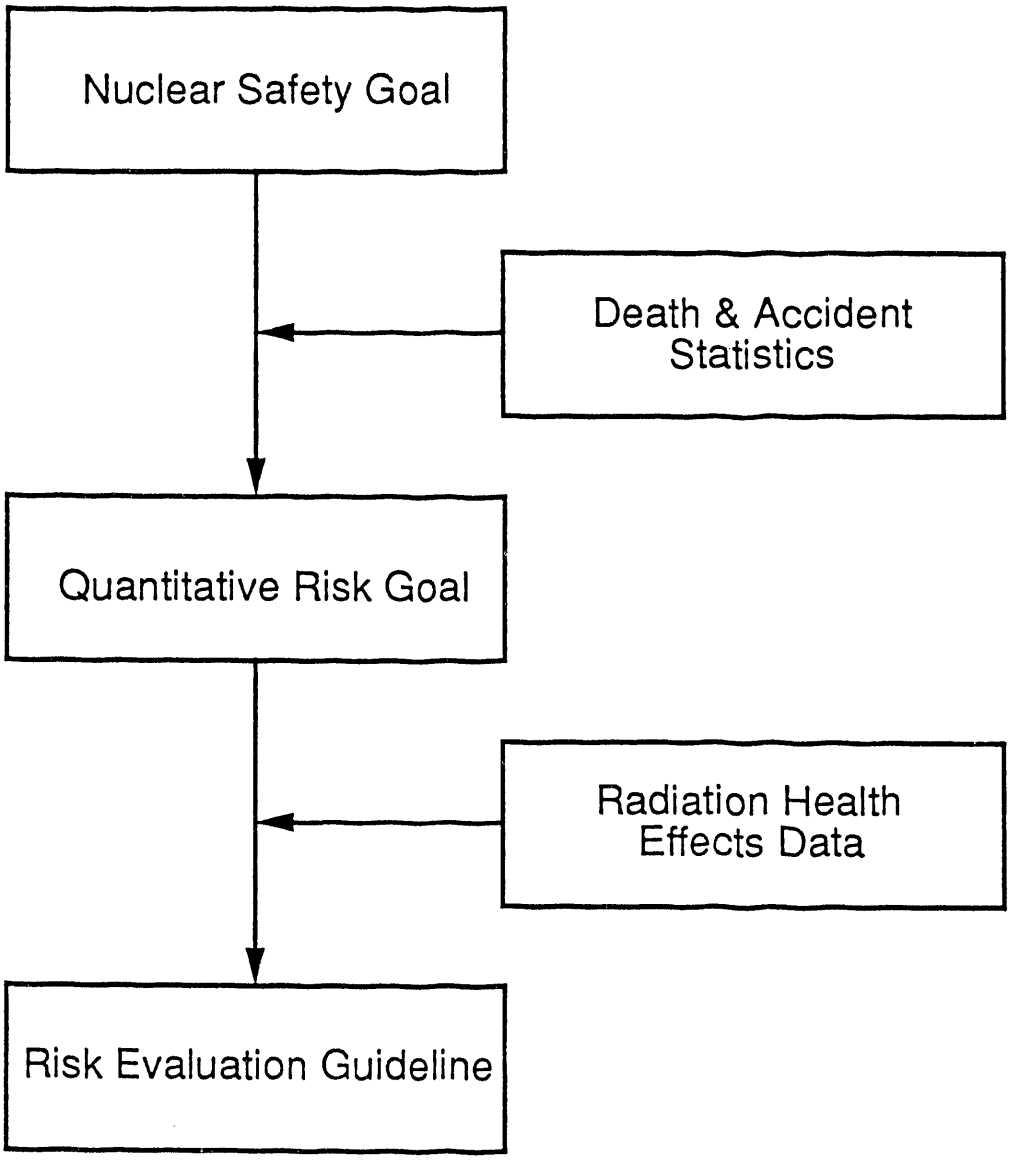

FIGURE 1. Process for Deriving PNL Radiological Risk Evaluation Guidelines from DOE Nuclear Safety Goals

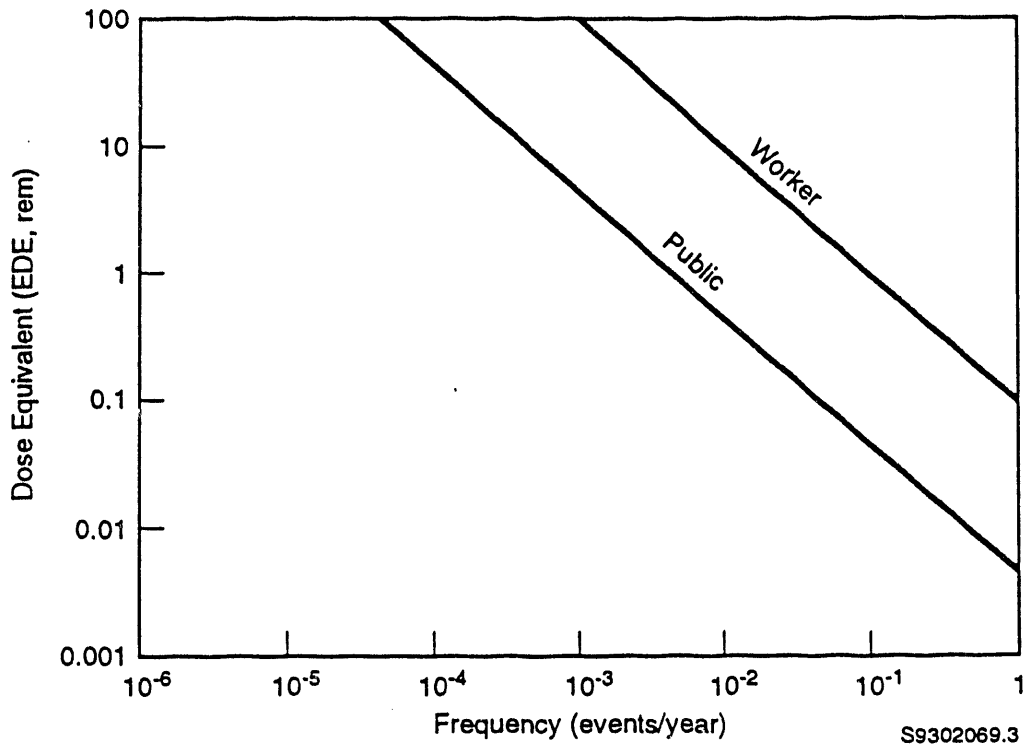

FIGURE 2. PNL Radiological Risk Goals for the Public and Workers

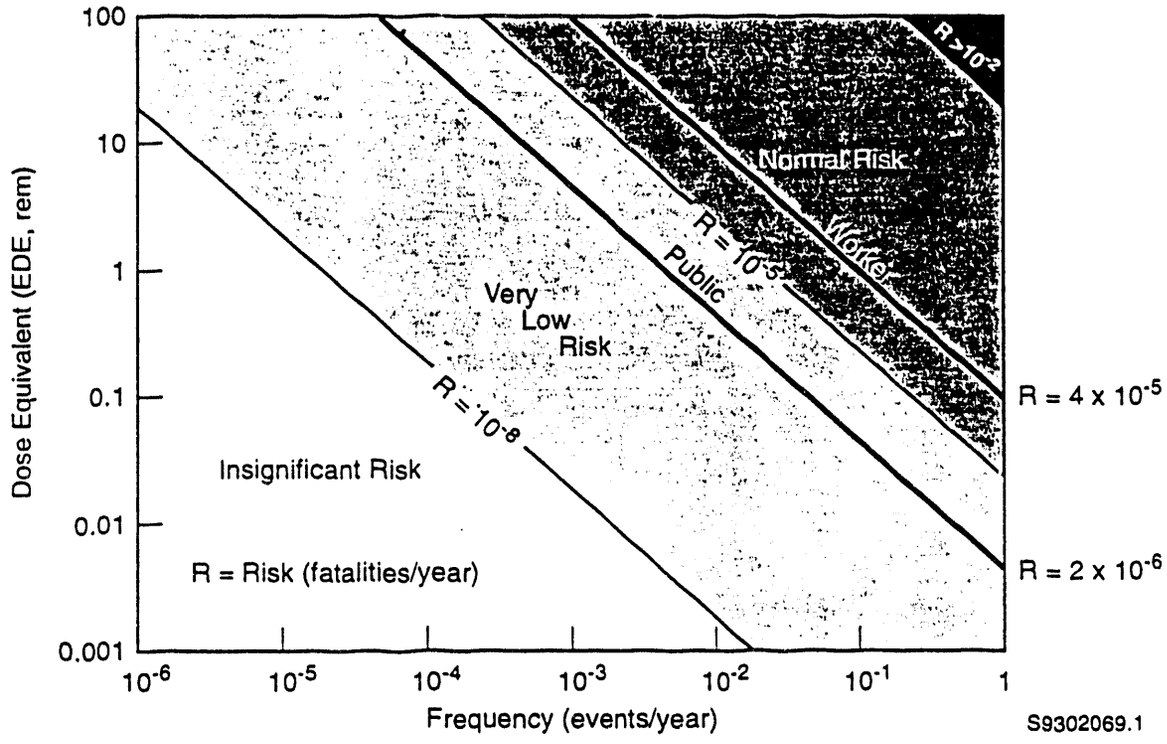

FIGURE 3. Regions of Risk and Comparison to PNL Radiological Risk Goals

Authors: Donna E. Lucas, Chief Engineer
Laboratory Safety Department
Pacific Northwest Laboratory
(509) 376-1331 FAX (509) 376-6663

Tracy A. Ikenberry, Senior Research Scientist
Health Physics Department
Pacific Northwest Laboratory
(509) 375-2338 FAX (509) 375-6943

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Alternate Category: Communicating the results of risk assessment and management to peers, decision makers, and the public

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